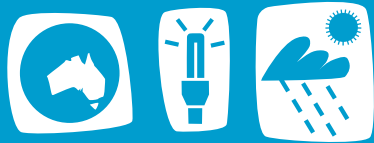




Australian Government
Department of Climate Change
and Energy Efficiency

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Accurate Answers to Professor Plimer's *101 Climate Change Science Questions*

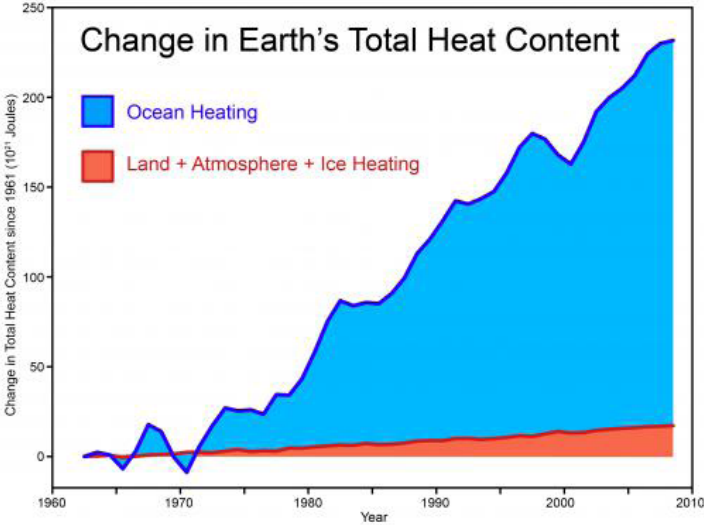
This document provides answers to the 101 questions on climate change posed by Professor Ian Plimer in his latest book, *How to get expelled from school: a guide to climate change for pupils, parents and punters* (2011). Many of the questions and answers in Professor Plimer's book are misleading and are based on inaccurate or selective interpretation of the science. The answers and comments provided in this document are intended to provide clear and accurate answers to Professor Plimer's questions. The answers are based on up-to-date peer reviewed science, and have been reviewed by a number of Australian climate scientists.

For additional reliable information on climate change science, good resources include:

- » The Australian Academy of Science's report *The Science of Climate Change: Questions and Answers* at www.science.org.au/policy/climatechange.html;
- » The Climate Commission's report *The Critical Decade* at www.climatecommission.gov.au/topics/the-critical-decade/;
- » The Intergovernmental Panel on Climate Change *Fourth Assessment Report* at www.ipcc.ch;
- » The CSIRO climate change website at www.csiro.au/en/Outcomes/Climate/Understanding.aspx; and
- » The Bureau of Meteorology climate change website at www.bom.gov.au/climate/change/.

Question #	Question	Answers and Comments
1	Is climate change normal?	<p>The climate has changed - temperatures have risen and fallen - throughout Earth's history. Change in the climate can be driven by any force that causes the Earth to gain or lose heat, causing it to become hotter or cooler. Past changes in the climate have been caused by forces including volcanic eruptions, the changing location of continents and oceans, changing ocean currents, natural variations in the levels of greenhouse gases in the atmosphere, changes to the sun's intensity, and variations in the Earth's orbit around the sun.</p> <p>However none of these forces can explain the climate changes we are now observing. Scientists have closely examined all the natural processes that can drive changes in the Earth's climate and have found that none explain the current warming of our climate.</p> <p>Scientists have shown, beyond doubt, that the current warming of our climate is being driven by human activities, such as burning fossil fuels and deforestation. These activities release additional greenhouse gases into the atmosphere.</p>
2	Is the global warming measured today unusual?	<p>Yes. The observed rise in global temperature is unusual, both because it has risen so rapidly, and because human activities are driving the change.</p> <p>For the majority of human civilisation on Earth (the last 12,000 years), global temperatures have remained relatively stable. However, over the past century global mean temperature has increased by around 0.8 degrees Celsius. This increase has occurred rapidly.</p> <p>The linear warming trend over the past 50 years of 0.13 degrees Celsius per decade is much more rapid than the rate of warming between ice ages and warm interglacial periods of around 0.01 degrees Celsius per decade. This rapid rate of warming is very unusual in the context of natural climate variability. It is particularly unusual for the period in which human civilisations have developed.</p> <p>The observed warming of the Earth's climate is also unusual because it is being driven by human activities. Activities such as burning fossil fuels and deforestation release additional CO₂ into the atmosphere. It is this additional CO₂ that is driving the current climate change. Ice core records show that the current levels of CO₂ in the atmosphere, 390 parts per million (ppm), are now well above the natural range of the last 800,000 years of between 172 and 300 ppm.</p>

Question #	Question	Answers and Comments
3	What drove climate change before humans were on Earth?	<p>Past changes in the climate have been caused by forces including volcanic eruptions, the changing location of continents and oceans, changes to the ocean currents, natural variations in the levels of greenhouse gases in the atmosphere, changes to the sun's intensity, and variations in the Earth's orbit around the sun.</p> <p>Scientists have studied all of the natural processes that can affect climate and have found that none can explain the sustained rise in global temperature that is being observed today. The observed current warming trend can <i>only</i> be explained by taking into account the impact of human produced greenhouse gases.</p>
4	Are we in a period of global warming?	<p>Yes, the Earth's climate system is warming. Global average air and ocean temperatures are rising, there is widespread melting of snow and ice, and sea levels are rising around the globe. The average air temperature at the Earth's surface has continued to rise at a rapid rate. The decade 2002-11 was the world's warmest on record, warmer than the 1990s which in turn was warmer than the 1980s (World Meteorological Organisation). In Australia, 2001-10 was also the warmest decade on record, and each decade since the 1940s has been warmer than the preceding decade.</p> <p>The majority of additional heat in the Earth's system has been absorbed by the ocean. Therefore measurements of ocean heat content provide strong evidence of climate change. The graph shows ocean heat content from the 1950's until 2008 and illustrates a clear warming trend.</p> <p>The blue, green and black lines show yearly ocean heat content for the top 700 m layer of the ocean. The bottom orange segments indicate the timing of major volcanic eruptions (NASA GISS, data ends in 1999). There are short periods where ocean heat drops for several years before the warming trend resumes. On several occasions, this is due to large volcanic eruptions which cause a short term drop in global temperatures.</p> <div> <p>Change in Ocean Heat Content (relative to 1961) Church et al. 2011</p> </div>

Question #	Question	Answers and Comments
5	<p>Will the 0.5 degrees of warming we experienced from 1977 to 1998 occur again?</p>	<p>This question incorrectly implies that the observed trend in global warming stopped in 1998. The graph below shows the build up of heat in the Earth's oceans, land, atmosphere and ice. It clearly illustrates that heat has continued to build up in the Earth system beyond 1998.</p> <p>Updated graphic of total heat content from Church et al 2011, http://sks.to/totalheatcontent.</p> <p>Global temperatures have risen 0.8 degrees Celsius over the 20th century and it is very likely that temperatures will continue to rise throughout this century and beyond.</p> <p>The influence of greenhouse gases on surface temperature is not instantaneous. If greenhouse gases were stabilised immediately, the planet would continue to warm for many decades. Other influences on the climate system, such as major volcanic eruptions, can temporarily slow the rate of warming. However these temporary influences will not significantly affect the long term warming trend.</p> <div data-bbox="1406 341 2107 922"> <p>Total Heat Content since 1961 (2011 update)</p>  </div>
6	<p>If we have dangerous warming and the global temperature has increased by 0.8 degrees since the Little Ice Ages, does this mean that the ideal temperature for life on Earth is that of the Little Ice Ages?</p>	<p>This question is misleading, as it incorrectly implies that the observed warming of nearly 0.8 degrees Celsius has occurred over the past 330 years. This amount of warming has occurred over the past century.</p> <p>For most of the time in which human civilisations have existed (the last 12,000 years), global temperatures have not changed significantly, until now. Although a change of 0.8 degrees Celsius may seem small, it has already had very serious impacts around the world (see question 8).</p>

Question

Question

Answers and Comments

7

The temperature increase between breakfast and lunch is far higher than the 0.8 degrees temperature rise over the last 150 years. Why is such a small change over 150 years dangerous yet larger changes everyday are not?

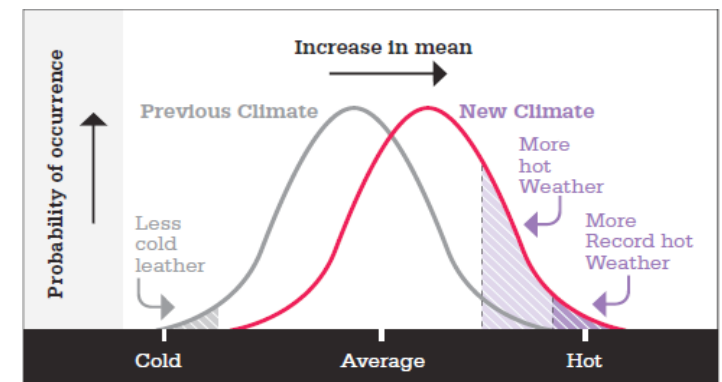
This question is misleading as it confuses the concept of weather and climate.

Short term weather changes (such as changes in daily temperature between the morning and afternoon) do not have a long term affect on the Earth's climate system. In contrast, a long term climate change (such as the 0.8 degrees Celsius warming that has occurred over the past century) does affect the Earth's climate system. A small change in climate (weather averaged over long periods) has a dramatic impact on the conditions we experience.

For example, the temperature difference between a cold glacial period and a warm interglacial period is about 5-6 degree Celsius. In contrast, the weather can change 5 or 6 degrees Celsius within one day without affecting the Earth's climate system.

In this context an increase in average global temperature of almost one degree Celsius is actually quite significant, especially as this increase has occurred over such a short time frame. For example, a shift in average climate has an effect on the probability of extreme events occurring. The graph shows how a shift from cooler to warmer average climate increases the occurrence of hot weather extremes.

Climate means (averages) and extremes



Source: IPCC Fourth Assessment Report, 2007

Question #	Question	Answers and Comments
8	If global warming is human in origin, when will we feel it and when will it be dangerous?	<p>The Earth's climate is already warming. Global average air and ocean temperatures are rising, there is widespread melting of snow and ice, and global average sea levels are rising.</p> <p>Scientists have shown, beyond doubt, that the current warming of our climate is being driven by human activities (such as burning fossil fuels and deforestation), which are releasing additional greenhouse gases into the atmosphere.</p> <p>Observed changes have already been attributed to human-induced climate change include:</p> <ul style="list-style-type: none"> » global temperatures have risen by 0.8 degrees Celsius during the past 100 years; » sea levels are rising at a rate of 3.1 mm per yr; » rainfall patterns are changing; » the oceans are warming; » there is more extreme hot weather, such as heat waves, and fewer cold extremes; and » mountain glaciers and polar ice sheets are melting. <p>Climate change becomes dangerous when it takes natural and human systems beyond environmental thresholds to which they can easily adapt. The more rapid the change, the less likely that adaptation can occur. Projections indicate that without action to reduce greenhouse gas emissions:</p> <ul style="list-style-type: none"> » temperatures in Australia could increase by up to 5 degrees by 2070; » sea levels could rise by up to 80 cm by the end of the century (baseline of 1990), with larger increases possible; and » we are likely to see more severe and intense extreme climatic events. <p>World governments have agreed that limiting temperature increases to 2 degrees Celsius above pre-industrial temperatures would help to reduce many of the most dangerous impacts of future climate change.</p>

Question #	Question	Answers and Comments
9	In the last 100 years, has there been global warming and global cooling?	<p>The climate is highly variable with natural cycles in the atmosphere and ocean systems that influence short term temperature trends. This natural variability in the climate system is why scientists look at long term records, of at least 30 years or more, to differentiate a climatic trend from shorter term variability.</p> <p>While natural variation in the temperature record does exist, during the past 100 years a clear global warming trend has occurred and global mean temperature has increased by around 0.8 degrees Celsius.</p>
10	In the last 100 years, we have had global warming alternating with global cooling on 60-year cycles. Which part of the global warming in the last 100 years has been driven by human actions and which part is natural?	<p>This is a misleading and incorrect question, as there is no evidence in the peer-reviewed science for a 60 year warming and cooling cycle. A paper by Loehle & Scafetta (2011) that suggested a 60 year astronomical influence on the Earth has been shown to be flawed.</p> <p>The Intergovernmental Panel on Climate Change (IPCC) <i>Fourth Assessment Report</i> (2007) found that warming of the climate system is unequivocal and that most of the observed increase in global temperatures since the mid-20th century is very likely due to the observed increase in human produced greenhouse gas emissions.</p>
11	Have past climate changes been greater and quicker than modern changes?	<p>Historical records reveal that the Earth has experienced significant past changes in its climate such as the changes between glacial and interglacial periods. However, none of the previous drivers of change in the Earth's climate are responsible for all the current temperature increases.</p> <p>The linear warming trend over the past 50 years of 0.13 degrees Celsius per decade is much more rapid than the rate of warming between ice ages and warm interglacial periods of around 0.01 degrees Celsius per decade. This rapid rate of warming is very unusual in the context of natural climate variability.</p>

Question

Question

Answers and Comments

12

Does the sun drive warming and cooling of the Earth?

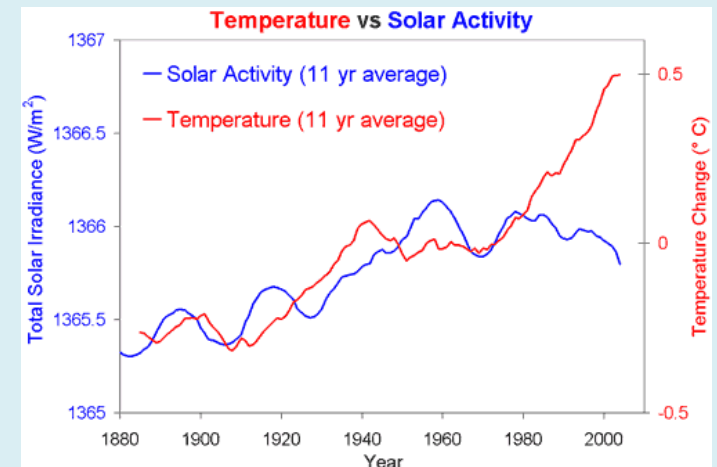
This is a misleading question, as it suggests that the sun is the only driver of our climate. Of course, as supplier of almost all the energy on Earth, the sun has a strong influence on climate. Studies comparing the energy from the sun and global temperatures have found temperatures closely match solar output.

However, since 1975 solar activity has shown little to no long-term increase while temperatures continue to rise (see the figure below). Therefore, the current rising temperatures cannot be explained by changes in the sun alone. In fact 2010, which is one of the hottest years on record, happens to coincide with the deepest solar minimum since satellite measurements began in the 1970s.

In the figure to the right, the red line shows the observed global average temperature (NASA GISS) and the blue line shows the total solar activity (1880 to 1978 from Solanki, 1979 to 2009 from PMOD). The graph, compiled by Skeptical Science, clearly shows that solar activity has been declining since the 1970's, while global temperatures have increased significantly <http://sks.to/sun>.

Scientists measure the contribution of different factors to the warming of the Earth in watts per square metre (W per m²). Changes in the sun since 1750 are assessed to have warmed the Earth by 0.12 W per m², compared to the 1.6 W per m² warming of the Earth due to human influences. Human contributions to global warming since 1750 are therefore more than 13 times greater than the solar contribution.

Warming due to solar energy can be distinguished from warming due to greenhouse gases using several lines of evidence. For example, warming due to solar increases should cause the troposphere (lowest part of the atmosphere) and stratosphere (upper part of the atmosphere) to warm uniformly, while warming due to increasing greenhouse gases should cause the troposphere to warm but the stratosphere to cool. Stratospheric cooling has been observed over the 20th century, providing evidence that greenhouse gases are causing the observed warming.



Question

Question

Answers and Comments

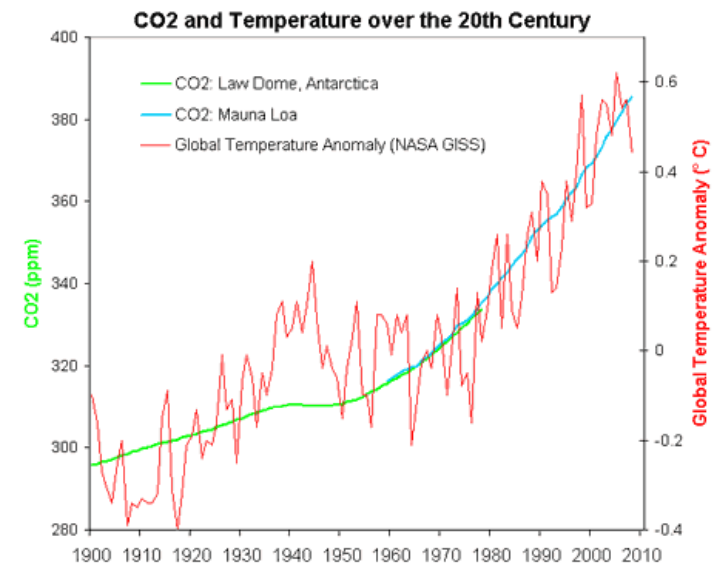
13

Why is there no correlation between global warming and atmospheric carbon dioxide yet there is a correlation between solar activity and temperature?

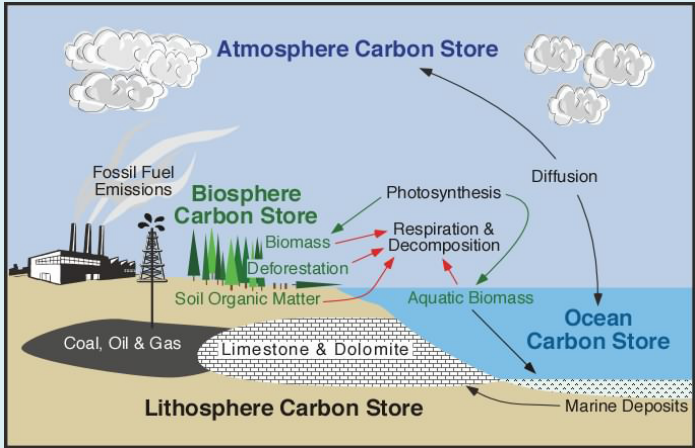
This question is misleading and incorrect. As mentioned in question 12 there has not been a correlation between solar activity and temperature since 1975. Climate records show there is a strong correlation between the amount of greenhouse gases, such as CO₂, in the atmosphere and global temperatures, as shown in the graph below.

In addition, global mean temperature is not the only indicator of global warming and climate change. Many different observations show that the globe is warming in a way that is consistent with greenhouse gas forcing.

The green line in the graph to the right shows the CO₂ levels from ice cores obtained at Law Dome, East Antarctica (CDIAC). The blue line shows CO₂ levels measured at Mauna Loa, Hawaii (NOAA). The red line shows annual global temperature anomaly (GISS). Graph compiled by Skeptical Science <http://sks.to/correlate>.



Question #	Question	Answers and Comments
14	Why do Mars and other planets show global warming?	<p>These questions are misleading and incorrect, as the suggestion that warming on Mars or other planets proves that the warming on Earth is natural fails on three key points:</p> <p>There is no evidence that demonstrates Mars and other planets are undergoing long term warming.</p>
15	If it is not the sun driving global warming on Mars, what industries on Mars are dumping carbon dioxide into the Martian atmosphere?	<p>While the basic physical processes are the same throughout the universe, the drivers of climate on Mars and other planets are very different to those on Earth and therefore direct comparisons cannot be made. For example, the variations in Mars' orbit around the sun are five times greater than those on Earth; there are no oceans on Mars and only a thin atmosphere so it cannot retain heat like Earth; and Mars is subject to large dust storms that can influence temperature.</p>
16	Where does the carbon dioxide in the atmosphere of the moon and Mars come from?	<p>Accurate measurements of the sun's incoming energy on many of the planets in our solar system have been taken from here on Earth. These measurements show that the sun is not heating up all the planets in our solar system.</p> <p>The CO₂ on Mars and other planets likely came from volcanic processes over the evolution of the planet or from collisions with comets.</p>
17	Billions of years ago, did the Earth's atmosphere contain carbon dioxide?	Yes.

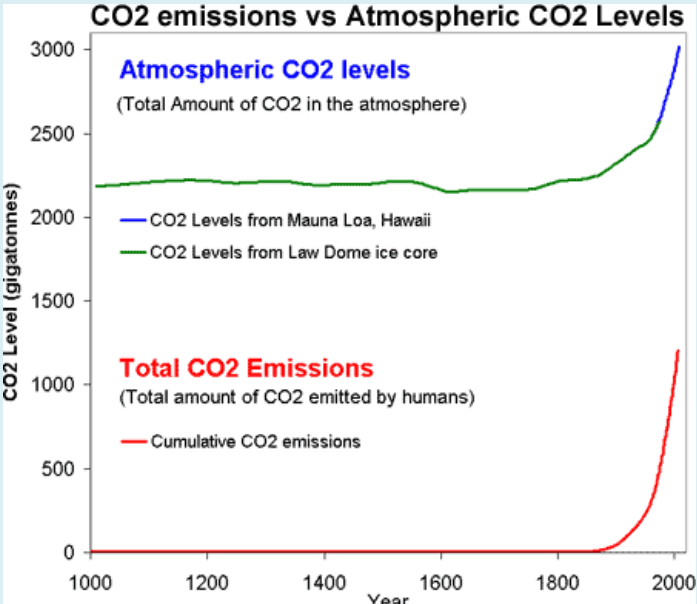
Question #	Question	Answers and Comments
18	Where did the carbon dioxide in the Earth's atmosphere billions of years ago come from?	<p>CO₂ in the Earth's atmosphere originally came from geological processes and potentially from collisions with comets. Carbon is naturally exchanged or cycled through the atmosphere, the land and the oceans. Over the history of the Earth, carbon has been stored deep in the oceans and underground in rocks and as gas, oil, and coal. Humans are extracting this stored carbon and returning it to the atmosphere through processes such as burning fossil fuels.</p>
19	If there was a lot of carbon dioxide in the atmosphere of early Earth, where did it go?	<p>The figure to the right shows how carbon is stored and cycled through our planet in a number of major sinks. These include the biosphere, the atmosphere, soils, fossil fuels and sedimentary rock deposits, and the oceans.</p> <p>http://www.physicalgeography.net/fundamentals/9r.html</p>  <p>The diagram illustrates the carbon cycle with three main carbon stores: the Atmosphere Carbon Store (top), the Biosphere Carbon Store (middle), and the Lithosphere/Ocean Carbon Store (bottom). The Atmosphere store is represented by clouds. The Biosphere store includes land (trees, grass) and aquatic (fish, algae) biomass. The Lithosphere/Ocean store includes fossil fuels (coal, oil, gas), sedimentary rocks (limestone, dolomite), and marine deposits. Arrows indicate the flow of carbon: Fossil Fuel Emissions release carbon from the lithosphere into the atmosphere. Photosynthesis moves carbon from the atmosphere into the biosphere. Respiration and decomposition return carbon from the biosphere to the atmosphere. Diffusion exchanges carbon between the atmosphere and the ocean. Deforestation releases carbon from the land biosphere into the atmosphere. Soil organic matter and marine deposits are shown as carbon sinks within the lithosphere/ocean store.</p>
20	How much carbon dioxide does limestone contain?	<p>Limestone is a sedimentary rock composed largely of the minerals calcite and aragonite, which are different crystal forms of calcium carbonate (CaCO₃). Limestone can contain up to about 40 per cent CO₂.</p>
21	Where did the carbon dioxide for limestone come from?	<p>Most limestone forms from skeletal fragments of marine organisms such as coral. The oceans absorb CO₂ from the atmosphere which allows invertebrate animals (animals with no backbones) in the ocean to take calcite from sea water to construct their shells. When they die their shells and skeletons fall to the sea bed and, over time, can form limestone.</p>

Question #	Question	Answers and Comments
22	Does this mean that the air billions of years ago had more carbon dioxide than now?	The natural carbon cycle of the Earth operates on very long time scales. Prior to human civilisation there were periods when CO ₂ concentrations and temperatures were much higher than present. For example, the late Ordovician period 445 million years ago was a glacial period which took place when evidence suggests CO ₂ levels were very high. However, during this period the sun was much cooler than it is now, preventing temperatures from becoming too high.
23	If the planet originally had far more carbon dioxide in the air than now, why isn't the planet permanently very hot?	In recent geological history, a cycle of ice ages interspersed by warm periods has been associated with changes in the global temperature of up to six degrees on timescales of around 100,000 years. This glacial cycle is driven by slow changes in the Earth's orbit that change the amount of energy from the sun that reaches the surface of the Earth.
24	If carbon dioxide drives global warming, how is it that we have had six major ice ages in the past yet atmospheric carbon dioxide was far higher than now?	<p>While CO₂ levels naturally increased during these warm interglacial periods, current CO₂ levels are now about 390 parts per million, well beyond anything experienced in the last 800,000 years. The rapid increase in CO₂ levels that has occurred since the industrial revolution is unusual in the geological record. In fact, the rate of warming during the 20th century (0.13 degrees Celsius per decade) is much faster than the rate of temperature change due to the glacial cycle (0.01 degrees Celsius per decade).</p> <p>This rapid increase in CO₂ levels and temperature is already having impacts including melting snow and ice, observed sea level rise, increased acidity of our oceans and more extreme heat events. Human civilisation as we know it has developed over the last 10,000 years with a relatively stable climate. The current changes are pushing us beyond the climate envelope in which civilisation has evolved. This will bring significant challenges for society including: coastal communities; infrastructure; water security; food production systems; and natural ecosystems.</p> <p>Note: Professor Plimer discusses the logarithmic relationship between CO₂ and temperature in his answer to these questions. This relationship is well understood by climate change scientists. Each doubling of CO₂ will result in about the same amount of warming in the atmosphere. For example, the IPCC <i>Fourth Assessment Report</i> found that the climate is likely to warm by about 3 degrees Celsius (with a likely range of 2.5 to 4.5 degrees Celsius) for each doubling of CO₂ concentration.</p>

Question #	Question	Answers and Comments
25	Will increased atmospheric carbon dioxide increase food production?	<p>It is currently unclear exactly how increased levels of atmospheric CO₂ will affect the production of all food produce. Growth of some plants is stimulated by increased levels of CO₂ when other conditions, such as the temperature and availability of water and nutrients, remain unchanged.</p> <p>However climate change is likely to lead to changes to the conditions which are necessary for food production (such as rising temperatures, changing patterns of rainfall and nutrients). These changes could counteract some of the potential benefits from increased CO₂ levels.</p> <p>Experiments to quantify the impact of CO₂ elevation indicate that increased growth does not occur for all plant species, potentially leading to changes in plant species distribution. The nutritional content of crops may also be reduced.</p>
26	What drives climate change?	<p>Scientists have shown, beyond doubt, that the current warming of our climate is being driven by human activities, such as burning fossil fuels and deforestation. These activities release additional greenhouse gases into the atmosphere.</p> <p>While emissions of CO₂ are not the only driver of climate, it currently has the biggest influence on global temperatures. Other forces that are currently influencing our climate include aerosols, changes in the sun's output, stratospheric water vapour, ozone, and other greenhouse gases such as methane, nitrous oxide and halocarbons.</p>

Question #	Question	Answers and Comments
27	Can humans change climate?	<p>Yes, scientists have shown beyond doubt that the current warming of our climate is being driven by human activities which release additional greenhouse gases into the atmosphere.</p> <p>The climate system is sensitive to changes in atmospheric chemistry. Greenhouse gases such as CO₂ strongly absorb and re-emit infrared radiation (felt as heat) from the sun. This process, called the greenhouse effect, maintains the Earth's temperature at 33 degrees Celsius warmer than it would otherwise be, allowing life on Earth to exist.</p> <p>Human activities have significantly increased the level of CO₂ and other greenhouse gases in the atmosphere, which increases the greenhouse effect and causes temperatures to rise.</p> <p>CO₂ levels in the atmosphere are now 40 per cent higher than they were before industrialisation, and measurements have revealed that this increase is due to human activities. Satellite and surface measurements find that less heat is escaping into space and more heat is returning to Earth at the wavelengths at which CO₂ absorbs heat. These measurements provide evidence that increased CO₂ emissions are causing global temperatures to rise.</p> <p>While Professor Plimer is correct in stating that water vapour is an important greenhouse gas, human activity does not directly affect the amount of atmospheric water vapour. However, human activity has significantly increased the concentrations of the other greenhouse gases, such as CO₂, which cause the Earth to warm. A warmer atmosphere can hold more water vapour, which then generates further warming, creating a reinforcing 'feedback'.</p> <p>All major climate models incorporate this water vapour feedback when developing simulations of the climate.</p>

Question #	Question	Answers and Comments
28	How much carbon dioxide is in the atmosphere at present?	<p>The current global concentration of CO₂ is around 390 ppm, which is 40 per cent higher than before industrialisation and well beyond the natural range of the last 800,000 years of between 172 and 300 ppm.</p> <p>The chemical properties of greenhouse gases, such as CO₂, mean that they strongly absorb and re-emit infra-red radiation, which is felt as heat. This process maintains the Earth's temperature at 33 degrees Celsius warmer than it would otherwise be, allowing life on Earth to exist.</p> <p>The greenhouse effect has been directly measured. Satellite and aircraft measurements have found a big drop in out-going heat at the exact wavelengths that greenhouse gases such as CO₂ absorb energy. This proves that greenhouse gases, such as CO₂, are absorbing heat and energy in the atmosphere.</p> <p>Over 99 per cent of the atmosphere is made up of oxygen and nitrogen, neither of which are greenhouse gases. CO₂ is a greenhouse gas and has a significant effect on the climate despite being a small percentage of the atmosphere.</p>
29	What proportion of annual carbon dioxide emissions derives from humans and what proportion is natural?	<p>The CO₂ that nature emits is balanced by natural land and ocean absorption processes so that the net CO₂ emissions from nature is in approximate balance. Human CO₂ emissions are upsetting this balance by adding additional CO₂ into the climate system from long term stores that are not part of the active natural cycle. Consequently, atmospheric CO₂ levels have risen to levels not seen in hundreds of thousands of years. To claim that human emissions are small compared to natural emissions ignores the natural carbon cycle which keeps our climate in balance.</p>
30	How does the 3 per cent of annual emissions of carbon dioxide, that is the human emissions, drive climate change and the other 97 per cent do not?	<p>Of the total amount of CO₂ that is released into the atmosphere per year, human activities are responsible for approximately 3 per cent. As long as we keep adding CO₂ into the atmosphere faster than natural sinks can absorb it, CO₂ levels will continue to rise and the Earth will continue to warm.</p> <p>There has been an accumulated 40 per cent increase in atmospheric CO₂ since the industrial revolution. Analysis of carbon molecules in the atmosphere show that this extra CO₂ has come from human activities such as the burning of fossil fuels.</p>

Question #	Question	Answers and Comments
31	<p>Why don't the variations in atmospheric carbon dioxide correlate with human emissions of carbon dioxide?</p>	<p>This question is incorrect. Variations in atmospheric CO₂ correlate closely with human emissions of CO₂ combined with the natural processes that cycle carbon through the atmosphere, oceans and land sinks (see figure). Natural variations in the Earth's climate, such as changing seasons and shifts between periods of El Niño and La Niña, can influence the amount of CO₂ absorbed by natural sinks such as the ocean, forests and soils.</p> <p>The graph to the right shows the total amount of CO₂ (billions of tonnes) in the atmosphere (top green and blue lines) and the total amount of CO₂ humans have emitted into the atmosphere (billions of tonnes) (bottom red line). There is a clear correlation between atmospheric CO₂ and human emissions of CO₂. Data from Law Dome, East Antarctica, Mauna Loa, Hawaii and the Carbon Dioxide Information Analysis Centre. Graph compiled by Skeptical Science http://sks.to/co2conc.</p> 
32	<p>Do plants know the difference between carbon dioxide emitted from human activities and carbon dioxide from natural emissions?</p>	<p>This is question is irrelevant. What is important is that humans are emitting additional greenhouse gases in the atmosphere, which accumulates, traps additional heat and cause temperatures to rise.</p> <p>Plants do, however, record the difference between of carbon from fossil fuels and carbon from natural sources. Carbon is composed of three different isotopes, or variants – carbon 12, 13 and 14. CO₂ produced from burning fossil fuels or burning forests has a different isotopic composition from CO₂ in the atmosphere. Tree-ring records show that the percentage of carbon 14 (which is not found in fossil fuels) has been decreasing in trees. If natural CO₂ is decreasing, it cannot be the cause for the observed increase in CO₂ levels. This means that the rise in CO₂ in the atmosphere is produced by burning fossil fuels and other human activities.</p>

Question #	Question	Answers and Comments
33	Is carbon dioxide poisonous?	<p>Yes. As with many substances, the toxicity of CO₂ is dependent on the concentration at which it occurs, and where it occurs. Everyday comparisons can be readily made. For example oxygen is essential for human life on Earth, however even oxygen can be toxic if consumed in high concentrations under pressure.</p> <p>At very high concentrations CO₂ can lead to serious health impacts and even death. For example, in 1986 Lake Nyos in the West African country of Cameroon suddenly emitted a large cloud of CO₂ which suffocated 1,700 people and 3,500 livestock in nearby towns and villages. Many survivors developed respiratory problems, lesions, and paralysis as a result.</p>
34	Is carbon dioxide a pollutant or is it used in photosynthesis?	<p>Many substances can be pollutants when they are in the wrong place or in the wrong quantity. Paracetamol, which we take in small doses for pain relief, can be life-threatening in extremely large doses. Ozone is an important part of the ozone layer, protecting us from dangerous solar radiation, however if inhaled ozone is a powerful irritant and can trigger respiratory problems.</p> <p>Likewise, CO₂ becomes a pollutant when its concentration in the atmosphere results in disruption to the Earth's climate system.</p> <p>Yes, CO₂ is used by plants for photosynthesis and is an essential part of our world. However, the current global concentration of CO₂ is around 390 ppm, well beyond the natural range of the last 800,000 years of between 172 and 300 ppm.</p> <p>The harmful impacts of increased CO₂ are already being observed. For example, increased acidity levels in the oceans due to increased CO₂ concentrations may have negative consequences for many calcifying marine organisms and reefs.</p>
35	Are atmospheric carbon dioxide levels a consequence of temperature, not the cause?	<p>Currently, increases in atmospheric CO₂ levels are causing global average temperatures to rise.</p> <p>However, atmospheric CO₂ has the ability to drive temperature change as well as be changed in response to changing temperatures.</p>
36	If the human body and food are composed of carbon compounds and all animals breathe out carbon dioxide, how can carbon be pollution?	<p>As previously outlined in question 34, many natural substances can be pollutants when they are in the wrong place or in the wrong quantity.</p> <p>The carbon we cycle through the food we eat and the carbon we exhale is part of the natural carbon cycle. Breathing does not add extra CO₂ into the atmosphere. In contrast, the burning of fossil fuels does add extra CO₂ into the atmosphere and this is disrupting our climate system. This is why CO₂ is considered a pollutant.</p>

Question #	Question	Answers and Comments
37	For thousands of years, prophets of doom have been telling us the world was about to end. It hasn't, otherwise we would not be here. Why is it that we should believe the modern prophets of doom who tell us that our carbon dioxide emissions will destroy the planet?	<p>This is a misleading and irrelevant question.</p> <p>Climate scientists have never claimed that the world is going to end due to climate change. Instead, scientists have outlined the impacts of increasing CO₂ from human activities. These impacts include increasing air and ocean temperatures, melting of snow and ice, sea level rise and increasing acidity of the world's oceans.</p> <p>Scientists have concluded that such changes in the climate will have significant impacts on our communities, economy and environment. For example, a study considering the vulnerability of Australia's coastal infrastructure to sea level rise found that existing residential buildings valued at a total of up to \$63 billion are potentially at risk of flooding from a 1.1 m sea level rise.</p>
38	If we double the amount of carbon dioxide in the air from human emissions, how much will temperature increase?	<p>Climate sensitivity is the estimate of how much the Earth's climate will warm if CO₂ concentrations are doubled (i.e. from pre-industrial levels of 280 ppm to 560 ppm). The estimate of climate sensitivity comes from a range of methods, including looking at past climate change through many different periods in Earth's history.</p> <p>The IPCC <i>Fourth Assessment Report</i> has found that the climate is likely to warm by around 3 degrees Celsius for each doubling of CO₂ concentrations.</p>
39	Over the history of time, why has atmospheric carbon dioxide decreased?	CO ₂ has increased and decreased in the atmosphere over time as it naturally cycles through the atmosphere, land and oceans. Over the history of the Earth, carbon has been sequestered and stored in the deep oceans, in plants and land, and also underground in rocks and as oil, gas, coal and methane hydrates.
40	Where has it all gone?	The natural carbon cycle operates over many thousands of years. In comparison, human-induced changes to the carbon cycle, such as burning fossil fuels and releasing the stored carbon into the atmosphere, oceans and biosphere, have been extremely rapid.

Question #	Question	Answers and Comments
41	China's carbon dioxide emissions each year rise by five times the proposed cuts to Australia's emissions. Will Australia cutting carbon dioxide emissions change global climate?	An effective global solution requires action from all major emitters. Australia, as one of the world's major emitters, and with one of the highest per capita emissions levels of all countries, must take strong action to tackle climate change. Fair and effective global action to stabilise atmospheric greenhouse gas concentrations at 450 ppm CO ₂ -equivalents or lower is squarely in Australia's national interest. This is necessary to limit temperature increases to below 2 degrees Celsius, the internationally-agreed goal to avoid the worst impacts of climate change.
42	Is water vapour or carbon dioxide the main greenhouse gas in the atmosphere?	<p>There is more water vapour in the atmosphere than other greenhouse gases. However changes in water vapour generally occur as a feedback mechanism and not as a primary driver of climate change. Human activities have resulted in extra CO₂ into the atmosphere. This causes the climate to warm, which allows the atmosphere to hold more water vapour, creating additional warming. In this context, CO₂ acts as the 'control knob' governing Earth's temperature because of its very long lifetime in the atmosphere.</p> <p>Human activity does not directly affect the amount of water vapour in the atmosphere.</p>
43	If water vapour is the main greenhouse gas, why doesn't the government have a tax for water vapour emissions?	
44	Does warming cause drought or does drought cause warming?	Drought can influence temperature on a regional scale over short time periods. However, drought is not responsible for the long term observed global warming – additional CO ₂ in the atmosphere from human activities is responsible. Climate change will change rainfall patterns bringing more drought to some areas and more rain to others.

Question #	Question	Answers and Comments
45	How can you explain why it was warmer in the Medieval Warm Period than now yet there were no carbon dioxide-emitting industries?	<p>The Medieval Warm Period (AD 800–1300) is a well known climate episode. Although evidence suggests that the Medieval Warm Period may have been as warm as the 20th century in some parts of the globe, evidence also suggests that some places, such as the tropical Pacific, were cooler than today. Recent increases in temperature have likely pushed the Earth beyond the temperatures experienced during the Medieval Warm Period.</p> <p>As previously explained, CO₂ is not the only driver of climate. During the Medieval Warm Period solar energy was higher than average and there was less volcanic activity, both of which lead to warmer temperatures. Changes in ocean circulation patterns are also thought to have played a very important role in bringing warmer seawater into the North Atlantic. This explains much of the unusual warmth in that region.</p>
46	If the warming in Medieval times was natural, what is the evidence to show that late 20th Century warming was not natural?	<p>However, none of these past natural forces can explain the climate changes we are now seeing. Scientists have closely examined all of the processes that can drive changes in the Earth's climate and have found that the pattern of warming observed during the 20th century is caused by increasing greenhouse gases from human activities.</p>

Question

Question

Answers and Comments

47

Since thermometer measurements were made, there has been warming from 1860 to 1880, cooling from 1880 to 1910, warming from 1910 to 1940, cooling from 1940 to 1977, warming from 1977 to 1998 and cooling from 1998 until now. Which warmings and coolings were of human origin?

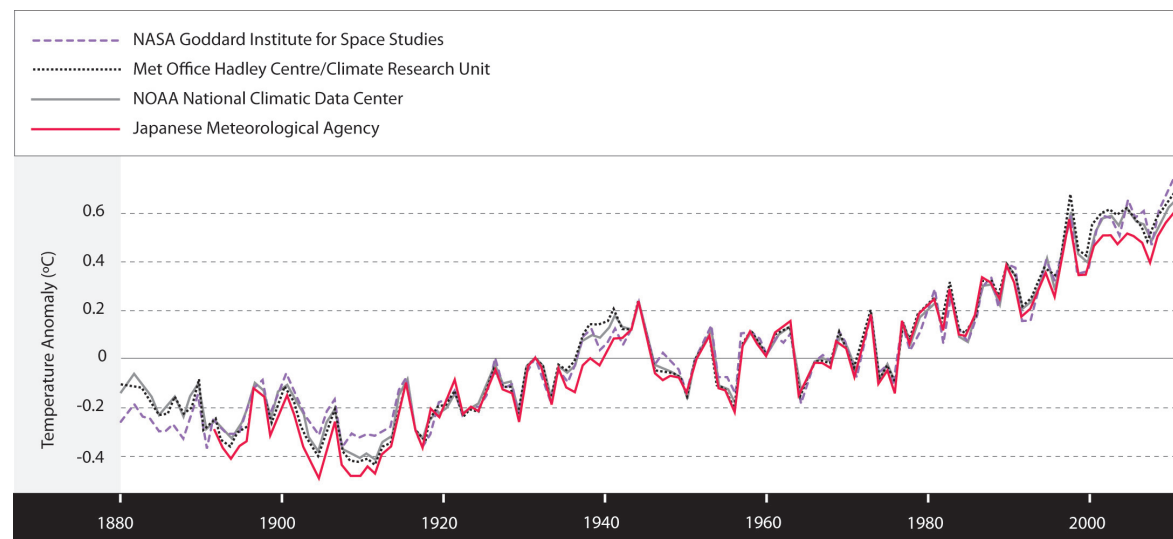
This is a misleading question, as it is statistically incorrect to pick particular short term periods to determine a long term warming or cooling trend.

Natural variability in the climate makes it inappropriate to use short time periods to draw conclusions on long term trends. For example, as 1998 was a particularly warm year choosing a period from 1998 to present incorrectly suggest that a warming trend has slowed.

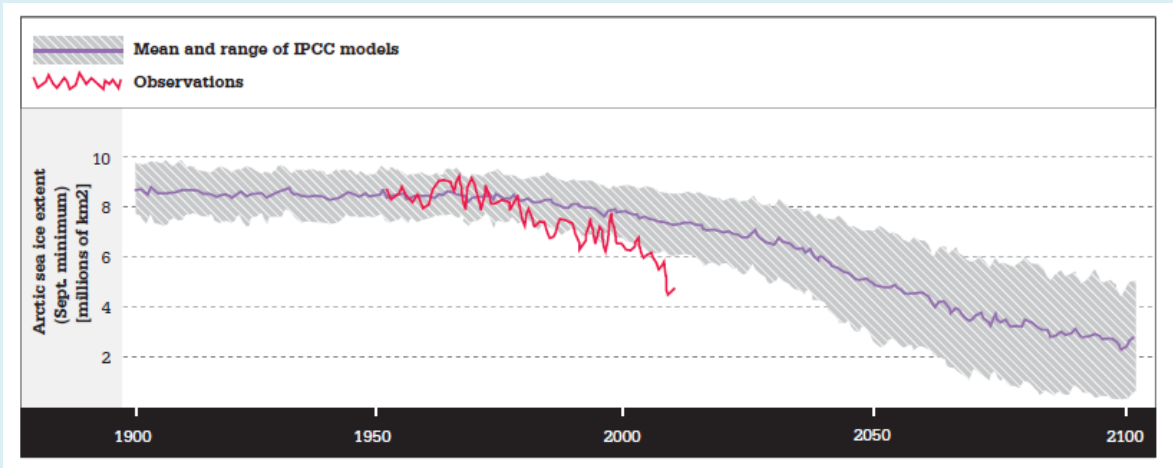
Scientists studying the climate are careful to look at trends over 30 years – and preferably much longer – because shorter-term changes can be misleading due to natural variability.

Records of global temperatures for the last century show that Earth's surface has warmed by about 0.8 degrees Celsius, and that the warming trend is continuing. Warming of the Earth can also be seen through increasing ocean temperature, increasing deep ocean heat content, increasing atmospheric pressure, reductions in Arctic sea-ice and melting of snow and glaciers.

The graph below demonstrates that a range of renowned international temperature data sets (from the National Aeronautics and Space Administration's Goddard Institute for Space Studies (NASA GISS), the Met Office Hadley Centre, the National Oceanic and Atmospheric Administration's National Climatic Data Center (NOAA NCDC) and the Japanese Meteorological Agency) all confirm that while there is yearly or decadal variation in global temperatures, there is a clear long-term warming trend over the past century.



<http://climatecommission.gov.au/topics/the-critical-decade/>

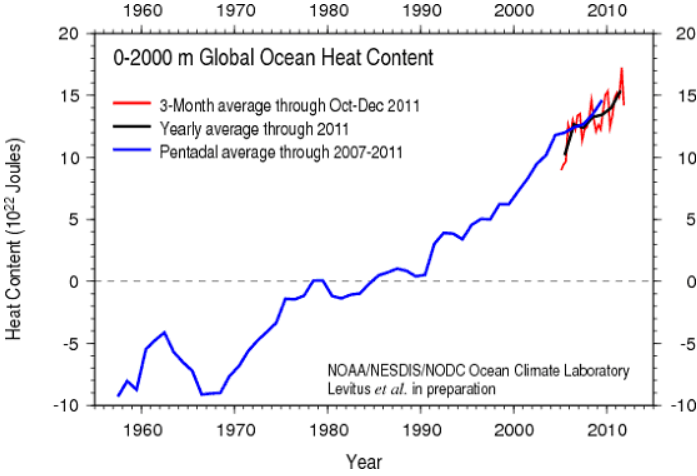
Question #	Question	Answers and Comments
48	Why could the Northwest Passage be navigated in the 1930s and 1940s in wooden boats yet it could not be navigated in the late 20th Century warming?	<p>These are misleading questions, as they incorrectly suggest that the Northwest Passage cannot currently be navigated. A list of the major vessels that have transited the Passage since Amundsen's transit in the schooner 'Gjoa' in 1903, including 18 vessels between 2000 and 2004, and 21 vessels during the 1990s can be found at www.nauticapedia.ca/Articles/NWP_Fulltransits. The Canadian Border Services Agency reported in September 2010 that traffic that year had more than doubled, with 17 vessels clearing customs in Inuvik that year, compared to 7 in 2009. While the passage may be effectively closed during the winter months, it is clear that it can readily be transited during the summer navigation season.</p>
49	In 1903 Amundsen passed through Canada's Northwest Passage from the Atlantic Ocean to the Pacific. If the planet is warming, why is it not possible now?	<p>The graph below demonstrates the observed decline (red line) in Arctic sea ice extent and modelled projections (in purple) from the IPCC <i>Fourth Assessment Report</i>.</p> 
50	I heard that 2010 was the hottest year since records have been kept. The Northwest Passage is closed by ice yet it was open in the 1930s. Was 2010 really the hottest year on record?	<p>The graph highlights that the observed decline in Arctic sea ice is greater than the IPCC projections http://climatecommission.gov.au/topics/the-critical-decade. Source: Stroeve et al. (2007), updated to include data for 2008.</p> <p>The World Meteorological Organization found that years 2010, 2005 and 1998 are the world's warmest years on record, and the decade 2002-11 was the world's warmest on record.</p>

Question #	Question	Answers and Comments
51	<p>Why has the temperature been decreasing since 1998 yet human emissions of carbon dioxide have been increasing?</p>	<p>This is a misleading and incorrect question, as the assertion that global warming has been decreasing since 1998 is incorrect.</p> <p>There is unequivocal evidence that the Earth is warming and climate change is occurring. Globally, mean atmospheric temperature has increased by around 0.8 degrees Celsius over the last 100 years. The 2002-11 decade was the warmest on record, warmer than the preceding decades.</p> <p>When climate change scientists talk about global warming they mean warming of the climate system as a whole, which includes the atmosphere, the oceans, and the cryosphere (ice, snow and frozen ground). Ocean temperatures are the best indicator of changes in the climate system. Measurements show that around 90 per cent of the world's observed warming has taken place in the oceans.</p> <p>The graph to the right shows the Earth's total heat content (updated graphic of total heat content from Church et al, 2011, http://sks.to/1998). It clearly shows that global warming has continued past 1998. The planet is still accumulating heat. The graph also shows that the heat capacity of the land and atmosphere is small compared to the ocean. Relatively small exchanges of heat between the atmosphere and ocean can cause significant changes in surface temperature.</p> <div data-bbox="1400 443 2101 1023"> <p>Total Heat Content since 1961 (2011 update)</p> </div>
52	<p>What is the mechanism that causes warming trends to reverse? Will the mechanism kick in with human-induced global warming?</p>	<p>The natural processes that can trigger cooling of global temperatures include changes in solar radiation, volcanic eruptions, increased surface albedo (reflectivity) or changes in ocean circulations. These natural processes are well understood and are unlikely to reverse human-induced global warming. For example, a large volcanic eruption could result in a short term cooling (of a couple of years), however this would not counteract the long-term warming from human emission of greenhouse gases.</p>

Question #	Question	Answers and Comments
53	The Earth has been warming since the Maunder Minimum 330 years ago. Is it surprising that temperature measurements would show a warming trend over the last 150 years?	<p>The Maunder Minimum refers to a time of very low sunspot activity, which resulted in relatively low global temperatures. Sunspot activity however, cannot explain the recent observed warming.</p> <p>Over the past century, global mean temperature has increased by around 0.8 degrees Celsius. This is a rapid rate of change.</p> <p>Scientists have shown, beyond doubt, that the current warming of our climate is being driven by human activities, which are releasing additional greenhouse gases into the atmosphere.</p> <p>While many believe that the Earth's temperature naturally cycles by itself over long periods, this is not the case. The climate will not change unless a physical driver changes the energy balance of the Earth. For example, the glacial interglacial cycle is driven by changes in solar radiation.</p>
54	How can there be a global average temperature?	Temperatures from all around the world are measured and averaged (a common statistical technique to determine overall trends in large datasets) to produce a measurement of 'global average temperature'.
55	What is the order of accuracy of temperature measurements?	There are a number of agencies that measure global surface temperature, through both direct observations and satellite measurements. Foremost among these are NASA, the NOAA NCDC and the Hadley Centre in collaboration with the University of East Anglia. Each has produced an independent global average near-surface temperature record which show close correlation with each other (see Q.47).
56	Is it valid to combine inaccurate 19th century temperature measurements with far more accurate measurements of the late 20th century?	<p>Consistency in these independent measurements demonstrates that temperature measurements are very accurate.</p> <p>The recent Berkeley Earth Surface Temperature study has provided yet another confirmation of the accuracy of global temperature measurements, finding that the influence of urban heat on global temperature records is nearly negligible.</p> <p>In general, scientific research suggests that global mean temperatures are accurate to a tenth of a degree.</p> <p>Yes, it is valid to use 19th century data, and historical climate data, in association with current observational data. A range of methodologies that take account of the different levels of accuracy of the datasets are used, and have been tested and published in peer reviewed scientific literature.</p>

Question #	Question	Answers and Comments
57	The number of measuring stations has greatly decreased over the last 20 years with the loss of stations in polar, mountainous, rural and remote areas. Does this create a warming bias to temperature measurements?	<p>No, changes in the number and distribution of weather stations do not generate a warming bias in the data. These temperature measurements are supported by satellite data (which covers the whole globe) and measurements of warming in the oceans.</p> <p>In fact, the loss of polar weather stations actually has a cooling bias because the warming trend is greater in polar regions. This cooling bias is accounted for in temperature measurements.</p>
58	When temperatures are used for models, are the actual raw measurements used or are corrected measurements used?	Global climate models do not use observed temperatures as inputs, other than to create a starting point for model simulations. Instead, global climate models rely on the physics and chemistry of the climate system.
59	What is the urban heat island effect?	The urban heat island effect describes how urban areas can generate and store more heat than nearby rural areas due to the concentration of buildings and heat from human activities (such as air conditioners).
60	Is there a standard method to correct for the urban heat island effect?	<p>The IPCC <i>Fourth Assessment Report</i> considered the effect of urban heat on long-term global temperature records and found that the observed global land warming trend is very unlikely to be influenced significantly by increasing urbanisation. Several studies (most recently the Berkeley Earth Surface Temperature study) have shown that relative to the scale of observed warming, the effect of urban heating is very small.</p> <p>There is no standard method for correcting such data — each site needs to be considered on a case-by-case basis. One approach is to exclude urban sites, for example urban measurement sites have been removed from such data sets as the HadCRUT3 and the Bureau of Meteorology's homogenised temperature data.</p>

Question #	Question	Answers and Comments
61	If land temperature measurements have to be “adjusted”, how do we know that the “adjusted” measurements are accurate?	<p>The base assumption in this question is that unadjusted temperature records are the closest ‘ground truth’ to changes in temperature that have actually occurred. This is incorrect and there is a vast amount of literature and experience across meteorological agencies around the world that show this assertion to be false. Raw records are subject to numerous influences and biases that create errors in the data. The need to carefully standardise temperature records is well supported in the peer reviewed literature.</p> <p>Land-based temperature measurements are adjusted according to mathematically-based and widely accepted statistical techniques. Land-based temperature measurements are also independently verified by satellite measurements, which are not affected by the urban heat island affect or other variables. Warming over the 20th century has been found to be robust and consistent across multiple independent data sets.</p>
62	If “adjusted” temperature measurements are used for computer predictions of future climate, how can we trust these models?	<p>As explained in question 58, observed temperatures are not used as direct inputs in global climate models. Climate models are based on the laws of physics and are used as tools to predict or estimate future climate change.</p> <p>Confidence in the reliability of models for climate projections is tested through the models’ ability to simulate observed climate trends in the recent past and in the climate from thousands of years ago. The more accurately the model is able to reproduce the past climate, the better it should be at predicting future climates.</p> <p>More generally, climate models are not the only type of model we use regularly in our daily lives. We trust many different sorts of models daily. For example, different sorts of models are used for petroleum exploration, medical imaging and aircraft design.</p>
63	Why have computer models that predicted high altitude warm air at the equator as a result of increased human emissions of carbon dioxide failed?	<p>Climate models have not failed.</p> <p>Scientists have found that there is no disagreement between the tropospheric temperature trends from models and from observations, when uncertainties in both are fully accounted for.</p> <p>More importantly, the vertical profile of temperatures due to increasing greenhouse gases is one of cooling in the high atmosphere (stratosphere) and warming in the lower atmosphere (troposphere). This pattern is a unique greenhouse ‘fingerprint’ (i.e. warming from the sun causes both the stratosphere and the troposphere to warm) and is the pattern that is observed over the past 100 years.</p>

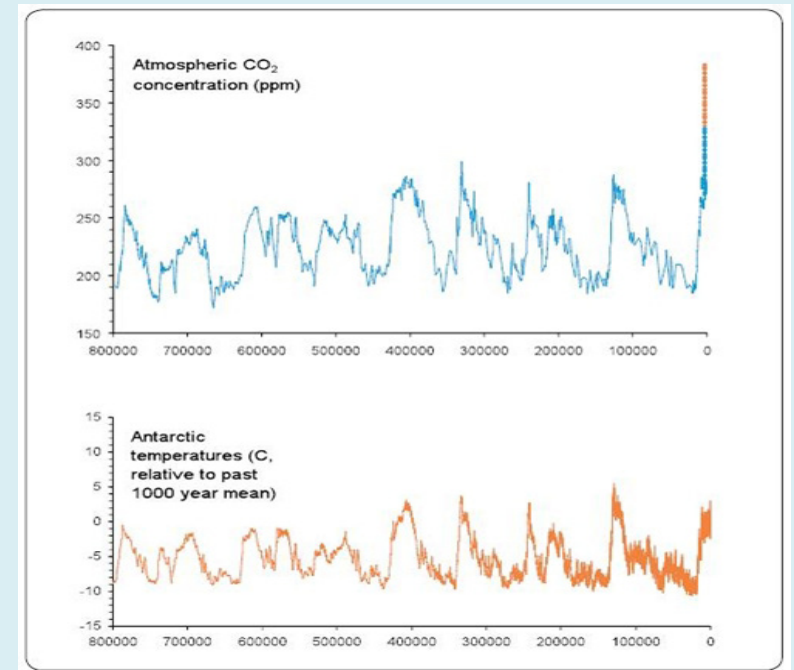
Question #	Question	Answers and Comments
64	Computer models predicted that the sea surface temperature would warm yet measurements show that there is cooling, why?	<p>This is a misleading and incorrect question, as the oceans <i>are</i> warming (see graph below). Sophisticated monitoring has shown that around 90 per cent of the observed warming of the climate system has taken place in the oceans. Estimates of ocean heat from the Argo network (a network of over 3,000 floats scattered across the global oceans that measure temperature and salinity) show continued warming of the upper ocean. This warming is confirmed by other independent estimates of ocean heat as well as more comprehensive measurements of ocean heat down to 2000 m deep.</p> <p>The graph to the right from the National Oceanographic Data Centre shows how the ocean heat content in the upper half of the ocean has continued to warm significantly.</p> <p>Source: www.nodc.noaa.gov/OC5/3M_HEAT_CONTENT/index.html</p> 
65	What information is accepted and rejected in models of future climate?	<p>Global climate models use information which has been peer reviewed and found to be accurate. The information consists of particular climate-related variables such as land, water and atmospheric temperatures. Climate models are based on the laws of physics and have been found to be able to reproduce many observed features of current and past climate changes.</p>

Question #	Question	Answers and Comments
66	<p>Computer models predict future climate changes far less than the changes experienced by humans over the last 6,000 years. Why should we worry about future climate?</p>	<p>This is a misleading question as the predicted changes (in the event of continued growth in CO₂ emissions) are much greater than changes experienced by humans over the last 6,000 years. Human civilisation has also changed greatly since 6,000 years ago. The population has expanded rapidly, and cities and infrastructure which may be affected by future climates has been developed.</p> <p>Global average temperatures have remained relatively stable during the last 12,000 years of human development (the Holocene period). However over the past century, global mean temperature has increased by around 0.8 degrees Celsius. This is a significant change and has already had serious impacts around the world.</p> <p>Changes to our climate system have already caused:</p> <ul style="list-style-type: none"> » Changes in extreme hot weather - there have been an increase in the number of record high temperatures and fewer extreme low temperatures. » Rising ocean surface temperatures - since 1961, the oceans have stored 90 per cent of the warming. By absorbing heat, the oceans' temperature has risen 0.5 degrees Celsius. » Melting ice caps and glaciers - several glacial regions worldwide have experienced melting from the 1850s to present. » Melting of Greenland and Antarctica - the loss of ice is due to melting snow and ice flowing into the ocean. The rate of ice loss in Greenland has risen since the 1990s. » Increased sea levels - global sea level has risen over the 20th century, and the rate of increase accelerated again in the 1990s. This rate of global sea level rise (3.1 mm per year since 1993) is faster than any similar time period in history.

Question #	Question	Answers and Comments
67	The models, code and data used by the IPCC for their climate predictions are not available yet computer climate predictions are the basis for suggestions of human-induced global warming. How can their predictions be independently checked?	<p>The IPCC does not undertake research, but instead it draws upon scientific and technical studies which have been peer-reviewed and published in recognised journals. Data and predictions are independently checked during the peer review process. All published and peer-reviewed literature is publicly available. For example, the main models used as a basis for IPCC assessments, the Coupled Model Intercomparison Project, makes all of its data available online at http://cmip-pcmdi.llnl.gov/cmip5/.</p>
68	How can I have confidence in the predictions of a climate model if don't know how it works and if they have been shown to be wrong?	<p>Models are not something used uniquely to understand the climate system. We trust many different sorts of models daily without understanding how they work. For example, every time we fly in a modern airplane we travel in a machine that has been designed by models and has used models to predict how the atmosphere and air currents work.</p> <p>It is incorrect to state that climate models have been shown to be wrong. Confidence in the reliability of climate models for climate projections has improved over time, based on tests of their ability to reproduce:</p> <ul style="list-style-type: none"> » current average climate and year-to-year variability; » observed climate trends in the recent past; » extreme events, such as storms and heat waves; and » climates from thousands of years ago. <p>Model verification is undertaken extensively as part of climate change research and is published in the international literature.</p> <p>Models show significant and increasing skill in representing many important mean climate features such as the large-scale distributions of atmospheric temperature, precipitation, radiation and wind, oceanic temperatures, currents and sea ice cover.</p> <p>Overall, climate models provide credible quantitative estimates of future climate change, particularly at continental scales and above. There will always be a range of uncertainty in climate projections and decision-makers need to incorporate this uncertainty in risk management.</p>

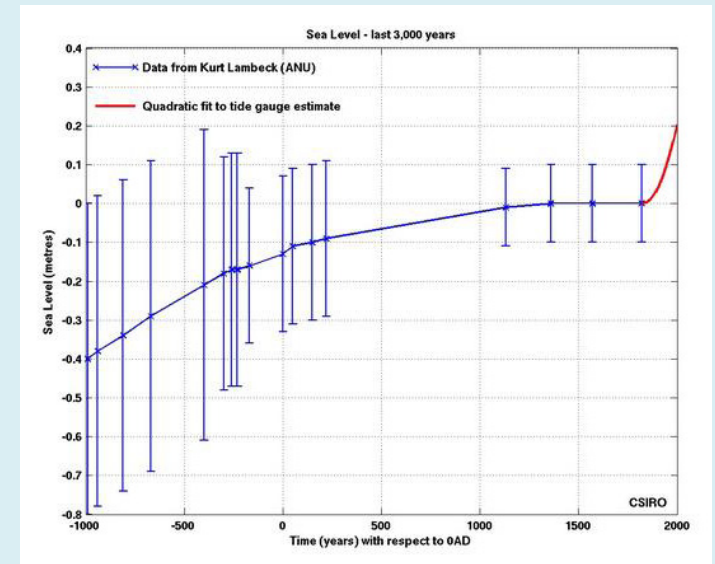
Question #	Question	Answers and Comments
69	Would you expect a warm climate after the Little Ice Age?	The Little Ice Age (loosely defined as occurring from the 16th to 19th centuries) was a period of low sunspot activity, causing relatively cold conditions. Heightened volcanic activity during the Little Ice Age and changes to ocean circulation may also have contributed to cooler conditions.
70	Since the depth of the Little Ice Age 330 years ago, the Earth has been warming. Which part of this warming is natural?	<p>The Earth's temperature does not increase or decrease without some factor forcing it (i.e. volcanic eruptions, increased or decreased solar activity, or an increase in greenhouse gas concentrations). Just because one period of time is cool does not mean that the temperature will subsequently 'bounce' back to some predetermined equilibrium. Some mechanism must force climate changes over long periods.</p> <p>As a result, you would only expect a warm climate following the Little Ice Age if there were new forces causing additional heat to be stored in the Earth.</p>
71	If most of the last 330 years of warming is natural, why isn't all of the latest warming natural?	<p>None of the natural warming forces which warmed the climate after past glacial periods can explain the rising temperatures we have seen over the past century. Scientists have closely examined all the natural processes that can drive changes in the Earth's climate and found that none explain the full extent of the current warming of our climate.</p> <p>Scientists have shown, beyond doubt, that the current warming of our climate is being driven by human activities which release additional greenhouse gases into the atmosphere.</p>
72	Why are there 60-year cycles of warming and cooling over the last 2,000 years?	<p>This is a misleading and incorrect question (similarly to question 10), as there is no evidence in the peer-reviewed science for a 60 year warming and cooling cycle.</p> <p>Professor Plimer suggests shifts in ocean processes every 25 to 30 years could cause this 60 year cycle. While changes in ocean processes can influence global temperatures, these processes move heat within the climate system and do not add additional heat to the system. For this reason, ocean processes cannot explain the observed increase in global temperatures.</p>

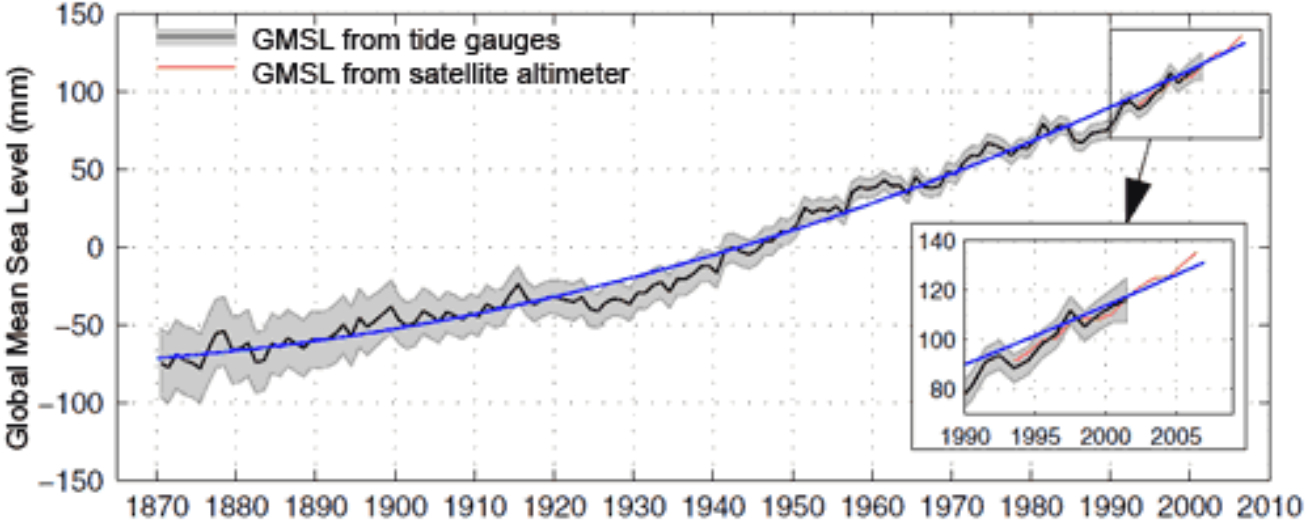
Question #	Question	Answers and Comments
73	During ice ages, do we get cycles of warm interglacials and cold glaciations?	Changes in the orbital pattern of the Earth, known as Milankovitch cycles, drive glacial and interglacial periods (that is warmer and cooler periods). These patterns of long-term warmer and cooler periods are cyclical, just as the orbital pattern of the Earth around the sun is cyclical. These periods have consistent and known temperature bounds. An interglacial period is a warmer climate by definition.
74	Why do we get cycles of glaciation and interglacials?	In the figure to the right, the below graph shows how temperature has varied over the last 800,000 years – the high periods are interglacials and the low periods are glaciations.
75	Would you expect a warm climate in an interglacial?	The top graph shows the atmospheric CO ₂ concentration (the blue line shows data from ice cores and the orange line shows data from Cape Grim Station, Tasmania). The bottom graph shows the Antarctic temperature variations derived from ice core isotopic proxies (Jouzel et al. 2007). Timescale is years before present (2009) (Source: David Etheridge, CSIRO) http://www.climatechange.gov.au/climate-change/understanding-climate-change/understand-cc-long-term.aspx .
76	Ice cores show a saw-tooth interglacial-glacial pattern with huge temperature variations in cold times. Why does temperature reach a maximum then fall and why were all past temperature maxima about the same?	

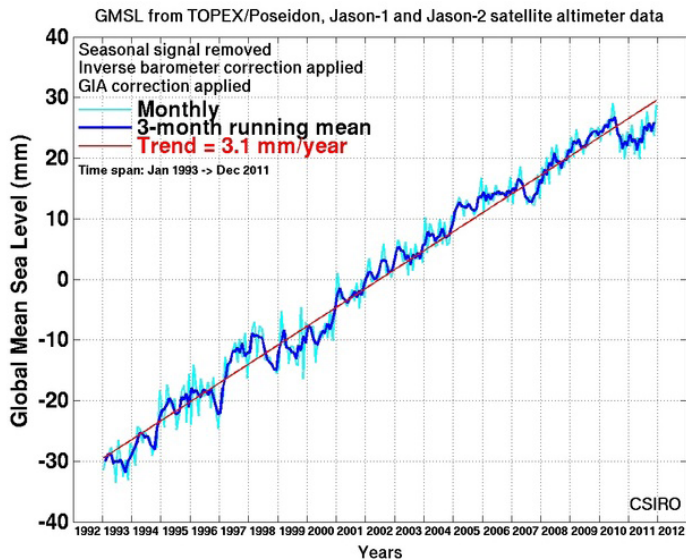


Question #	Question	Answers and Comments
77	Ice core records show that carbon dioxide in the air increases 800 to 2,000 years after a natural event of global warming. Does temperature drive an increase in carbon dioxide or do the ice cores show that an increase in carbon dioxide drives temperature?	<p>Atmospheric CO₂ can drive temperature change as well as be changed in response to changing temperatures. Currently, increases in anthropogenic atmospheric CO₂ levels are causing global average temperatures to rise.</p> <p>Ice core studies have shown that during past ice ages CO₂ levels only started to rise about 800 years after the initial temperature increase. This is because it takes about 800 years for ocean processes to transfer the initial temperature rise to an increase in atmospheric CO₂. This release of CO₂ as the oceans warm then results in further warming.</p> <p>While increased temperatures have led to an increase in CO₂ levels in the past, scientific data shows that the recent increase in atmospheric CO₂ levels has caused temperatures to rise.</p> <p>The ability of CO₂ to cause changes in the climate is well understood. The chemical properties of greenhouse gases, such as CO₂, mean that they strongly absorb and re-emit infra-red radiation, which is felt as heat. This process maintains the Earth's temperature at 33 degrees Celsius warmer than it would otherwise be, allowing life on Earth to exist.</p>

Question #	Question	Answers and Comments
78	Does sea level rise and fall?	<p>Yes, sea levels rise and fall on a range of timescales, from short periods such as tides, to long periods such as glaciations (10,000 – 20,000 years).</p> <p>Over the last 2,000 years long-term sea levels have been relatively stable. The increase in sea level during the past century is unusual (shown by the red line in the figure to the right) due to its rapid rise (Church, http://www.cmar.csiro.au/sealevel/sl_hist_intro.html).</p> <p>Scientists use past changes in sea level to estimate the sensitivity of sea level rise to changes in global temperature. The IPCC <i>Fourth Assessment Report</i> projects sea level rise of 18-59 cm by the end of this century (compared with 1980 to 2000 averages), plus an allowance of another 10-20 cm for a potential dynamic response of the major ice sheets. Research conducted since the IPCC <i>Fourth Assessment Report</i> suggests that a plausible estimate of the amount of sea level rise by 2100 compared to 1990 is 0.5-1.0 m, but higher levels cannot be ruled out.</p>
79	Does the land level rise and fall?	<p>Yes, land levels do rise and fall. This is due to a range of geological drivers, such as the movement of continents, sedimentation, and rise and fall of land in response to glaciation periods.</p>
80	If sea level goes up and down and land level goes up and down, how is global sea level measured?	<p>The movement of land and continents is understood and has been measured. Measurements of global sea levels take into account these land movements and sea level data is adjusted accordingly.</p> <p>Sea levels are measured using both tide gauges and satellite altimeters. Tide gauges measure sea level at specific locations, whereas satellites generate average data over oceans.</p>

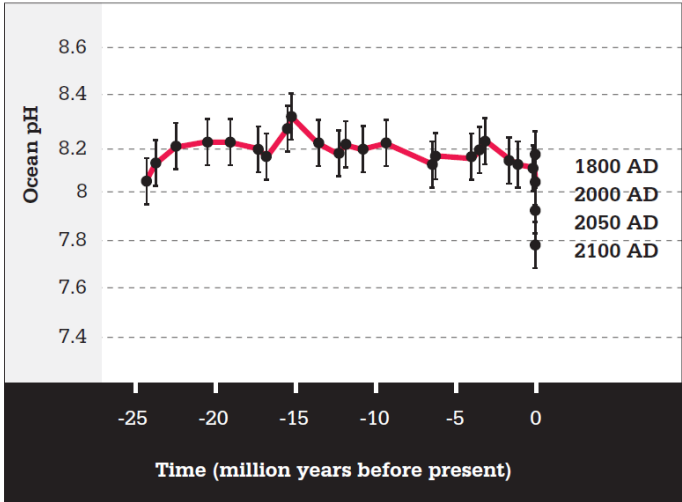


Question #	Question	Answers and Comments
81	Why did the rate of sea level rise double as soon as satellites started to measure sea level?	<p>This is a misleading and incorrect question as both satellite measurements and tide gauge data show that sea levels are rising at an increased rate. Since 1993, the rate of sea level rise has been about 3.1 mm per year, compared to a longer term average of 1.7 mm per year over the 20th century.</p> <p>The graph below shows that since satellite measurements began in the early 1990s (see box graph within graph below) both tide gauge and satellite measurements show a similar accelerated sea level rise trend.</p> <p>Global Mean Sea Level (GIA corrected) from Jan 1870 to Dec 2006</p>  <p>(Church, 2008, Sustainable Science, http://academics.eckerd.edu/instructor/hastindw/MS1410-001_FA08/handouts/2008SLRSustain.pdf, p. 12)</p>
82	Did sea level rise in the 400- year long Medieval Warming or the 600-year Roman Warming?	<p>No, studies have shown that global sea level stabilised between 2000-3000 years ago and did not change significantly from them until this past century.</p> <p>The Roman Warm Period (250 BC - 400 AD) and the Medieval Warm Period (950 - 1250 AD) are periods that are associated with modest regional temperature increases. Given that the changes were regional, global sea levels were unlikely to be significantly affected.</p>

Question #	Question	Answers and Comments
83	Is sea level rising now?	<p>Yes, sea level is currently rising by about 3.1 mm per year. The long term rise in sea levels is shown in the graph. The red line is the rising trend (3.1 mm per year since 1993) and the blue line is the yearly variations due to seasonal changes (Church, http://www.cmar.csiro.au/sealevel/sl_hist_last_15.html).</p> 
84	Would we expect sea level to rise in an interglacial?	<p>Yes. Interglacial periods are times when temperatures are higher, and which are long enough (10,000 or more years) that a significant quantity of heat could be transferred into the ocean. As the ocean's temperature rises, it expands causing sea levels to rise. In addition, the melting of ice sheets during interglacial warm periods would add water to the ocean, also contributing to higher sea levels.</p>
85	How much has sea level risen in the current interglacial and how long did this take?	<p>Over the last 140,000 years sea level has varied over a range of more than 120 m. The most recent large change was an increase of more than 120 m as the last ice age ended (12,000-6,000 years ago).</p> <p>Sea level stabilised over the last few thousand years, and then began to rise again in the 19th century, with an acceleration in the 20th century.</p>

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86	Why does sea level rise?	<p>When global average temperatures rise, it causes sea levels to rise. Ocean waters expand as they get warmer causing sea levels to rise (thermal expansion). Land based ice, such as ice sheets and glaciers, melt in higher temperatures which adds new water to the ocean and causes sea levels to rise. There are other processes which can also affect sea level at the regional level, such as changes to ocean currents, large movements of land, and gravitational forces such as the moon's orbit around Earth.</p>
87	Is the land sinking at Venice or is Venice being flooded because of sea level rise?	<p>Venice is both sinking and being flooded, from three main changes: land subsidence, tectonic movement and sea level rise.</p> <p>Venice began to subside rapidly in the 20th century due to the pumping of freshwater from the underlying aquifer. The rate of subsidence has declined since pumping was stopped in the 1970s.</p> <p>Venice is also subsiding due to tectonic movement as the African Plate, on which Venice is located, slides under the European Plate.</p> <p>It is estimated that Venice has experienced 13cm of sea level rise over the past century. This, along with about 12cm of land subsistence, has resulted in more frequent flooding of urban areas in Venice (Climate Dynamics, 2010, http://adsabs.harvard.edu/abs/2010ClDy...35.1039C).</p>
88	Is the land rising in eastern Australia?	<p>Research suggests that Australia is tilting, with the northeast region tilting downwards. As a result, it is possible that land is very slowly rising, but only in the south.</p> <p>When determining sea level rise, vertical land movement is quantified and accounted for in measurements. The observed trend in relative sea level includes the effect of any vertical land movement at the tide gauge site, which must be taken into account in order to estimate absolute sea level rise.</p> <p>Global mean sea level increased by 210 mm between 1880 and 2009, and is continuing to rise at a fairly steady rate of about 3.1 mm per year.</p>
89	Why are there old beaches in the Murray Darling Basin hundreds of kilometres from the modern shoreline and over 100 meters above sea level?	<p>The present location of these ancient beaches is due to a combination of changes in sea level and changes in the height of the land over millions of years.</p>

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90	If sea level has risen to separate Tasmania from Victoria, is the same natural process still in operation?	<p>The rise in sea level that likely created the island of Tasmania was around 6,000 years ago, at the start of the last interglacial (warming) period. Since then, sea levels stabilised about 2,000 years ago until the end of the 19th century.</p> <p>Sea levels started to rise at the end of the 19th century and are still rising, as a result of the current warming of our climate.</p>
91	How did aboriginal people get to Australia before boats were invented?	<p>Current archaeological evidence suggests that Aboriginal people arrived in north-western Australia as early as 60,000 years ago. At this time, sea levels were about 60 m lower than they are today, with smaller distances between dry land. However to reach Australia at this time Aboriginal people also had to cross the Wallace Line (separating Irian Jaya and the rest of Indonesia), which would have remained submerged. There is no conclusive evidence to suggest that boats or canoes were not used by Aboriginal people at this time.</p>
92	Which part of the present sea level rise is due to post-glacial sea level rise and which part is due to human activity?	<p>The idea of post-glacial climate change is misleading. Warming over the 20th century, as expressed in all thermal indicators, including temperatures over land, sea surface temperatures and sea-level rise, is occurring much faster than changes due to the glacial cycle. There are no studies that have attributed changes over the last 150 years to 'post-glacial warming'. There are many studies linking recent changes to human influences.</p> <p>Sea level rise over the past century until present has largely been driven by the warming climate, which in turn is being caused by the CO₂ released by human activities.</p>
93	Why do Al Gore and Tim Flannery tell us that sea level will rise more than 8 meters and yet they have expensive waterside properties?	<p>The IPCC <i>Fourth Assessment Report</i> projected sea level rise of 0.18-0.59 m by the end of this century, depending on if and how we change the CO₂ emissions we produced. A further 0.1-0.2 m was added to this to account for changes in ice sheets. The IPCC noted that larger increases in sea levels cannot be ruled out. Sea levels will continue to rise well beyond this century.</p> <p>There is enough land-based ice contained in the Greenland and West Antarctic ice sheets to raise global sea levels by about 7 and 6 m respectively (a total of 13 m). However, this will not occur in our life time, in our children's lifetime, or even in our grandchildren's lifetime.</p>
94	What is pH?	<p>The pH scale measures the acidity (or basicity) of a solution. It uses a logarithmic scale, and is based on measurements of the concentration of hydrogen ions.</p>

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95	What is the pH of the oceans?	The pH of seawater has historically remained at about 8.2, which is slightly alkaline (pure water is neutral - pH 7). However, CO ₂ from human activities has caused the pH of ocean surface waters to drop by 0.11 pH units. This is equivalent to about a 30 per cent increase in acidity. Unless human CO ₂ emissions are significantly reduced, the pH is expected to fall by a further 0.5 pH units by the end of the century. This represents a 320 per cent increase in acidity. This would have devastating impacts for our oceans' biodiversity.
96	What is a buffer?	A buffer is a solution that has a highly stable pH. If you add acid or base to a buffered solution, the pH will not change significantly.
97	Why haven't the oceans become acid in past times when atmospheric carbon dioxide was high?	<p>There is a natural buffering process in sea water which prevents large changes in pH under natural climate conditions. This buffering process works over long periods of time. As the amount of CO₂ in the atmosphere normally changes slowly, the buffering process can keep pace.</p> <p>However, the acidification of the ocean caused by CO₂ from human activities is happening much faster than natural changes. As a result, the natural buffer system has not been able to prevent a large increase in ocean acidity.</p> <p>The following figure shows ocean acidity over the past 25 million years to now, and illustrates how acidity is likely to change this century http://climatecommission.gov.au/topics/the-critical-decade/.</p>  <p>Source: Turley et al. (2006)</p>

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98	Is there any activity in my life that does not involve the emission of carbon dioxide?	<p>This is a rhetorical question. The biological processes of most life on Earth, such as breathing and photosynthesis, generally involve CO₂, as it is a by-product of metabolism.</p> <p>However natural levels of CO₂ are in a stable and delicate balance - natural emissions of CO₂ are matched by the natural uptake of CO₂.</p> <p>The Earth's carbon balance is now changing as a result of the additional CO₂ released by human activities.</p>
99	Why do those advocating human-induced global warming vilify scientists who disagree rather than addressing genuine scientific questions?	<p>Genuine scientific disputes are normally addressed through publication of alternative theories in peer-reviewed scientific journals. However, the scientists and others disagreeing with the consensus on human-induced climate change have rarely published in such journals, therefore avoiding critical scientific assessment of their work.</p> <p>There is no single paper, or set of papers, that provides a plausible alternative explanation of recent warming. The few papers that do exist have been demonstrated to be flawed by the weight of peer-reviewed literature. There is now a vast body of literature supporting the mainstream understanding of climate change.</p>
100	What funds does the Australian government give for grants annually to show the existence of human-induced global warming?	<p>The Australian Government does not grant funding dictated by the results of research.</p> <p>The Australian Government supports a broad range of climate change science research activities to help us to better understand global and regional climate.</p> <p>This research is aimed at improving our understanding of the causes, nature, timing and consequences of human influences on the climate and natural ecosystems so that industry, community and government decisions can be better informed.</p>
101	What funds does the government grant to consider the possibility that there might not be human-induced global warming?	<p>Details of Government funding can be found on the Department of Climate Change and Energy Efficiency website at: www.climatechange.gov.au.</p> <p>More generally, science does not proceed in the manner suggested by these questions. Researchers investigate the causes of climate variability and change, and they investigate the role of natural variability, natural forcing and anthropogenic forcing. They do not set out to prove that warming is natural or otherwise, they set out to determine what signals exist in the observational record, and how they may be explained.</p>