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The Five Types of Climate Change Denial Argument

This chapter looks at the five types of climate change denial arguments and considers nine key denial arguments as examples within these categories. These five types of denial argument are:

1 Conspiracy theories;
2 Fake experts;
3 Impossible expectations;
4 Misrepresentations and logical fallacies; and
5 Cherry-picking (Diethelm and McKee, 2009).

We list here nine common denial arguments, but there are dozens of others. These can be found at the website www.skepticalscience.com, which is managed by one of us (Cook). We suggest readers may wish to visit the website to examine denial arguments in more detail.

Pascal Diethelm and Martin McKee (2009) observe that the various movements that deny an overwhelming scientific consensus all exhibit common characteristics. Their goal is to convince the public and the media that there are sufficient grounds not to take the action recommended by the consensus position of mainstream science. To achieve this, the vocal minority employ rhetorical arguments that give the appearance of legitimate debate where there is none. The various denial movements employ some or all of the five types of denial described below. Note that these five categories apply to almost all denial, not just climate change denial.

Conspiracy Theories

'Climategate proves conspiracy'

In November 2009, the email servers at the University of East Anglia in Britain were illegally hacked and emails were stolen. When a selection of emails between

climate scientists was published on the internet, a few suggestive quotes were seized upon to claim that global warming was all just a conspiracy (Cook, 2010). The incident, dubbed 'Climategate', is symptomatic of a movement that denies the scientific consensus (Delingpole, 2009). If one disagrees with a view held by the great majority of the world's scientists, the most common response is to assume all those scientists are involved in a *vast conspiracy to deceive*.

To determine if there had been any wrongdoing, a series of international investigations independently investigated the Climategate emails and *all cleared climate scientists of any wrongdoing*. The House of Commons Science and Technology Committee found that the criticisms of the Climate Research Unit (CRU) were misplaced and that 'Professor Jones's [of the CRU] actions were in line with common practice in the climate science community' (Willis et al, 2010). The University of East Anglia's Scientific Assessment Panel, in consultation with the Royal Society, assessed the integrity of the research published by the CRU and concluded there was 'no evidence of any deliberate scientific malpractice in any of the work of the Climatic Research Unit' (Oxburgh, 2010). The Independent Climate Change Email Review examined the emails to assess whether manipulation or suppression of data occurred and concluded that 'the scientists' rigor and honesty are not in doubt' (Russell et al, 2010).

Thus independent investigations conclude unanimously that nothing in the Climategate emails actually affected the science. The issue was of isolated quotes taken out of context. The most quoted email was from Phil Jones discussing palaeo-data used to reconstruct past temperatures:

> I've just completed Mike's Nature trick of adding in the real temps to each series for the last 20 years (i.e. from 1981 onwards) and from 1961 for Keith's to hide the decline.

The phrases often repeated from this email are 'Mike's Nature trick' and 'hide the decline', interpreted to reveal nefarious intent. However, the issues discussed in this email are openly published in the peer-reviewed literature. 'Mike's Nature trick' refers to a technique (in other words a '*trick* of the trade') used in a paper published in *Nature* by lead author Michael Mann (Mann et al, 1998). The 'trick' is the technique of plotting recent instrumental data along with the reconstructed palaeo-data. This places recent global warming trends in the context of temperature changes over longer timescales.

The most common misconception regarding this email is to assume that 'hide the decline' refers to declining temperatures. Republican Sarah Palin argued, 'The emails reveal that leading climate "experts" deliberately destroyed records, manipulated data to "hide the decline" in global temperatures' (McCullagh, 2010). The 'decline' actually refers to a decline in tree-ring growth in certain high-latitude regions since the 1960s. This is known as the 'divergence problem', where some tree-ring proxies diverge from modern instrumental temperature records after 1960. This was discussed in the peer-reviewed literature as early as 1995, suggesting a change in the sensitivity of tree growth

to temperature in recent decades (Jacoby and D'Arrigo, 1995). When you look at Jones's email in the context of the science discussed, it is not the scheming of a climate conspiracy, but technical discussions of data-handling techniques readily available in the peer-reviewed literature.

The second most cited email is from climate scientist and IPCC lead author Kevin Trenberth:

> The fact is that we can't account for the lack of warming at the moment and it is a travesty that we can't.

This has been interpreted by climate change deniers as climate scientists secretly admitting among themselves that global warming has stopped. Trenberth is actually discussing a paper he'd recently published that discusses the planet's energy budget – how much net energy is flowing into our climate and where it's going (Trenberth, 2009). In Trenberth's paper, he discusses how the planet is continually heating due to increasing CO_2. Nevertheless, surface temperature sometimes shows short-term cooling periods. This is due to internal variability as the ocean exchanges heat with the atmosphere. Trenberth laments that our observation systems can't comprehensively track all the energy flow through the climate system. However, Trenberth expressed this openly and frankly in the peer-reviewed literature. They didn't need to steal his emails.

It's important to put the Climategate emails in perspective. A handful of scientists discuss a few pieces of climate data. Even without this data, there is still an overwhelming and consistent body of evidence, painstakingly compiled by independent scientific teams across the globe. They find that humans are massively emitting CO_2 into the atmosphere, with the result that atmospheric CO_2 levels have increased by 36 per cent from pre-industrial levels. Various lines of evidence find that rising CO_2 levels are causing an energy imbalance and trapping heat. Thousands of lines of evidence find the planet is subsequently warming, with numerous fingerprints of warming unique to an increasing greenhouse effect. A few suggestive quotes taken out of context may serve as a distraction for those wishing to avoid the physical realities of climate change, but they change nothing about our scientific understanding of humanity's role in global warming.

Fake Experts

'There is no consensus'

There have been claims purporting to prove there is no scientific consensus on human-caused global warming. Often you will see statements made with the apparent aura of scientific expertise, but these are misleading. The most prominent is the Petition Project, published in early 2008 by the Oregon Institute of Science and Medicine (OISM, 2008). This petition features a list of over 31,000 people who claim to be scientists and reject the science behind the theory of human-caused global warming. However, anyone with a BSc or higher

can be listed. These include graduates of computer science, mechanical engineering, zoology, medicine, metallurgy and other fields unrelated to climate science. Around 0.1 per cent of the signatories were climatologists. Obviously, the OISM were going for quantity, not quality. Their approach raises the question: is a veterinarian or a mechanical engineer qualified to have an authoritative opinion on the complexities of climate science?

Confirmation of a scientific consensus comes from the peer-reviewed scientific literature. A survey of all peer-reviewed abstracts on the subject 'global climate change' published between 1993 and 2003 shows that not a single paper rejected the consensus position that human activities are causing global warming (Oreskes, 2004). Seventy-five per cent of the papers agreed with the consensus position, while 25 per cent made no comment either way (focused on methods or palaeoclimate analysis). A comprehensive survey of 3146 earth scientists asked the question 'Do you think human activity is a significant contributing factor in changing mean global temperatures?' (see Figure 7). Overall, 82 per cent of the scientists answered yes. Of scientists who were non-climatologists and didn't publish research, 77 per cent answered yes. In contrast, *97.5 per cent* of climatologists who actively published research on climate change responded yes (Doran and Zimmerman, 2009).

Figure 7 *Response to the survey question 'Do you think human activity is a significant contributing factor in changing mean global temperatures?'*

Source: Doran and Zimmerman (2009); public data from Gallup (2009)

As the level of active research and specialization in climate science increases, so does agreement that humans are significantly changing global temperatures. Especially striking is the divide between expert climate scientists (97.5 per cent) and the general public (58 per cent). The paper concludes:

> It seems that the debate on the authenticity of global warming and the role played by human activity is largely nonexistent among those who understand the nuances and scientific basis of long-term climate processes. The challenge, rather, appears to be how to effectively communicate this fact to policymakers and to a public that continues to mistakenly perceive debate among scientists.

This overwhelming consensus among climate experts is confirmed by an independent study that surveys all climate scientists who have publicly signed declarations supporting or rejecting the consensus (Anderegg et al, 2010). They found that between 97 and 98 per cent of climate experts support the consensus.

Impossible Expectations

'Climate models are unreliable'

The uncertainties of climate models are often used as an excuse to reject them along with all evidence of human-caused global warming. A common denier argument is 'Scientists can't even predict the weather next week, so how can they predict the climate years from now?'. This betrays a misunderstanding of the difference between weather, which is chaotic and unpredictable, and climate, which is weather averaged over time. In weather terms, you can't predict the exact route a storm will take, but the average temperature and precipitation will still be the same for a region over a period of time.

There are various difficulties in predicting future climate. The behaviour of the Sun is difficult to predict. Short-term perturbations like El Niño or volcanic eruptions are difficult to model. Nevertheless, the major forcings that drive climate are well understood. In 1988, James Hansen projected future temperature trends using three different greenhouse gas emission scenarios (Hansen et al, 1988). Scenario A assumed continued accelerating greenhouse gas growth, Scenario B assumed a slowing and eventually constant rate of growth, and Scenario C assumed a rapid decline in greenhouse gas emissions around 2000. Several decades later, we can compare those initial projections with subsequent observations (Hansen et al, 2006).

The greenhouse gas emissions in Hansen's Scenario B (with the triangles in Figure 8) most closely match actual greenhouse emissions. The projected temperature change in Scenario B slightly overestimates the observed warming (darker line) for two main reasons. First, Scenario B slightly overestimated how much greenhouse gas emissions would increase, and second, Hansen's model used a higher climate sensitivity of around four degrees Celsius for a doubling of atmospheric CO_2. In order to accurately predict global warming over the past

Figure 8 *Global surface temperature computed by Hansen for Scenarios A, B and C, compared with 12-month moving average of observational data*

Source: redrawn from Hansen et al (2006) with GISS updated to August 2010

22 years, Hansen's climate model would have needed a climate sensitivity of just over 3 degrees Celsius. This is consistent with the range of IPCC climate sensitivity values of 2–4.5 degrees Celsius, with a most likely value of 3 degrees Celsius (IPCC, 2007).

When Mount Pinatubo erupted in 1991, the sulphate aerosols thrown into the atmosphere had a dramatic cooling effect as they reflected incoming sunlight back out to space. This event provided an opportunity to test how successfully models would predict the climate response. The models accurately forecast subsequent global cooling of about 0.5 degrees Celsius. Furthermore, the radiative, water vapour and dynamical feedbacks included in the models also matched the observed response (Hansen et al, 2007).

A common misconception is that climate models are biased towards 'exaggerating' the effects from CO_2. But it's worth mentioning that uncertainty can go either way. In fact, in a climate system with net positive feedback, uncertainty means climate change is likely to be greater than expected (Roe and Baker, 2007). For this reason, many of the IPCC predictions have subsequently been shown to *underestimate* the climate response (Freudenburg and Muselli, 2010). Satellite and tide-gauge measurements show that sea-level rise is accelerating faster than IPCC predictions. The average rate of rise for 1993–2008 as measured from satellites is 3.4 mm/yr, while the IPCC Third Assessment Report projected a best estimate of 1.9mm/yr for the same period (Allison et al, 2009). Sea-level observations are tracking along the upper range of IPCC projections.

Figure 9 *Sea-level change: Models and observations*

Tide gauge data and satellite data are indicated; the grey band shows the projections of the IPCC Third Assessment Report.

Source: Allison et al (2009)

Similarly, summertime melting of Arctic sea ice has accelerated far beyond the expectations of climate models. The area of sea-ice melt during 2007–2009 was about 40 per cent greater than the average prediction from IPCC AR4 (Fourth Assessment) climate models. The thickness of Arctic sea ice has also been on a steady decline over the last several decades.

Should we wait until climate models are 'completely certain' before acting to reduce CO_2 emissions? Models are in a constant state of development to include more processes, rely on fewer approximations and increase their resolution as computer power develops. The complex and non-linear nature of climate means there will always be a process of refinement and improvement. The main point is we now know enough to *act*. Models have evolved to the point where they successfully predict long-term trends and are now developing the ability to predict more chaotic, short-term changes. They don't need to be exact in every respect to give us an accurate overall trend. If you knew there was a 90 per cent chance you'd be in a car crash, would you get in the car? The IPCC conclude a greater than 90 per cent probability that humans are causing global warming. To wait for 100 per cent certainty would mean society would never act on anything.

Figure 10 *Observed and modelled September Arctic sea-ice extent in millions of square kilometres*

Solid black line gives the average of 13 IPCC AR4 models while the grey area represents their range. The 2009 minimum has recently been calculated at 5.10 million km², the third lowest year on record and well below the IPCC worst case scenario.

Source: Allison et al (2009)

Misrepresentations and Logical Fallacies

'Climate's changed in the past'

One argument is that 'climate has changed naturally in the past and therefore current climate change must be natural'. This argument is logically flawed, akin to saying 'forest fires have occurred naturally in the past so any current forest fires must be natural'. We do not see a movement of 'arson deniers' being seen as credible. However, the 'past climate change' argument is popular among climate change deniers, being the major theme in *Heaven and Earth* (Plimer, 2009).

In addition, this argument betrays a lack of understanding of the nature of *climate sensitivity*. Our planet is governed by the principle that when you add more heat to our climate, global temperatures rise. Conversely, when the climate loses heat, temperatures fall. This energy imbalance is known as radiative forcing, the change in net energy flow at the top of the atmosphere. When the Earth experiences a positive energy imbalance, our climate builds up heat and global temperature warms. As it gets warmer, a number of feedbacks come into play. What climate scientists are particularly interested in is the net feedback – the overall result when you add up all the various positive and negative feedbacks. Another way of expressing this is 'climate sensitivity' – how sensitive is our climate to a change in energy balance?

Climate sensitivity and net feedback can be empirically determined by looking at past climate change. One needs to find a period where we have

temperature data and measurements of the various forcings that drove the climate change. Once you have the change in temperature and radiative forcing, climate sensitivity can be calculated. There have been many estimates of climate sensitivity using data spanning the past 150 years. Several studies used the observed surface and ocean warming over the 20th century. Satellite data for the radiation budget has been analysed in various studies. Some recent analyses used the well-observed forcing of major volcanic eruptions. A number of studies examined palaeoclimate reconstructions from the last millennium to millions of years ago (Knutti and Hegerl, 2008).

There are independent studies covering a range of periods, studying different parts of climate and employing various methods of analysis. They all yield a broadly consistent answer, indicating that the net climate feedback is *significantly positive*. There is no credible line of evidence that yields very high or very low climate sensitivity. When past climate change is cited to refute the human influence on global warming, this ignores the science that such changes show net positive feedback that further warms the Earth. Ironically, past climate change actually provides evidence that human actions can affect climate *now*.

Cherry-picking

The human fingerprint on climate change is observed by multiple sets of independent observations. However, science operates in something of an adversarial process. People put forward data and ideas, and these get tested by other scientists to see if the data stands up to scrutiny. Sometimes it doesn't and the authors themselves accept there was an error or another explanation for their data. That is how scientific consensus is achieved. Nonetheless, the papers that *seemed* to show an anomaly were published in peer-reviewed journals and are still out there. To avoid accepting human-caused climate change, climate deniers commonly *select* isolated papers that challenge the consensus – to the neglect of the broader body of research. Similarly, deniers often focus on narrow pieces of data while ignoring other evidence that does not support their viewpoint. Sometimes they publish only part of the data or graph (Oreskes and Conway, 2010). Most denier arguments adopt this technique of 'cherry-picking'.

'Temperature measurements are unreliable'

There is a denial movement seeking to cast doubt on the surface temperature record using photographs of weather stations positioned near car parks, air-conditioners and other warming influences (Watts, 2010). These photos attempt to communicate that the global warming trend is being inflated by poor temperature data. To assess this, you need to compare the trend from the good sites to that from the bad sites. This analysis has been done and the results are surprising.

Poor sites show a *cooler* trend than good sites. All those photographed weather stations near car parks are actually giving cooler readings than pristine weather stations. This is largely due to a change in instruments during the mid

Figure 11 *Annual average maximum and minimum unadjusted temperature change calculated using (a) maximum and (b) minimum temperatures from good and poor exposure sites*

Source: Menne et al (2010)

and late 1980s. When this change is taken into account, as well as other biases such as station relocation and time of observation, the trend from good sites show close agreement with poor sites (Menne et al, 2010; see Figure 11).

However, one needs to take a step back to observe the cherry-picking at play here. Surface temperature is not measured solely by thermometers. It's also measured by satellites, which are not influenced by urban heat islands or nearby car parks. When we compare the satellite temperature data to the surface temperature data, we find consistent results (Figure 12).

So the evidence for the warming trend over the last few decades is based on independent lines of evidence. The campaign to persuade the public with photos of weather stations is an attempt to distract them from the many physical signs of global warming happening all over the globe, such as:

- Ice sheets melting at an accelerating rate, losing billions of tonnes of ice each year (Velicogna, 2009);
- Sea levels rising at an accelerating rate, largely due to diminishing ice sheets (Church and White, 2006);
- Signs of warming being observed in tens of thousands of species all over the world as they respond to earlier springs and migrate towards the poles (Parmesan and Yohe, 2003);

Figure 12 *Annual global temperature from UAH and NASA GISS*

Source: redrawn from UAH (2010) and NASA GISS Temperature Index

- Glaciers retreating, threatening water supplies for millions of people (Kehrwald et al, 2008);
- Arctic permafrost warming at greater depths and degrading, releasing methane (IASC, 2010); and
- Arctic sea ice declining at an accelerating rate (Stroeve et al, 2008).

To get a full understanding of climate, we need to look at all the evidence. What we see are many lines of evidence all pointing to the same conclusion – global warming is a physical reality.

'Global warming stopped in 1998'

A common refrain from deniers is that global warming stopped in 1998. This is based on a temperature record compiled by the Hadley Centre of the UK Met Office and the Climatic Research Unit (CRU), often referred to as HadCRUT. This dataset (Figure 13) shows unusually warm temperatures in 1998, leading to that year being the hottest in the HadCRUT record. These unusually warm conditions were due to the strongest El Niño on record occurring at the time.

It's important to realize that the HadCRUT record is not a truly global temperature record. It doesn't include regions where the fastest warming is occurring. An analysis by the European Centre for Medium-Range Weather Forecasts (ECMWF) calculated global temperature utilizing a range of sources including surface temperature measurements, satellites, radiosondes, ships and buoys. They found recent warming has been higher than that shown by

Figure 13 *Twelve-month average of global temperature anomaly from the Hadley Centre*

Source: plotted from HadCRUT, 2010

HadCRUT, as the latter misses out on regions of greatest warming (Simmons et al, 2010).

This is confirmed by NASA GISS, which found that a major contributor to recent warming is the extreme Arctic warming (Hansen et al, 2006). As there are few meteorological stations in the Arctic, NASA extrapolated temperature anomalies from the nearest measurement stations. They found that the estimated strong Arctic warmth was consistent with infrared satellite measurements and record low sea-ice concentrations. According to the NASA GISS global temperature record, the hottest 12 months on record was from June 2009 to May 2010, statistically tied with 2005 (see Figure 14).

However, even this doesn't give the full picture. The surface temperature record tells us only about air temperatures at the Earth's *surface*, which (as Figure 15 demonstrates) is only a small part of global warming. Did this energy imbalance stop in 1998? To determine this, one study measured the Earth's total heat content since 1950 (Murphy et al, 2009). The authors used measurements of ocean heat content to 3000 metres depth. The amount of heat in the atmosphere was calculated using the surface temperature record and the heat capacity of the lower atmosphere.

Figure 14 *Twelve-month average of global temperature anomaly from NASA GISS*

Source: plotted from NASA GISS Temperature Index, June 2010

Figure 15 *Total Earth heat content from 1950 to 2003*

Source: redrawn from original data in Murphy et al (2009, Figure 6b)

The results find that the planet is clearly still building up heat *after* 1998. Global warming has not stopped, but most of the warming has gone into the oceans. The heat capacity of the land and atmosphere is small compared to that of the oceans. Consequently, relatively small exchanges of heat between atmosphere and ocean can cause large changes in surface temperature. In 1998 we experienced the strongest El Niño on record, moving massive amounts of heat from the Pacific Ocean into the atmosphere. Conversely, 2007 saw the strongest La Niña conditions in over 20 years, which had a cooling effect on global temperatures. In 2010 the Pacific transitioned back to El Niño conditions, although not as strong as in 1998. Nevertheless, this resulted in the warmest 12 months on record from June 2009 to May 2010.

'The hockey stick was broken'

This issue was touched on in Chapter 2, but we will enlarge on this denial argument. The rejection of the 'hockey stick' figure of global temperature increase over time is another example of wishful cherry-picking. The hockey stick refers to a 1998 reconstruction of temperature over the past 1000 years using tree rings, ice cores, coral and other records that act as proxies for temperature (Mann et al, 1999). The reconstruction by Michael Mann et al (1998) found that global temperature gradually cooled over the last 1000 years with a sharp upturn in the 20th century (the head of the hockey stick). The principal result shown by the hockey stick graph is that global temperatures over the last few decades are the warmest in the last 1000 years.

A critique of the hockey stick was published in 2004 claiming the hockey stick shape was the inevitable result of using a particular statistical method (McIntyre and McKitrick, 2005). However, an independent assessment of Mann's hockey stick was conducted by the National Center for Atmospheric Research. They reconstructed temperatures employing a variety of statistical techniques (with and without principal components analysis). Their results found slightly different temperatures in the early 15th century. Nevertheless, they confirmed the principal results of the original hockey stick – that the warming trend and temperatures over the last few decades are *unprecedented* over at least the last 600 years (Wahl and Ammann, 2007).

While many deniers continue to fixate on Mann's early work on proxy records, the science of palaeo-climatology has moved on. Since 1999 there have been many independent reconstructions of past temperatures, using a variety of proxy data and a number of different methodologies. All find the same result – that the last few decades are the hottest in the last 500 to 2000 years (depending on how far back the reconstruction goes). These include temperature from boreholes (Huang et al, 2000), determining temperature from stalagmites (Smith et al, 2006) and historical records of glacier length (Oerlemans, 2005). Figure 16 illustrates the similarities between the reconstructions for the last 1000 years.

When you combine all the various proxies, including ice cores, coral, lake sediments, glaciers, boreholes and stalagmites, it's possible to reconstruct Northern Hemisphere temperatures (without tree-ring proxies) going back 1300

Figure 16 *Composite Northern Hemisphere land and land plus ocean temperature reconstructions and estimated 95 per cent confidence intervals*

Shown for comparison are published Northern Hemisphere reconstructions

Source: Mann et al (2008)

years (see Figure 16). The result is that temperatures in recent decades exceed the maximum proxy estimate (including uncertainty range) for the past 1300 years. When you include tree-ring data, the same result holds for the past 1700 years. Palaeo-climatology draws upon a range of proxies and methodologies to calculate past temperatures. This allows independent confirmation of the basic hockey stick result: that *the past few decades are the hottest in the past 1300 years*. A narrow focus on an early paper from 1998 has no bearing on over a decade's worth of research independently confirming the hockey stick result.

'It's the Sun'

The most common alternative explanation for global warming among deniers is the Sun. This is an intuitive response – it's not hard to imagine the huge, fiery ball on the sky has a significant influence on climate. Indeed it does. As supplier of almost all the energy in the Earth's climate, changes in solar output have an effect on global temperature. A comparison of Sun and climate over the past 1150 years found temperatures closely match solar activity (Usoskin et al, 2005). This correlation is enough for skeptics to conclude that the Sun must be causing global warming. However, this doesn't take into account all the data. After 1975, temperatures rose while solar activity showed little to no long-term trend. Usoskin et al (2005) concluded:

> During these last 30 years the solar total irradiance, solar UV irradiance and cosmic ray flux has not shown any significant secular trend, so that at least this most recent warming episode must have another source.

In fact a number of independent measurements of solar activity indicate the Sun has shown a *slight cooling* trend since 1960, over the same period that global temperatures have been warming (Lockwood, 2008). Over the last 35 years of global warming, Sun and climate have been moving in opposite directions (see Figure 17). The Sun does have an influence on climate, but in recent decades its cooling has been slightly masking the warming from greenhouse gases.

Figure 17 *Change in annual global temperature (top line) and total solar irradiance (TSI; bottom line) with 11-year moving average*

Source: Temperature data from NASA GISS Temperature index. TSI from 1880 to 1978 was reconstructed from sunspot numbers (data from Krivova et al, 2007), while after 1979 the data comes from satellites (data from Frohlich, 2006).

'Global warming is good'

The argument that global warming is good may be used with claims that global warming is either natural or human-caused. Either way deniers argue that warming can only bring good things (see, for example, Plimer, 2009). To do so the denial argument cherry-picks certain data to suggest this. The best way to put this denial argument in perspective is to compare the positives of global warming to the negatives, as in the table on the following pages.

Positives	Negatives
Agriculture • Improved agriculture in some high-latitude regions (Mendelsohn et al, 2006) • Increased growing season in Greenland (Nyegaard, 2007) • Increased productivity of sour orange trees (Kimball et al, 2007)	**Agriculture** • Decreasing human water supplies, increased fire frequency, ecosystem change and expanded deserts (Solomon et al, 2009) • Decline in rice yields due to warmer night-time minimum temperatures (Peng et al, 2004; Tao et al, 2008) • Increase of western US wildfire activity, associated with higher temperatures and earlier spring snowmelt (Westerling et al, 2006) • Encroachment of shrubs into grasslands, rendering rangeland unsuitable for domestic livestock grazing (Morgan et al, 2007) • Decreased water supply in the Colorado River Basin (McCabe and Wolock, 2007) • Decreasing water supply to the Murray–Darling Basin (Cai and Cowan, 2008)
Glacier Melt	**Glacier Melt** • Severe consequences for at least 60 million people dependent on ice and snow melt for water supply (Kehrwald et al, 2008; Immerzeel et al, 2010) • Contribution to rising sea levels (Pfeffer et al, 2008; Vermeer and Rahmstorf, 2009)
Economics • Increased cod fishing leading to improved Greenland economy (Nyegaard, 2007)	**Economics** • Economic damage to poorer low-latitude countries (Mendelsohn et al, 2006) • Billions of dollars of damage to public infrastructure (Larsen et al, 2008) • Reduced water supply in New Mexico (Hurd and Coonrod, 2008)

Positives	Negatives
Arctic Melt • An ice-free Northwest Passage, providing a shipping shortcut between the Pacific and Atlantic Oceans (Kerr, 2002; Stroeve et al, 2008)	**Arctic Melt** • Loss of 2/3 of the world's polar bear population within 50 years (Amstrup et al, 2007) • Less compacted ice, hazardous floes and more mobile icebergs posing increased risk to shipping (International Ice Charting Working Group, 2009) • Drying of arctic ponds with subsequent damage to ecosystems (Smol and Douglas, 2007) Warming causes methane to escape from Arctic regions, contributing additional greenhouse warming. The following have been observed: • Melting of Arctic lakes leading to methane bubbling (Walter et al, 2007) • Leakage of methane from the East Siberian Shelf seabed sediments (Shakhova et al, 2008) • Escape of methane gas from the seabed along the West Spitsbergen continental margin (Westbrook et al, 2009)
Health • Winter deaths will decline as temperatures warm (Health Protection Agency, 2007)	**Health** • Increased deaths to heatwaves – 5.7% increase to heatwaves compared to 1.5% to cold snaps (Medina-Ramon and Schwartz, 2007) • Increased heat stress in humans and other mammals (Sherwood and Huber, 2010) • Spread in mosquito-borne diseases such as malaria, dengue fever and encephalitis (Epstein et al, 1998) • Increase in occurrence of allergic symptoms due to rise in allergenic pollen (Rogers et al, 2006)

Positives	Negatives
Environment • Greener rainforests and enhanced plant growth due to higher sunlight levels due to fewer rain clouds (Nemani et al, 2003; Saleska et al, 2007) • Increased vegetation activity in high northern latitudes (Zhou et al, 2001) • Increase in Chinstrap and Gentoo penguins (Ducklow et al, 2007) • Recent increase in forest growth (McMahon et al, 2010)	**Environment** • Between 18 and 35% of plant and animal species could be committed to extinction by 2050 (Thomas et al, 2004) • More severe and extensive vegetation die-off due to hotter droughts (Breshears et al, 2005) • Rainforests releasing CO_2 as regions become drier and burn (Saleska et al, 2007) • Reduction in area of the Amazon due to reduced rainfall and greater evaporation (Nepstad et al, 2007; Phillips et al, 2009) • Extinction of the European land leech (Kutschera et al, 2007) • Decrease in Adélie penguin numbers (Ducklow et al, 2007) • Disruption to New Zealand aquatic species such as salmonids, stream invertebrates and fishes (Ryan and Ryan, 2007) • Oxygen-poor ocean zones are growing (Stramma et al, 2008; Shaffer et al, 2009) • Increased mortality rates of healthy trees in western US forests (Pennisi, 2009) • Increased pine tree mortality due to outbreaks of pine beetles (Kurz et al, 2008) • Increased risk of coral extinction from bleaching and disease driven by warming waters (Carpenter et al, 2008) • Decline in lizard populations (Sinervo et al, 2010) • In southwest Australia a drop in rainfall of 10–20% and a 40–50% reduction of inflow to Perth's water supply (Sadler, 2003; Pittock, 2009)

Positives	Negatives
Ocean Acidification **Note:** this is not caused by warming temperatures but by the oceans absorbing more CO_2 (Dore et al, 2009). • Ocean uptake of CO_2 moderates future global warming (Orr et al, 2005)	**Ocean Acidification** • Oceans cease to be a sink for CO_2 and become a source, so the moderating buffer aspect of oceans ceases (Canadell et al, 2007) • Substantial negative impacts to marine ecosystems (Orr et al, 2005; Fabry et al, 2008) • Inhibiting of plankton development; disruption of carbon cycle (Turley et al, 2006) • Increased mortalities of sea urchins (Miles et al, 2007)
Sea-Level Rise	**Sea-Level Rise** • Coastal erosion in Nigeria (Okude and Ademiluyi, 2007) • Displacement of hundreds of millions of climate refugees this century (Dasgupta et al, 2007)

In summary, there are both more negative effects than positive, and some of them have far greater impacts. Global warming cannot be seen as a 'good thing' overall. It may indeed benefit certain areas (for example Greenland can now grow potatoes) if temperatures do not rise too much. However, the larger the global warming, the worse the impact. These impacts are already starting to be felt.

Conclusion

The above lists the five categories of denial arguments and gives examples of them. There are many more such climate change denial arguments (see www.skepticalscience.com) and almost all fit under these categories. We are sure that new denial arguments will keep coming. For this reason it is important to consider any denial argument that is put to you. What sort of argument is it? Is it suggesting conspiracy? Is it a fake expert who has no expertise in climate science? Does it demand impossible expectations, such as requiring 100 per cent proof? Is it a logical fallacy? Does it cherry-pick the evidence to support its claims and ignore all other evidence? Remember, true 'skepticism' is a *search for the truth*. We should approach climate change denial arguments with true skepticism. We need to assess what the argument relies on, whether it is logical,

and whether it considers *all* the many independent strands of scientific evidence that show climate change is both happening now and is caused by human actions.

References

Allison, I., Bindoff, N. L., Bindschadler, R. A., Cox, P. M., de Noblet, N., England, M. H., Francis, J. E., Gruber, N., Haywood, A. M., Karoly, D. J., Kaser, G., Le Quéré, C., Lenton, T. M., Mann, M. E., McNeil, B. I., Pitman, A. J., Rahmstorf, S., Rignot, E., Schellnhuber, H. J., Schneider, S. H., Sherwood, S. C., Somerville, R. C. J., Steffen, K., Steig, E. J., Visbeck, M. and Weaver, A. J. (2009) *The Copenhagen Diagnosis, 2009: Updating the World on the Latest Climate Science*, The University of New South Wales Climate Change Research Centre (CCRC), Sydney, Australia

Amstrup, S., Marcot, B. and Douglas, D. (2007) 'Forecasting the rangewide status of polar bears at selected times in the 21st century', Administrative report, US Geological Survey, Alaska Science Center, Anchorage, AK

Anderegg, W., Prall, J., Harold, J. and Schneider, S. (2010) 'Expert credibility in climate change', *Proceedings of the National Academy of Sciences*, vol 107, no 27, pp12,107–12,109

Breshears, D. D., Cobb, N. S., Rich, P. M., Price, K. P., Allen, C. D., Balice, R. G., Romme, W. H., Kastens, J. H., Floyd, M. L., Belnap, J., Anderson, J. J., Myers, O. B. and Meyer, C. W. (2005) 'Regional vegetation die-off in response to global-change-type drought', *Proceedings of the National Academy of Sciences*, vol 102, no 42, pp15,144–15,148

Cai, W. and Cowan, T. (2008) 'Evidence of impacts from rising temperature on inflows to the Murray–Darling Basin', *Geophysical Research Letters*, vol 35, L07701

Canadell, J. G., Le Quéré, C., Raupach, M. R., Field, C. B., Buitenhuis, E. T., Ciais, P., Conway, T. J., Gillett, N. P., Houghton, R. A. and Marland, G. (2007) 'Contributions to accelerating atmospheric CO_2 growth from economic activity, carbon intensity, and efficiency of natural sinks', *Proceedings of the National Academy of Sciences*, vol 104, no 47, pp18,866–18,870

Carpenter, K. E., Abrar, M., Aeby, G., Aronson, R. B., Banks, S., Bruckner, A., Chiriboga, A., Cortes, J., Delbeek, J. C., DeVantier, L., Edgar, G. J., Edwards, A. J., Fenner, D., Guzman, H. M., Hoeksema, B. W., Hodgson, G., Johan, O., Licuanan, W. Y., Livingstone, S. R., Lovell, E. R., Moore, J. A., Obura, D. O., Ochavillo, D., Polidoro, B. A., Precht, W. F., Quibilan, M. C., Reboton, C., Richards, Z. T., Rogers, A. D., Sanciangco, J., Sheppard, A., Sheppard, C., Smith, J., Stuart, S., Turak, E., Veron, J. E. N., Wallace, C., Weil, E. and Wood, E. (2008) 'One-third of reef-building corals face elevated extinction risk from climate change and local impacts', *Science*, vol 321, no 5888, pp560–563

Church, J. and White, N. (2006) 'A 20th century acceleration in global sea-level rise', *Geophysical Research Letters*, vol 33, L01602

Cook, J. (2010) 'What do the "Climategate" hacked CRU emails tell us?', *Skeptical Science* website, see www.skepticalscience.com/Climategate-CRU-emails-hacked.htm

Dasgupta, S., Laplante, B., Meisner, C., Wheeler, D. and Yan, J. (2007) 'The impact of sea-level rise on developing countries: A comparative analysis', Research Working Paper No 4136, World Bank, Washington, DC

Delingpole, J. (2009) 'Climategate: The final nail in the coffin of "Anthropogenic Global Warming"?', *Telegraph*, 20 November, see http://blogs.telegraph.co.uk/news/jamesdelingpole/100017393/climategate-the-final-nail-in-the-coffin-of-anthropogenic-global-warming/

Diethelm, P. and McKee, M. (2009) 'Denialism: What is it and how should scientists respond?', *European Journal of Public Health*, vol 19, no 1, pp2–4

Doran, P. and Zimmerman, M. (2009) 'Examining the scientific consensus on climate change', *Eos, Transactions, American Geophysical Union*, vol 90, no 3, pp22–23

Dore, J., Lukas, R., Sadler, D., Church, M. and Karl, D. (2009) 'Physical and biogeochemical modulation of ocean acidification in the central north Pacific', *Proceedings of the National Academy of Sciences*, vol 106, no 30, pp12,235–12,240

Ducklow, H., Baker, K., Martinson, D., Quetin, L., Ross, R., Smith, R., Stammerjohn, S., Vernet, M. and Fraser, W. (2007) 'Marine pelagic ecosystems: The west Antarctic peninsula', *Philosophical Transactions of the Royal Society B: Biological Sciences*, vol 362, no 1477, pp67–94

Epstein, P., Diaz, H., Elias, S., Grabherr, G., Graham, N. and Martens, W. (1998) 'Biological and physical signs of climate change: Focus on mosquito-borne disease', *Bulletin of the American Meteorological Society*, vol 78, pp409–417

Fabry, V., Seibel, B., Feely, R. and Orr, J. (2008) 'Impacts of ocean acidification on marine fauna and ecosystem processes', *ICES Journal of Marine Science*, vol 65, no 3, pp414–432

Freudenburg, W. R. and Muselli, V. (2010) 'Global warming estimates, media expectations, and the asymmetry of scientific challenge', *Global Environmental Change*, vol 20, no 3,pp483–491

Frohlich, C. (2006) 'Solar irradiance variability since 1978: Revision of the PMOD composite during solar cycle 21', *Space Science Reviews*, vol 125, pp53–65, ftp://ftp.pmodwrc.ch/pub/data/irradiance/composite/DataPlots/composite_d41_62_0906.dat

Gallup (2009) Poll on environment, see www.gallup.com/poll/1615/Environment.aspx

HadCRUT (2010) HadCRUT3 global monthly surface air temperatures since 1850, http://hadobs.metoffice.com/hadcrut3/index.html

Hansen, J., Fung, I., Lacis, A., Rind, D., Lebedeff, S., Ruedy, R., Russell, G. and Stone, P. (1988) 'Global climate changes as forecast by Goddard Institute for Space Studies three-dimensional model', *Journal of Geophysical Research-Atmospheres*, vol 93, pp9341–9364

Hansen, J., Sato, M., Ruedy, R., Lo, K., Lea, D. and Medina-Elizade, M. (2006) 'Global temperature change', *Proceedings of the National Academy of Sciences*, vol 101, pp16,109–16,114

Hansen, J., Sato, M., Ruedy, R., Kharecha, P., Lacis, A., Miller, R., Nazarenko, L., Lo, K., Schmidt, G. A., Russell, G., Aleinov, I., Bauer, S., Baum, E., Cairns, B., Canuto, V., Chandler, M., Cheng, Y., Cohen, A., DelGenio, A., Faluvegi, G., Fleming, E., Friend, A., Hall, T., Jackman, C., Jonas, J., Kelley, M., Kiang, N. Y., Koch, D., Labow, G., Lerner, J., Menon, S., Novakov, T., Oinas, V., Perlwitz, Ja., Perlwitz, Ju., Rind, D., Romanou, A., Schmunk, R., Shindell, D., Stone, P., Sun, S., Streets, D., Tausnev, N., Thresher, D., Unger, N., Yao, M. and Zhang, S. (2007) 'Climate simulations for 1880–2003 with GISS modelE', *Climate Dynamics*, vol 29, no 7, pp661–696

Health Protection Agency (2007) 'The health effects of climate change in the United Kingdom', *Health Protection Report*, vol 1, no 19, see www.hpa.org.uk/hpr/archives/2007/hpr1907.pdf

Huang, S., Pollack, H. and Shen, P. (2000) 'Temperature trends over the past five centuries reconstructed from borehole temperatures', *Nature*, vol 403, pp756–758

Hurd, B. and Coonrod, J. (2008) 'Climate change and its implications for New Mexico's water resources and economic opportunities', Agricultural Experiment Station Technical Report 45, New Mexico State University, Las Cruces, NM

IASC (2010) 'Permafrost in the Arctic', in J. Walsh et al (eds) *Arctic Climate Assessment, Section 6.6*, International Project of the Arctic Council and International Arctic Science Committee, see www.eoearth.org/article/Permafrost_in_the_Arctic, retrieved 21 July 2010

Immerzeel, W. W., van Beek, L. P. H. and Bierkens, M. F. P. (2010) 'Climate change will affect the Asian water towers', *Science*, vol 328, no 5984, pp1382–1385

International Ice Charting Working Group (2009) 'National ice services advise of continuing navigation hazards', see http://nsidc.org/noaa/iicwg/IICWG_2009/IICWG_X_NEWS_RELEASE-2009-10-16.pdf

IPCC (2007) S. Solomon et al (eds) *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (AR4)*, Cambridge University Press, Cambridge, UK, and New York

Jacoby, G. and D'Arrigo, R. (1995) 'Tree ring width and density evidence of climatic and potential forest change in Alaska', *Global Biogeochemical Cycles*, vol 9, pp227–234

Kehrwald, N., Thompson, L., Tandong, Y., Mosley-Thompson, E., Schotterer, U., Alfimov, V., Beer, J., Eikenberg, J. and Davis, M. (2008) 'Mass loss on Himalayan glacier endangers water resources', *Geophysical Research Letters*, vol 35, L22503

Kerr, R. (2002) 'A warmer arctic means change for all', *Science*, vol 297, no 5586, pp1490–1493

Kimball, B., Idso, S., Johnson, S. and Rillig, M. (2007) 'Seventeen years of CO_2 enrichment of sour orange trees: Final results', *Global Change Biology*, vol 13, pp2171–2183

Knutti, R. and Hegerl, G. C. (2008) 'The equilibrium sensitivity of the Earth's temperature to radiation changes', *Nature Geoscience*, vol 1, no 11, pp735–743

Krivova, N., Balmaceda, L. and Solanki, S. (2007) 'Reconstruction of solar total irradiance since 1700 from the surface magnetic flux', *Astronomy & Astrophysics*, vol 467, pp335–346, www.mps.mpg.de/projects/sun-climate/data/tsi_1611.txt

Kurz, W., Dymond, C., Stinson, V., Rampley, G., Neilson, E., Carroll, A., Ebata, T. and Safranyik, L. (2008) 'Mountain pine beetle and forest carbon feedback to climate change', *Nature*, vol 452, pp987–990

Kutschera, U., Pfeiffer, I. and Ebermann, E. (2007) 'The European land leech: Biology and DNA-based taxonomy of a rare species that is threatened by climate warming', *Naturwissenschaften*, vol 94, no 12, pp967–974

Larsen, P., Goldsmith, S., Smith, O., Wilson, M., Strzepek, K., Chinowsky, P. and Saylor, B. (2008) 'Estimating future costs for Alaska public infrastructure at risk from climate change', *Global Environmental Change*, vol 18, no 3, pp442–457

Lockwood, M. (2008) 'Recent changes in solar output and the global mean surface temperature. III. Analysis of the contributions to global mean air surface temperature rise', *Proceedings of the Royal Society A*, vol 464, pp1–17

Mann, M., Bradley, R. and Hughes, M. (1998) 'Global-scale temperature patterns and climate forcing over the past six centuries', *Nature*, vol 392, pp779–787

Mann, M., Bradley, R. and Hughes, M. (1999) 'Northern Hemisphere temperatures during the past millennium: Inferences, uncertainties, and limitations', *Geophysical Research Letters*, vol 26, no 6, pp759–762

Mann, M., Zhang, Z., Hughes, M., Bradley, R., Miller, S., Rutherford, S. and Ni, F. (2008) 'Proxy-based reconstructions of hemispheric and global surface temperature variations over the past two millennia', *Proceedings of the National Academy of Sciences*, vol 105, no 36, pp13,252–13,257

McCabe, G. and Wolock, D. (2007) 'Warming may create substantial water supply shortages in the Colorado River basin', *Geophysical Research Letters*, vol 34, L22708

McCullagh, D. (2010) 'Sarah Palin on Climategate, Copenhagen: Beware politicized science', *CBS News*, www.cbsnews.com/8301-504383_162-5943590-504383.html

McIntyre, S. and McKitrick, R. (2005) 'Hockey sticks, principal components, and spurious significance', *Geophysical Research Letters*, vol 32, L03710, doi:10.1029/2004GL021750

McMahon, S., Parker, G. and Miller, D. (2010) 'Evidence for a recent increase in forest growth', *Proceedings of the National Academy of Sciences*, vol 107, no 8, pp3611–3615

Medina-Ramon, M. and Schwartz, J. (2007) 'Temperature, temperature extremes, and mortality: A study of acclimatization and effect modification in 50 US cities', *Occupational and Environmental Medicine*, vol 64, no 12, pp827–833

Mendelsohn, R., Dinar, A. and Williams, L. (2006) 'The distributional impact of climate change on rich and poor countries', *Environment and Development Economics*, vol 11, no 2, pp159–178

Menne, M., Williams, C. Jr and Palecki, M. (2010) 'On the reliability of the US surface temperature record', *Journal of Geophysical Research-Atmospheres*, vol 115, D11108, doi:10.1029/2009JD013094

Miles, H., Widdicombe, S., Spicer, J. and Hall-Spencer, J. (2007) 'Effects of anthropogenic seawater acidification on acid–base balance in the sea urchin *Psammechinus miliaris*', *Marine Pollution Bulletin*, vol 54, pp89–96

Morgan, J., Milchunas, D., LeCain, D., West, M. and Mosier, A. (2007) 'Carbon dioxide enrichment alters plant community structure and accelerates shrub growth in the shortgrass steppe', *Proceedings of the National Academy of Sciences*, vol 104, no 37, pp14,724–14,729

Murphy, D S., Solomon, R., Portmann, W., Rosenlof, K., Forster, P. and Wong, T. (2009) 'An observationally based energy balance for the Earth since 1950', *Journal of Geophysical Research-Atmospheres*, vol 114, D17107, doi:10.1029/2009JD012105

NASA GISS Temperature Index (2010) GLOBAL Land–Ocean Temperature Index by the Goddard Institute of Space Studies at NASA, see http://data.giss.nasa.gov/gistemp/tabledata/GLB.Ts+dSST.txt

Nemani, R., Keeling, C., Hashimoto, H., Jolly, W., Piper, S., Tucker, C., Myneni, R. and Running, S. (2003) 'Climate-driven increases in global terrestrial net primary production from 1982 to 1999', *Science*, vol 300, no 5625, pp1560–1563

Nepstad, D., Tohver, I., Ray, D., Moutinho, P. and Cardinot, G. (2007) 'Mortality of large trees and lianas following experimental drought in an Amazon forest', *Ecology*, vol 88, pp2259–2269

Nyegaard, H. (2007) *Climate Change and the Greenland Society*, World Wide Fund for Nature (WWF), Copenhagen, Denmark

Oerlemans, J. (2005) 'Extracting a climate signal from 169 glacier records', *Science*, vol 5722, pp675–677

OISM (2008) Petition Project, Oregon Institute of Science and Medicine, see www.petitionproject.org/

Okude, A. and Ademiluyi, I. (2007) 'Coastal erosion phenomenon in Nigeria: Causes, control and implications', *World Applied Science Journal*, vol 1, no 1, pp44–51

Oreskes, N. (2004) 'Beyond the ivory tower: The scientific consensus on climate change', *Science*, vol 306, p1686

Oreskes, N. and Conway, E. M. (2010) *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming*, Bloomsbury Press, New York

Orr, J., Fabry, V., Aumont, O., Bopp, L., Doney, S., Feely, R., Gnandesikan, A., Gruber, N., Ishida, A., Joos, F., Key, R., Lindsay, K., Maier-Reimer, E., Matear, R., Monfray, P., Mouchet, A., Najjar, R., Plattner, G., Rodgers, K., Sabine, C., Sarmiento, J., Schlitzer, R., Slater, R., Totterdell, I., Weirig, M., Yamanaka, Y. and Yool, A. (2005) 'Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms', *Nature*, vol 437, pp681–686

Oxburgh, R. (2010) Report of the International Panel set up by the University of East Anglia to examine the research of the Climatic Research Unit, see www.uea.ac.uk/mac/comm/media/press/CRUstatements/SAP

Parmesan, C. and Yohe, G. (2003) 'A globally coherent fingerprint of climate change impacts across natural systems', *Nature*, vol 421, no 6918, pp37–42

Peng, S., Huang, J., Sheehy, J, Laza, R., Visperas, R., Zhong, X., Centeno, G., Khush, G. and Cassman, K. (2004) 'Rice yields decline with higher night temperature from global warming', *Proceedings of the National Academy of Sciences*, vol 101, no 27, pp9971–9975

Pennisi, E. (2009) 'Ecology: Western US forests suffer death by degrees', *Science*, vol 323, no5913, pp447ff

Pfeffer, W., Harper, J. and O'Neel, S. (2008) 'Kinematic constraints on glacier contributions to 21st-century sea-level rise', *Science*, vol 321, no 5894, pp1340–1343

Phillips, O. L., Aragao, L. E. O. C., Lewis, S. L., Fisher, J. B., Lloyd, J., Lopez-Gonzalez, G., Malhi, Y., Monteagudo, A., Peacock, J., Quesada, C. A., van der Heijden, G., Almeida, S., Amaral, I., Arroyo, L., Aymard, G., Baker, T. R., Banki, O., Blanc, L., Bonal, D., Brando, P., Chave, J., de Oliveira, A. C., Cardozo, N. D., Czimczik, C. I., Feldpausch, T. R., Freitas, M. A., Gloor, E., Higuchi, N., Jimenez, E., Lloyd, G., Meir, P., Mendoza, C., Morel, A., Neill, D. A., Nepstad, D., Patino, S., Penuela, M. C., Prieto, A., Ramirez, F., Schwarz, M., Silva, J., Silveira, M., Thomas, A. S., Steege, H., Stropp, J., Vasquez, R., Zelazowski, P., Davila, E. A., Andelman, S., Andrade, A., Chao, K. J., Erwin, T., Di Fiore, A., Honorio, E., Keeling, H., Killeen, T. J., Laurance, W. F., Cruz, A. P., Pitman, N. C. A., Vargas, P. N., Ramirez-Angulo, H., Rudas, A., Salamao, R., Silva, N., Terborgh, J. and Torres-Lezama, A. (2009) 'Drought sensitivity of the Amazon rainforest', *Science*, vol 323, no 5919, pp1344–1347

Pittock, A. B. (2009) *Climate Change: The Science, Impacts and Solutions*, CSIRO/Earthscan, London

Plimer, I. (2009) *Heaven and Earth: Global Warming: The Missing Science*, Connorcourt Publishing, Ballan, Australia

Roe, G. and Baker, M. (2007) 'Why is climate sensitivity so unpredictable?', *Science*, vol 318, no 5850, pp629–632

Rogers, C., Wayne, P., Macklin, E., Muilenberg, M., Wagner, C., Epstein, P. and Bazzaz, F. (2006) 'Interaction of the onset of spring and elevated atmospheric CO_2 on ragweed (*ambrosia artemisiifolia* l.) pollen production', *Environmental Health Perspectives*, vol 114, no 6, June, pp865–869

Russell, M., Boulton, G., Clarke, P., Eyton, D. and Norton, J. (2010) *The Independent Climate Change E-mails Review*, see www.cce-review.org/pdf/FINAL%20REPORT.pdf

Ryan, P. and Ryan, A. (2007) 'Impacts of global warming on New Zealand freshwater organisms: A preview and review', *New Zealand Natural Sciences*, vol 31, pp43–57

Sadler, B. (2003) 'Informed adaptation to a changed climate: Is South Western Australia a national canary', in *Living with Climate Change*, proceedings of national conference on climate change impacts and adaptation, Australian Academy of Science, Canberra, pp207–217

Saleska, S., Didan, K., Huete, A. and da Rocha, H. (2007) 'Amazon forests green-up during 2005 drought', *Science*, vol 318, no 5850, pp612ff

Shaffer, G., Olsen, S. and Pedersen, J. (2009) 'Long-term ocean oxygen depletion in response to carbon dioxide emissions from fossil fuels', *Nature Geoscience*, vol 2, pp105–109

Shakhova, N., Semiletov, I., Salyuk, A. and Kosmach, D. (2008) 'Anomalies of methane in the atmosphere over the East Siberian shelf: Is there any sign of methane leakage from shallow shelf hydrates?', *Geophysical Research Abstracts*, vol 10, EGU2008-A-01526, 2008, SRef-ID: 1607-7962/gra/ EGU2008-A-01526

Sherwood, S. and Huber, M. (2010) 'An adaptability limit to climate change due to heat stress', *Proceedings of the National Academy of Sciences*, vol 107, no 21, pp9552–9555

Simmons, A., Willett, K., Jones, P., Thorne, P. and Dee, D. (2010) 'Low-frequency variations in surface atmospheric humidity, temperature, and precipitation: Inferences from reanalyses and monthly gridded observational data sets', *Journal of Geophysical Research-Atmospheres*, vol 115, D01110, doi:10.1029/2009JD012442

Sinervo, B., Mendex, F., Miles, D., Heulin, B., Bastiaans, E., Villagran-Santa Cruz, M., Lara-Resendix, R., Martinez-Mendez, N., Calderon-Espinosa, M., Meza-Lazaro, R., Gadsden, H., Avila, L., Morando, M., De la Riva, I., Supelveda, P., Rocha, C., Ibarguengoytia, N., Puntriano, C., Massot, M., Lepetz, V., Oksanen, T., Chapple, D., Bauer, A., Branch, W., Clobert, J. and Sites J. Jr (2010) 'Erosion of lizard diversity by climate change and altered thermal niches', *Science*, vol 328, no 5980, pp894–899

Smith, C., Andy, B., Fairchild, I., Frisia, S. and Borsato, A. (2006) 'Reconstructing hemispheric-scale climates from multiple stalagmite records', *International Journal of Climatology*, vol 26, no 10, pp1417–1424

Smol, J. and Douglas, M. (2007) 'Crossing the final ecological threshold in high Arctic ponds', *Proceedings of the National Academy of Sciences*, vol 104, no 30, pp12,395–12,397

Solomon, S., Plattner, G-K., Knutti, R. and Friedlingstein, P. (2009) 'Irreversible climate change due to carbon dioxide emissions', *Proceedings of the National Academy of Sciences*, vol 106, no 6, pp1704–1709

Stramma, L., Johnson, G., Sprintall, J. and Mohrholz, V. (2008) 'Expanding oxygen-minimum zones in the tropical oceans', *Science*, vol 320, no5876, pp655–658

Stroeve, J., Serreze, M., Drobot, S., Gearheard, S., Holland, M., Maslanik, J., Meier, W. and Scambos, T. (2008) 'Arctic sea ice extent plummets in 2007', *Eos, Transactions, American Geophysical Union*, vol 89, no 2, doi:10.1029/2008EO020001

Tao, F., Hayashi, Y., Zhang, Z., Sakamoto, T. and Yokozawa, M. (2008) 'Global warming, rice production, and water use in China: Developing a probabilistic assessment', *Agricultural and Forest Meteorology*, vol 48, no 1, pp94–110

Thomas, C., Cameron, A., Green, R., Bakkenes, M., Beaumont, L., Collingham, Y., Erasmus, B., Siqueira, M., Grainger, A., Hannah, L., Hughes, L., Huntley, B., Jaarsveld, A., Midgley, G., Miles, L., Ortega-Huerta, M., Peterson, A., Phlllips, O. and Williams, S. (2004) 'Extinction risk from climate change', *Nature*, vol 427, pp145–148

Trenberth, K. (2009) 'An imperative for climate change planning: Tracking Earth's global energy', *Current Opinion in Environmental Sustainability*, vol 1, no 1, pp19–27

Turley, C., Blackford, J., Widdicombe, S., Lowe, D., Nightingale, P. and Rees, A. (2006) 'Reviewing the impact of increased atmospheric CO_2 on oceanic pH and the marine ecosystem', in H. Schellnhuber et al (eds) *Avoiding Dangerous Climate Change*, Cambridge University Press, Cambridge, UK, pp65–70

UAH website (2010) 'MSU global monthly lower troposphere temperatures since December 1978' (MSU = 'microwave sounding units' on satellites), accessed June 2010 see http://vortex.nsstc.uah.edu/data/msu/t2lt/uahncdc.lt

Usoskin, I., Schüssler, M., Solanki, S. and Mursula, K. (2005) 'Solar activity over the last 1150 years: Does it correlate with climate?', in F. Favata, G. Hussain and B. Battrick (eds) *Proceedings of the 13th Cambridge Workshop on Cool Stars, Stellar Systems and the Sun, ESA SP-560*, European Space Agency, Hamburg, Germany

Velicogna, I. (2009) 'Increasing rates of ice mass loss from the Greenland and Antarctic ice sheets revealed by GRACE', *Geophysical Research Letters*, vol 36, L19503, doi:10.1029/2009GL040222

Vermeer, M. and Rahmstorf, S. (2009) 'Global sea level linked to global temperature', *Proceedings of the National Academy of Sciences*, vol 106, no 51, pp21,527–21,532

Wahl, E. and Ammann, C. (2007) 'Robustness of the Mann, Bradley, Hughes reconstruction of Northern Hemisphere surface temperatures: Examination of criticisms based on the nature and processing of proxy climate evidence', *Climatic Change*, vol 85, pp33–69

Walter, K., Edwards, M., Grosse, G., Zimov, S. and Chapin, F. (2007) 'Thermokarst lakes as a source of atmospheric CH_4 during the last deglaciation', *Science*, vol 318, no 5850, pp633–636

Watts, A. (2010) SurfaceStations.org, see www.surfacestations.org/

Westbrook, G. K., Thatcher, K. E., Rohling, E. J., Piotrowski, A. M., Pälike, H., Osborne, A. H., Nisbet, E. G., Minshull, T. A., Lanoisellé, M., James, R. H., Hühnerbach, V., Green, D., Fisher, R. E., Crocker, A. J., Chabert, A., Bolton, C. T., Beszczynska-Möller, A., Berndt, C. and Aquilina, A. (2009) 'Escape of methane gas from the seabed along the West Spitsbergen continental margin', *Geophysical Research Letters*, vol 36, L15608

Westerling, A., Hidalgo, H., Cayan, D. and Swetnam, T. (2006) 'Warming and earlier spring increase western US forest wildfire activity', *Science*, vol 313, no 5789, pp940–943

Willis, P., Blackman-Woods, R., Boswell, T., Cawsey, I., Dorries, N., Harris, E., Iddon, B., Marsden, G., Naysmith, D., Spink, B., Stewart, I., Stringer, G., Turner, D. and Wilson, R. (2010) 'The disclosure of climate data from the Climatic Research Unit at the University of East Anglia', House of Commons Science and Technology Committee, see www.publications.parliament.uk/pa/cm200910/cmselect/cmsctech/ 387/387i.pdf

Zhou, L., Tucker, C., Kaufmann, R., Slayback, D., Shabanov, N. and Myneni, R. (2001) 'Variations in northern vegetation activity inferred from satellite data of vegetation index during 1981 to 1999', *Journal of Geophysical Research-Atmospheres*, vol 106, pp20,069–20,083, doi:10.1029/2000JD000115

4

The History of Denial

The Long History of Denial

Denial is as old as humanity. This book focuses on the history of denial of *environmental* problems, though it has been pointed out how successful creationists have also been in the US in keeping the American public ignorant about evolution. Both evolution and environmental denial feature 'a denial of facts and circumstances that don't fit religious or other traditional beliefs' (Ehrlich and Ehrlich, 1998). Paul and Anne Ehrlich in 1998 tabulated the common themes or claims of denial anti-science, which were:

- Environmental scientists ignore the abundant good news about the environment;
- Population growth does not cause environmental damage and may even be beneficial;
- Humanity is on the verge of abolishing hunger – food scarcity is a local or regional problem and is not indicative of overpopulation;
- Natural resources are superabundant, if not infinite;
- There is no extinction crisis, so most efforts to preserve species are both uneconomic and unnecessary;
- Global warming and acid rain are not serious threats to humanity;
- Stratospheric ozone depletion is a hoax;
- The risks posed by toxic substances are vastly exaggerated; and
- Regulation is wrecking the economy.

These arguments are still being made in virtually the same format (see, for example, Plimer, 2009). It is thus important to realize that today's denial about climate change follows on from a long trend in denial about the environmental crisis. The campaign to deny the need to protect natural areas and wilderness was one of the first great denial issues and continues today (Oelschlaeger, 1991; Washington, 2006). Rachel Carson's (1962) *Silent Spring* raised the problems of