# <u>Climate Change: Contrasting Viewpoints on Risk and Uncertainty</u>

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## Introduction

As hurricane Irene whirled up the east coast of America, towards New York, people everywhere held their breath and followed this major story in the media around the globe. For New Yorkers familiar life stopped, as trains and flights were halted, Times Square was empty and mandatory evacuation was ordered for low lying areas. In the end it weakened, but not before wreaking death and destruction. There were, however, at the time only few voices from scientists, claiming any direct connection with climate change. This was despite their near unanimous warnings over the years, about the risk of more or more intense catastrophes resulting from climate change. The mechanisms by which global warming increases humidity and changes air currents, and thus increases the probability of violent storms, has long been understood and accepted by climate science, but the multiple interacting causes of individual events make precise calculations of probability uncertain and inhibit the attribution of direct causality to any one of them. Over the years few scientists have voiced more than tentative suggestions that climate change 'could be' 'a contributor' to specific events. Given this hesitation, it is not surprising that lay people gain the impression, either that there is no evidence of a causal connection, or else that climate science is divided and unsure, an impression fostered by those with special interests in inaction.

Laymen respond to their direct experience of weather, manifest as events in a particular place and time. Long term, wide ranging scientific future projections and models may have less credibility, or even be mentally classified with disaster fiction. Sociologists have described how a tendency to increasingly short term thinking has affected western societies over the last three or four decades but there has been little discussion about whether the trend could be reversible. Economists build a ‘discounting of the future’ into their calculations, according to which people value present goods more than future ones. This is based on a questionable assumption about a supposedly universal and timeless human nature.

In contrast, climate scientists have sought to approach certainty about global climate change, through long term and world wide averages. Where gaps remain in their understanding or possible alternative causation has been proposed, they have been ingenious, persistent and even heroic in their search for data. Overall they have built a very solid base of evidence for the warming of the planet and its connection with rising levels of anthropogenic (caused by humans) greenhouse emissions, which fits with well understood natural processes.

Climate change, its causes, its risks and the mitigation and adaptation needed to confront it, also involves social, political, ethical and economic questions, at all levels from the personal to the global, as well as in many fields of science and technology. A broad multi-disciplinary approach is sorely needed, but there are many obstacles, misunderstandings and contrasts of perspective and focus to be overcome.

## I People and Weather

People are often confused about the distinction between climate and weather. They wonder how scientists can express confidence about the expected changes in the former, in decades or centuries to come, but are unable to tell them correctly whether it will rain locally next week, or how hard Hurricane Irene would hit New York the following day.

### Discounting the future

Economists explain, and sometimes justify, the limited public acceptance of costly climate change mitigation measures, by a supposedly universal individualist calculation that 'discounts the future'. The present, it is claimed, is worth more to us than the future, which progressively loses value the further away it is. Risks to the planet and to hundreds of generations of our descendents in centuries yet to come would thus soon fade into insignificance (Garnaut 2009: 1-2). Such discounting, seen as a universal human preference, underpins the short term cost benefit calculations that are a staple tool of economists prescriptions. The claim has often also been accepted at face value by other social scientists as well as the media and politicians.

Although economist Nicholas Stern and sociologist Anthony Giddens have recently repeated the stark warnings of climate scientists, they have both been inhibited in their hopes for decisive action by their disciplines' conviction that most people are only oriented to short term needs and immediate satisfactions. Stern 'navigates a delicate path between optimism and Armageddon' (Aitkenhead 2009: 2) and seeks to moderate pessimism about mitigation possibilities, by proposing a low rate for future discounting. His cost benefit analysis is constrained to assume as realistic cuts in atmospheric concentrations that would still leave a 50% probability of more than 3 degrees of warming, more than has occurred during the last 10,000 years, and well above the level considered 'safe' by many (Shaw 2009: 118) . Shaw documents the doubts of many scientists about the supposed safety of even a 2 degrees limit.

Giddens propounds what he calls the 'Giddens paradox' which states that

> Since the dangers posed by global warming aren't tangible, immediate or visible in the course of day-to-day life… many will sit on their hands and do nothing… Yet waiting until they become visible, and acute before being stirred to serious action will by definition be too late (2009: 2).

**Discounting in history.** There is in fact substantial evidence that, rather than such discounting of the future being in some way a universal attribute of human nature, it has in fact become much more prominent over the last thirty or forty years, and even now is far from universal or set in concrete. A possibly apocryphal but widely quoted American Indian saying enjoins 'considering the consequences of your actions unto the seventh generation'. 'Planting trees for your grandchildren' is recommended in many cultures. Fear of eternal damnation after death, or of the long term sullying of a family's future reputation, have been powerful motivators throughout history. The cathedrals of the Middle-Ages, like the pyramids of Egypt, were projects that took centuries to complete, aiming at eternal life in the hereafter. The construction of political and economic dynasties takes more than one lifetime. Many immigrants, even today, risk their lives in rickety boats and sacrifice status and security, in countries where their language and qualifications will never be recognised, in order to secure the education and future of their children. Savings rates for old age are high in poor societies, although the taxes and contributions we pay for pensions or superannuation schemes have to be compulsory.

**New social short-termism.** Acceptance of future discounting, by both sociology and economics, seems to be reflecting only quite recent changes in society, not ones that are as immutable as they appear to believe. Sociologists have studied the new social, economic and cultural developments in recent decades that have promoted this new 'short termism', which can divert attention and credibility from the long term analyses, risks and remedies that climate science proposes. One pervasive aspect of the trends of the last 35 years has been a foreshortening of time. Flexible response, facilitated by IT, in a competitive and unpredictable environment, has replaced long term planning (McKinlay and Starkey 1994: 190-191). Short-term profits have become the main motivators, not only of stockholders but also for managers, whose bonuses are linked to dividend returns. Computerised retail check-outs send instant messages about consumer demand, rapidly updating inventories. Product life cycles have shrunk and the time from conception to marketing has dropped dramatically, while new fashions and entertainment gizmos replace each other ever faster. Workers find that predictable career paths and job security have declined sharply, as part time, casual and contract jobs multiply, along with threats of redundancy, closure and relocation (Cappelli 1995; Uchitelle 2006). The current looming recession brings economic risks to the forefront, obscuring the more long term ones.

**Is this short-termism reversible?** Even today the extent to which people are willing to discount risks to future generations may be questioned. Shane Frederick (2003) asked 401 respondents to choose between various hypothetical life saving programs that weighed present and future lives against each other differently. The results varied dramatically with the form of the question, but many formats revealed no preference at all for the lives of current generations over future ones. Discussions with respondents afterwards indicated that for many of those who seemed unwilling to sacrifice the present for the future, what was at issue was not a differential valuation but, in some cases, a mistrust of unknown future power holders and in others an expectation that growing prosperity and scientific progress would in any case protect future lives (48-50).

**Future scenarios - winners and losers.**

Serious action to mitigate or prepare for climate change is likely to alter the distribution of social advantage, creating different winners and losers, and might accompany major cultural shifts. Powerful potential losers can find fertile ground to enlarge popular doubts about the reality or urgency of climate change, and create sceptical opposition to serious action. (Dunlap and McCright 2010). Mitigating action presents immediate prospects of job and capital losses that would follow from any serious decarbonising of our energy and transport systems. Although there would be alternative growth sectors, there would be new winners and losers, among workers and companies, as well as a likely change in the pecking order of countries and regions (Tracy 2010). There would probably need to be a large shift of resources from the production of consumer goods to the new capital goods and infrastructure and the primacy of commercial capital could be undermined by any retreat from market-based consumerism. Large, long term capital-intensive mitigation projects, backed by central government subsidy and support, such as carbon sequestration, geothermal and hydro power, could surely also restore the dominant position of some major industrial corporations, but their autonomy from government regulation would be reduced. A new kind of government-industrial complex might emerge.

On the other hand, policies that focus on developing localised sources of renewable energy might boost innovative small firms. These in turn might strengthen and be promoted by some more local levels of government, looking perhaps for support to international treaties rather than nation states, a development already appearing in South Australia and California (Lever-Tracy 2010).

**If mitigation fails** and business as usual drives climate disaster we could surely enter the world of fictional disaster movies, with water and food wars and xenophobic walls to keep out the waves of climate refugees. John Urry, one of the very few sociologists to have considered seriously the possible impact of climate change, suggests two likely scenarios for society in such a future. The first is a Hobbesian world of 'wild zones' and 'regional war-lordism', as inadequate pre-emptive action fails to curb the breakdown of 'mobility, energy and communication connections… a plummeting standard of living, a re-localisation of mobility patterns… and relatively weak imperial or national forms of governance'. The second is an Orwellian society, a 'digital panopticon' where reduced consumption is enforced by total control and monitoring of the strict carbon and mobility rations allowed to each individual (Urry 2007; Urry 2011: Ch 9).

## III Extreme weather events.

Measurement of averages is well advanced, but data on range extremes, and associated disasters, is rarer. This is, of course, what concerns lay people most. Individual weather records are broken somewhere every year, but only if the record breaking becomes repeatedly more prevalent and widespread can these be accepted by scientists as indicators of a changing climate. The risks of particular weather events and catastrophes, with their multiple interacting causes, are very hard to predict, and there is always uncertainty about the relative significance of a variety of short term and long term, local or global causes.

### Natural disasters

Extreme events can be seen as rare but widely publicised harbingers of what could be common in a future of changed climate. As such they might be the place where scientific explanations and popular experience-based understandings of risk converge. So far this has happened only rarely and tenuously. Few scientists have voiced more than tentative suggestions that climate change ‘could be’ ‘a contributor’ to specific exceptional events, for example to the unprecedented fires in Russia (that are said to have killed 56,000 people) or Australia or to heatwaves in Europe, or to unseasonal floods in Pakistan or droughts in Africa or rising seas in Bangla Desh and Pacific Islands or a hurricane threatening New York.

While global media bring such localised, time specific experiences home to the lay public around the world, scientists have been perhaps excessively wary of claiming them. Each disaster has many, often complex and mediated causes, and assessing the extent to which global warming can be considered ‘responsible’ for any particular event is hard, and can lay a scientist open to accusations of ‘scare mongering’. It takes many occurrences at different times and places and in a variety of circumstances, before models can be adjusted and rising probabilities predicted with confidence. Such scientific hesitation, in the absence of a high level of detailed certainty, has often tended to deter the media.

**Drought, flooding and La Nina[1].** In August 2011, *Time* Magazine ran a major feature on the 'record breaking' drought affecting much of the South of the United States (Walsh 2011). It unhesitatingly attributed its 'immediate meteorological' cause to an unusual cooling of the Southern Pacific by an 'exceptionally strong' La Nina effect. References to climate change were, however, all in the future tense, as something that 'is expected further to dry out much of the region, multiplying the impact' (24). While they were expected to 'increase precipitation levels globally, warming related shifts in weather patterns are [also] likely to make already dry areas drier still' (27). No causal relationship between global warming and the stronger La Nina is suggested in the article.

This year's La Nina weather system, the strongest in 50 years, has been explicitly blamed by scientists for drought or heavy rain and flooding in many places, including Africa, Australia and South America. However, while climate scientists find quite plausible a mechanism to link such a La Nina to global warming (Leahy 2011) they as yet lack the amount and accuracy of data they need to speak out with a clear causal statement.

### Scientists slowly gaining confidence

The insurer Munich Re had found 2010 one of the worst on record for natural disasters, nine-tenths of which were related to extreme weather (Connor 2011)[2]. Some disasters, which might, at first, have seemed to be once off exceptions, have returned, sometimes with even greater ferocity, in the summer of 2011. Many of them were widely and graphically reported in the media, and some appeals attracted great sympathy and substantial donations from around the world. At first, as before, only a few scientists were willing to make causal attribution to climate change, confirming to the media and the public that there was quite possibly no such link.

**Rainfall.** Scientists are, however, now beginning to speak out as experience and evidence cumulate and converge and as long term and wide ranging data are brought together. In February 2011 scientists from universities in Canada and Scotland published, in *Nature*, results of a study of rainfall totals collected from 6000 rain gauges across the northern

[1] La Nina and El Nino are alternating manifestations of the El Nino-Southern Oscillation (ENSO) climate pattern, involving low or high Pacific sea surface temperatures. (Wikipedia).
[2] Insurance losses may however also reflect greater wealth or growing population or desire to be insured against risk.

hemisphere, between 1951 and 1999 (Min et al. 2011). They found extreme rain and floods had increased by 7% during the second half of the 20th century, and this correlated with expectations from computer models that factored in climate change (Mark and Osborne, 2011). Interviewed researcher Dr. Zwiers commented that

> It has often been suggested that the changes in precipitation extremes are likely linked to greenhouse gas increases. Our research provides the first scientific evidence that human induced greenhouse gas increases have contributed to [more intense rainfall events] over large parts of the Northern Hemisphere.

**British floods.** In a second study in the same issue of *Nature*, an international team ran replicating computer models which indicated that global warming contributed substantially to the probability of the extraordinary British floods of October-November 2000. Climate scientists elsewhere welcomed the studies as 'exciting' and 'innovative'. Although they accepted that such modelling techniques were still in their 'infancy', and noted the many continuing uncertainties, they argued that refining the models to better simulate climate extremes should be a top priority (Mark and Osborne 2011).

**Linking climate change and extreme weather**. In July 2011the International Union of Geophysics and Geodesy (IUGG www.iugg2011.com) held a conference in Melbourne titled *Earth on the Edge*. Scientists there argued that climate had already changed enough for it to be affecting the probability of an extreme event such as a hurricane, drought or flood. The British Met Office Hadley Centre and the US National Center for Atmospheric Research (NCAR) announced that they had joined forces with other climate organisations, including the influential US National Oceanic and Atmospheric Administration (NOAA), to carry out detailed investigations of extreme weather events (including the vast flooding in Pakistan the previous year), to see whether they could detect a climate change 'signal' as a likely cause.

Kevin Trenberth, a distinguished senior scientist at the US National Centre for Atmospheric Research (NCAR) in Boulder, Colorado, told the *Independent* newspaper (Connor 2011) that despite large weather variability

> The time has come to emphasise the link between extreme weather and the global climate in which it develops...When we have things that occur usually four per cent of the time start to occur ten per cent of the time, that's when we begin to notice. The main way we perceive climate change is in changes in the extremes. This is when we break records.

An international group of researchers have formed a new coalition called the *Attribution of Climate Related Events* (http://www.cgd.ucar.edu/cas/ace/) who are preparing to assess each extreme weather event and combine their findings in a report, to be given at the meeting of the *World Climate Research Programme* in Denver later in 2011 (Connor 2011; WCRP 2011).

**Risks to biodiversity.**

The risk of mass extinctions, substantially reducing biodiversity over coming decades, is widely reported and certainly arouses public concern (Caldwell 2010; Editorial 2011). As with risks to humans, climate change often features as an, unquantified, part of a long list of (mainly anthropogenic) contributing causes. Recently, however, it has graduated to being seen as one of the primary causes and policies to address it are being proposed.

Changes that have been reported in the media include: declining krill stocks around Antarctica; earlier break-up of river ice in Mongolia; genetic shift in the pitcher plant mosquito in North America; declining productivity of Lake Tanganyika; earlier death of old growth trees in the western US; a failure to spawn by millions of Pacific salmon; higher temperatures proving too much for many lizard species with declining numbers in France, Mexico and Africa and other places and declining shell fish stocks in an acidifying Arctic ocean. This year (2011) more extreme hurricanes are reported to have destroyed turtle nests in Florida, and the unprecedented cyclone in Queensland has destroyed food sources for dugongs and turtles around the Great Barrier Reef, leading to starvation and much greater death rates (ABC Radio 2011). Species can also adjust to warming, perhaps leading to encroachment on others or a new ecological balance. Recently, for the first time, polar bears were photographed hunting birds on land in caves (*Sunday Mail*, Adelaide 2011: 1, 46-47) and sightings of whales and dolphins have increased in warming waters off Ireland and South Africa.

Such accounts can evoke strong sympathy in people, but may not carry so much scientific weight. As with other indicators, individual effects can be due to multiple, hard to disentangle, causes, and contrary cases also need counting. However, the accumulation of anecdotal evidence is now increasingly impressing scientists and broader studies are linking them into a bigger picture.

Bringing a mass of information together, Parmesan and Yohe had already reported in *Nature* in 2003, that 1,700 plant, animal and insect species had moved nearer to the poles, since the mid 20$^{th}$ century, at an average rate of about six kilometres per decade. Unfortunately this was an adaptation too slow to match the changes in climate. Australian East coast climate zones, they reported, had moved 200 k in 60 years, an average of 33 k a decade (Powell 2003).

Two recent texts about biodiversity conservation (Worboys et al. 2010: 2, 3 and Steffen 2009: 2) give a new prominence to climate change, as one of the most important risks to the survival of species. Canadian scientists reported in *Nature*, in July 2011, a strong link between higher sea surface temperatures and a major decline, since 1950, of around 40%, in phytoplankton which forms the basis of the marine food chain. Another study mapped global biodiversity patterns for over 11,000 marine species living in 'ocean hot spots', and found diversity strongly linked with temperature for every group (Caldwell, 2011).

**The precautionary principle and extreme risks.**

The precautionary principal enjoins us to tread warily and to avoid action if significant harm from it is possible, even if not certain. It has been argued as appropriate for novel human interventions in nature, such as gene technology. Unfortunately it is now too late to be of much help in mitigating climate risks. The human interventions that initiated the build up of greenhouse gases commenced long ago, and their long lived effects in the atmosphere and the deep oceans will not dissipate for centuries, and may mean we are already close to or past a point of no return – a precautionary inaction is not a viable option.

James Hansen (2009: 141) points out that the last time the Earth was even just two or three degrees warmer than today, was about three million years ago, when sea levels were 25 metres higher than today (covering land where currently about a billion people live) and Florida was under water.

Economist Nicholas Stern, who respects the expertise of climate scientists, questions short term analysis:

> We're the first generation that has had the power to destroy the planet. Ignoring that risk can only be described as reckless...We have to recognise the scale of the risk. If we go on at anything like business as usual, we'll be at concentration levels by the end of this century which will give us around a 50-50 chance of being above five degrees centigrade relative to say the 19th century. We humans are only 100,000 years old. We haven't seen that for 30 to 50 million years (Aitkenhead 2009).

We need science and technology to focus on finding, improving and carefully comparing, on a case by case basis, the effectiveness of alternatives to our greenhouse emissions. Many of these also carry risks. The most common forms of biofuel take land from food production and are already accused of contributing to rising global food prices; nuclear power has demonstrated its dangers in Fukushima this year; natural gas fracking can poison water ways; hydro electric dams can drown vegetation (that then emits methane) and displace local populations and wild life; the replacement of, methane emitting, paddy field rice growing by fertilised dry land increases nitrous oxide emissions (McGrath 2011); geo-engineering proposals such as giant sunshades in space or seeding oceans with iron filings could lead to dangerous unexpected consequences (Rayner 2010). Of course these calculations also need to take into account the non climatic risks from 'business as usual', from coal mining and oil spill accidents and the health impacts of their pollution. (See for example McCarthy 2011).

More research and development, to avoid or counteract the risks, is clearly needed urgently, but there are as many social and political problems as technical and scientific ones. The sources of climate danger are deeply embedded in our technology and lifestyle and overcoming them requires global co-operation. To support damaging measures because 'climate change is more dangerous' adds also the further risk of alienating those worst affected by the measures, and destroying the necessary consensus; but a simple 'precautionary' response would paralyse innovation and action. As Ross Garnaut says, climate change is indeed a 'wicked problem' (2009: 4).

## IV Predicting future risks and reducing uncertainties

**What we know.**

**Rising CO2.** Much is known with confidence by climate scientists about the mechanism, first proposed in 1822 by Fourier and quantified in 1898 by Arrhenius, which links increasing anthropogenic carbon dioxide, and other gases such as methane and nitrous oxide in the atmosphere, to global warming. Since David Keeling first measured CO2 in the unpolluted atmosphere at Mauna Loa in 1958, he and others have persisted in annual measurements and his curve shows the levels rising from 315 parts per million in 1958 to 378 by 2005 (Simple 2005), reaching 387 in 2009, at the extreme end of predictions made only two years earlier (2011 Wikipedia).

An eight-year European study, drilling deep Antarctic ice cores to measure the composition of the air bubbles trapped within, reported in 2005 that CO2 levels in the atmosphere were now at least 30 per cent higher than any time in the last 65,000 years. The speed of the rise was unprecedented, from 280 parts per million (ppm) before the industrial revolution to 392 in 2011 (*SBS* 2005; Wikipedia). On 20 January 2006, *SBS TV World News* also reported that a British Antarctic survey, analysing CO2 in crevasse ice in the peninsula, had found recent levels higher than any in the previous 800,000 years. Human greenhouse emissions continue to rise, by one per cent a year, 20 years ago, to around three per cent by the end of the 'noughties', as energy use in both developed and developing countries, is still increasing.

**Warming.** The IPCC (International Panel on Climate Change) fourth report stated in 2007 that

> The warming of the climate system is unequivocal, as is now evident from [improved and expanded] observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level'.

They noted that eleven of the twelve years between 1995 and 2006 ranked among the twelve hottest ever recorded (IPCC 2007)[3]. The first decade of the new century now ranks as the hottest decade on record. When unusually cold weather in the northern winter of 2011 spread public doubts about global warming, scientists were able to explain how the changing circulation patterns of deep ocean currents and of cold Arctic winds had produced a regional cooling despite continuing overall warming (Thornalley 2011).

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[3] For a fuller account of the theory, mechanism and parameters of global climate change see Pittock 2010a or Walker and King 2008.

The analysis, by the UAE and British Met office, of data from 1995 to 2009, to ascertain whether global warming was continuing, only reached a 90% probability level, not enough to meet high standards of 'significance'[4]. However, as the final measurements for 2010 were added into the longer term total, it became clear that the very high 95% threshold for significant warming over this period, required by the IPCC, had now been met. Monthly measurements from over 3000 weather stations around the world over 16 years, added up to a 0.19 degrees centigrade global increase since 1995, which is consistent with other major records for the period (BBC 2011). If this does not sound like much to the layman, let us remember that a 3C rise in global average temperature would make the earth hotter than it has been in six million years.

**Doubts and gaps in our knowledge.**

**Constructing models.** Deriving changing climate patterns from many measurements of multi causal and fluctuating weather is a complex task. Climatologists must rely on accumulating large numbers of observations over long periods of current and historical time and in all parts of the world, including in places out of sight and far from human experience. The calculation of climate risks is about finding the links between an accumulation of information about what is already manifest and known, and the probability of uncertain future dangers.

Using this (partial) knowledge, they construct (imperfect) computer models of future expectations, which are continually updated and corrected to incorporate newly acquired data and information about unfolding events as they manifest themselves. On this basis they can develop continually improving (but never absolute) levels of confidence about general trends and changes in the earth's climate and about their causation. Climate scientists thus look to long term and global factual information to increase their level of confidence in risk probabilities. Many challenges and uncertainties remain, however, and the science advances by tackling them and investigating them in detail and in depth.

**The sunspot cycle.** Sceptics seeking to downplay the role of human greenhouse emissions in rising temperatures, have claimed the crucial factor is really a correlation between cyclical

[4] Sceptics prematurely hailed this report on temperatures up to 2009 as somehow meaning warming was 'not significant'.

solar variations and climate fluctuations on earth. Barrie Pittock has over many years pointed to the absence of any such contemporary association, proportionate to current temperature changes on earth.

Most studies suggest that before the industrial age, there was indeed a close relationship between natural *forcings* - solar fluctuations and other factors - and average global temperatures. However, no correlation can be found between solar activity and the strong warming during the past 40 years. Direct measurements of solar output since 1978 show a steady rise and fall over the 11-year sunspot cycle, but no upwards or downward trend (Pittock, 2009).

**Is such warming continuing and cumulative** or is it an acceptable and reversible temporary variation, as many sceptics insist? The trend in global temperature fluctuates, and has at times seemed ambiguous. Nineteen ninety eight remained the hottest year ever recorded until matched in 2010. Doubters have been suggesting for years that the world will now revert to cooling. In 2005 a team led by NASA's James Hansen reported in the online journal *Science Express* on a 10 year oceanic study showing that the earth was holding on to more solar energy than it was emitting back into space. The Institute's director said 'This energy imbalance is the 'smoking gun' that we have been looking for' (reported in *ABC TV News* 29 April 2005). Much of the cumulating energy retained is stored in the deep oceans, to be progressively released over centuries to come.

**Clouds**. One major remaining source of ambiguity is clouds. Overall warming increases the evaporation rate. Water vapour is itself a greenhouse gas but normally returns quite rapidly to a more or less constant global equilibrium. Attempts to model the effects of clouds and humidity on the earth's temperature have had to deal with particularly complex and contradictory interactions. While on the one hand clouds hold off the sun's heat from above, by reflecting it away, on the other they keep in the heat rising from below. As warming increases evaporation and cloud cover, clarifying which clouds do what becomes important. (Morgan and McCrystal 2009: 181-2, 202, 245).

In attempting to model more precisely these contradictory effects, a recent study of jet contrails illustrates the lengths to which climate scientists go, to add missing pieces to their jig saw. The study had been hampered by the difficulty of separating contrails from other vapour emissions in the atmosphere. The problem was resolved when they found historical records of ground temperatures beneath the flight paths of World War II bomber squadrons on clear nights (while civilian aircraft were absent). The net effect was indeed one of warming (*New Scientist*, 16 July 2011: 14).

(For an updated summary of the scientific evidence for anthropogenic climate change at regional as well as global level, see Stott et al 2010. http://wires.wiley.com/WileyCDA/WiresArticle/wisId-WCC34.html).

## V Multidisciplinarity

**Why we need co-operation of natural and social science.**

Climate scientists have been in the forefront of warning about the unprecedented scale and scope of the looming climate crisis. The long term social, economic and political risks of such climate change are also huge and some are already becoming manifest. There are many proposals and tentative (although inadequate) measures to reign in global greenhouse emissions.

The development of mitigation remedies also requires scientific and especially technical research. However understanding the forces that would help or hinder their application and implementation, and the social interests and risks they may disadvantage or favour, requires social, political and economic expertise. When it comes to devising mitigation measures, technological and scientific expertise can, for example develop fuel efficiency or electric cars. It cannot explain how and why the trend to reduced oil consumption in the 1990s was reversed by a fashion for (much more profitable) 4X4 vehicles, or why the earlier electric car models were suppressed[5].

Some sociologists, applying their expertise about media cycles or the fickleness of popular fashions, have argued that the global warming story would run its course and then fade away,

[5] The film 'Who Killed the Electric Car' documents the recall and trashing of GM's EV car in the 1990s. Average fuel efficiency in sedans had doubled by the late 1980s but the gains were cancelled by the rise of petrol guzzling SUVs. *ABC TV*, 'Background Briefing' 15 June, 2003. Since then rising petrol prices have again restored some of the earlier trend.

especially when seemingly discredited by a ‘climate-gate’ scandal, or contradicted by experience of local heavy rains or a cold winter. However, whether such interruptions to public concern are permanent will also depend on how correct is the climate science that expects continued average warming and more frequent climate related disasters. Writing in September 2011, I see no sign of the story disappearing. Multidisciplinary co-operation, in a spirit of mutual respect, is needed to obtain a complete picture.

**Natural science.**

**Searching in obscure places.** Unlike most other scientists, climatologists cannot experiment in order to separate and hold constant the multiple variables that affect the weather. Instead they have sought to collect a huge range of facts about climate averages and the range of extremes, over long periods of time and in remote places. They have developed increasingly obscure and convoluted methods, such as the examination of ocean sediments, ice cores and ancient tree rings and other sources of historic and pre-historic data to extend and refine broad understandings and expectations.

Much of what climatologists have discovered would never be visible without targeted searching in places usually inaccessible and thus not visible to society. Knowledge may also be socially available but its significance not understood except in the context of scientific knowledge. Just before the end of the century, American researchers released ice-thickness data, gathered by nuclear submarines, that the Pentagon had been sitting on for 10 years, which showed that over the previous 40 years the ice depth in all regions of the Arctic Ocean had declined by some 40 percent (Leggett 2000: 322).

**Growing scientific consensus.** As a result of the accumulating data and confidence of climate science, since the 1980s, there has been a growing world scientific consensus about the reality of global warming, its likely human causes and the long term risks and, more recently and hesitantly, about its current impacts. While in 1995 most scientists (other than specialist climate scientists) believed the effects of global warming were still far away, by ten years later only a few doubted they were already becoming manifest.

In May 2001 16 of the world’s national academies of science issued a statement, confirming that the IPCC should be seen as the world’s most reliable source of scientific information on climate change, endorsing its conclusions and stating that doubts about them were ‘not justified’. In July 2005 the heads of 11 influential national science academies of (Brazil, Canada, China, France, Germany, India, Italy, Japan, Russia, the UK and the US), wrote to the G8 leaders warning that global climate change was ‘a clear and increasing threat’ and that they must act immediately. They outlined

> Strong and long-term evidence from direct measurements of rising surface air temperatures and sub-surface ocean temperatures and from phenomena such as increases in average global sea levels, retreating glaciers and changes to many physical and biological systems (Leggett, 2005: 178).

Despite the failure of the global conference in Copenhagen (Clemencon and Carson 2010), a new push by sceptics and a public opinion distracted by problems in the global economy, no decline in concern has occurred among scientists themselves. Delegates from 62 academies to the April 2010 meeting of the Inter-Academy Panel – the global network of the world’s science academies – were asked what global issues concerned them most, ‘looking ahead to 2020’. By a substantial margin climate change ranked first among scientists from both rich and poor countries. In May 2010 a letter signed by 284 members of the US National Academy of Sciences was published in *Science* (DOI: 10.1126/science.328.5979.689) claiming that:

> There is compelling, comprehensive and consistent objective evidence that humans are changing the climate in ways that threaten our societies and the ecosystems on which we depend. Many recent assaults on climate science and, more disturbingly, on climate scientists by climate change deniers are typically driven by special interests or dogma, not by an honest effort to provide an alternative theory that credibly satisfies the evidence.... (pp689-690).

It called for an end to ‘the harassment of scientists by politicians seeking distractions to avoid taking action, and the outright lies being spread about them’.

A study by Stanford University, published in *Proceedings of the National Academy of Sciences* in June 2010, surveyed the top 100 climate researchers in the world, and found that 97 per cent of them agreed with the IPCC’s 2007 assessment of the reality and human causation of climate change.

**Sociology and climate change.**

In contrast to climate scientists, sociologists, like economists and psychologists, have generally focussed on living human beings in the present, their actions and beliefs, and how they perceive and respond to the natural environment. Their focus is directed by that of their subject matter and the question of the long term factual accuracy of these perceptions is given less attention.

**Social experience**. Most people usually rely on their own experience of local or recent weather for their future expectations. The ways in which climate change may already affect this experience, in particular places and times, can be counterintuitive – for example water flow from melting ice might in some areas produce cooling rather than warming (Monbiot, 2010); increased humidity in the atmosphere may at times create storms and floods or shift wind patterns to produce drought. Even where climate change is clearly not an initiating cause, as for example with volcanoes or earthquakes, it can intervene in ways people do not immediately understand, to produce unexpected results. A tsunami, set off by an earthquake under the sea, can be more devastating on land if it interacts with the rising sea levels caused by warmer water or melted ice. Another example is the closing of European air space in 2010, because of the threat of ash from the Eyjafjoell volcanic eruption in Iceland. It was the altered wind patterns around the North Pole, themselves probably an indirect effect of changes in the climate, which caused the ash to cross the flight paths of European air traffic. The flight paths were themselves of course social products, established by a variety of economic and political factors.

**Ignoring the issue.** For a long time social scientists were uncomfortable with engaging with any reality of nature not socially visible, or with the concerns and findings of climate scientists. I conducted a web search for the words ‘climate change’, ‘global warming’ or ‘greenhouse gas’ in articles in eight major Anglophone, mainstream sociology journals (*Acta Sociologica, American Journal of Sociology, American Sociological Review, British Journal of Sociology, Current Sociology, International Sociology, Journal of Sociology and Sociology*) as well as in the influential Marxist journal *New Left Review*, from January 2000 to mid-2005. There was not a single finding in titles or abstracts, not one article focused on the subject (Lever-Tracy 2008: 451). An updated search from mid 2005 to September 2010, found only six appearances of the terms in titles or abstracts in these seven journals.

**Ulrich Beck,** whose theory of 'risk society' as a 'second age of modernity' has been influential in sociology, hardly mentions climate change until his latest book in 2009. In 2000, despite calls for a general multi-disciplinarity, he had written of the need to challenge the 'dominance of science' and denied that scientists could be trusted to add useful knowledge about risks, asserting that '... ultimately: *it is cultural perception and definition that constitutes risk*. 'Risk' and the 'public definition of risk' are one and the same' (2000: 213. Italics and quotes in the original). This leaves little role for natural scientists in the study of risk.

In 2009 he does acknowledge that 'It requires crass ignorance or decidedly selective vision to overlook the link between an ominously rising temperature curve and increasing greenhouse gas emissions, notwithstanding the uncertainty of the correlation' (92). However, he avoids engaging with the issue too deeply by asserting (surprisingly) that 'After all, 'climate change' [Beck's quotation marks] is not yet a reality. It is a risk, something which threatens to become a reality, a future projected into the present, an anticipation bearing all the hallmarks of uncertainty...' (85). In light of his reassertion (13) of claims in his earlier books that 'the objectivity of a risk is a product of its perception and its staging' (13), one wonders what is left for climate scientists to tell us.

**Uncertainty.** Given the multiple interacting causes that determine local weather it is not hard to dismiss as 'uncertain' claims about the underlying and accumulating contribution of climate change. Much of current rising temperatures are disproportionately affecting the poles and the deep oceans, out of our sight. While impacts of climate change are already being experienced, most of the potential dangers are not yet manifest and can only be surmised from scientists' knowledge about overall climate systems or about the history of the earth or other planets. There is thus a mismatch between the long term and global sources of confidence, relied on by climate scientists, and the direct and local experience which is the subject matter of most social scientists. While trust in science may bridge this gap, it can be undermined by scepticism and conspiracy theories, especially when well funded by special interests.

**Some signs of convergence** are beginning to appear, however. In 2006 economist Nicholas Stern broke the mould with his *Stern Review* on climate change, commissioned by Gordon Brown, the British prime minister, and in 2009 Anthony Giddens did the same for sociology with his *Politics of Climate Change.* Both were significantly influenced by and respectful of the findings of the science of climate change. On the other side of the divide climatologists are now, for the first time, trying to quantify the probability of a climate change role in specific events.

Many originally tentative projections and models, speculating about future effects, have by now been verified or modified and specified more exactly by climate scientists. However, looking only at nature ignores the need for well researched projections of likely human actions and the likely impact of these on nature. On the other hand, looking only at climate change through the lens of social perception and action, ignores the growing evidence that, even in the short term, nature continues to change, in ways that are often not immediately visible, and that can be partly but never completely explained by altered social pressures. [6]

It would thus seem obvious that there should be respect, communication and indeed co-operation between social and natural scientists. Climate change demonstrates daily examples of this need for the integration of knowledge about society and nature, starting with the origins, development and impacts of the industrial age and through to the implications of finding alternatives to fossil fuel based energy.

## Conclusion

Mark Lynas was an advisor on climate change to the low lying Maldive Islands, that have begun to sink under the rising sea. In his new book *The God Species,* he writes that 'Global warming is not about overconsumption, morality, ideology or capitalism. It is largely the result of human beings generating energy by burning hydrocarbons and coal'. This problem should, he says, be disconnected from other issues, and given priority. In this case a single cause is unambiguously linked to effects which threaten the future of the planet, and our task is to choose what mix of energy sources will best reduce or eliminate these emissions and how to fund it.[7] The difficulty is with the word 'best'. While technical and scientific criteria are important, the goal will not be achievable unless global support for it can be mobilised and sustained. Even if the attitude of 'discounting the future' is recent and reversible, there

[6] For an unrelated illustration think of how the evolution of drug resistant viruses was certainly promoted by social practices such as the mass feeding of antibiotics to cattle and by the bringing into contact with each other of previously separated viruses, through globalisation of travel by human carriers. It is however clear that social scientists by themselves are ill equipped to understand the mechanisms, likelihood or outcomes of viral mutation.

[7] Cited in review by Peter Forbes, *The Guardian* 19/08/2011, p39

are limits to what most would accept in sacrificing the present. I will conclude this paper by proposing three considerations that should always be borne in mind, in addition to effectiveness and efficiency. These three may point in different directions, but finding ways to maximise reconciliation between them is essential.

**Urgency.** The longer we wait the more costly and the harder will it be to halt or reverse the damage. Stern (Aitkenhead 2009) estimates the economic cost will only rise the more we delay, and many climate scientists are fearful we might suddenly reach a tipping point, into irreversible or escalating damage[8]. There is clear evidence the process has been speeding up. Polar researchers reported, in September 2011, evidence from satellites that Arctic ice was melting faster than the record breaking speed of 2010. The researchers had no doubt that this was caused by anthropogenic global warming and not by any by any natural weather variability. Such rates indicate the Arctic could be ice free in summer well before mid century, forty years earlier than had been anticipated by the International Panel on Climate Change (IPCC) in their 2007 report (Vidal 2011). In August 2011 a crew was able to row a boat, for the first time, through clear water to the magnetic North Pole. As oceans absorb CO2 they become more acidic, and this reduces their future ability to absorb more. As ice melts the exposed dark surface ceases to reflect back the sun's rays into space. As temperature rises, forests burn and release their carbon. Such effects are particularly hard to quantify or predict and have not been factored into IPCC assessments of what constitutes a dangerous level of CO2 or of temperature (Shaw 2010).

**Long term solutions.** The future for all our descendents, and indeed for life on earth, creates an ethical imperative to work towards a long term and all encompassing decarbonisation of our production systems (Brown 2011. See Appendix). This implies that the long term effectiveness of mitigation measures becomes a paramount value and short term cost benefit analysis must rank much lower.

In the case of existing forms of fission based nuclear power for example, the absence so far of any solution to the long term disposal of large amounts of nuclear waste makes its widespread adoption probably undesirable. However, the promise of safe, cheap and unlimited fusion power (and some Gen IV fission approaches that consume their own waste) must surely be explored and demonstrated or disproved, even if such research and

[8] A recent estimate given to me verbally, by a climate expert, was that effects might move up smoothly as temperature rose by 3-4 degrees. Beyond that it could shift rapidly to 7 degrees and more, with catastrophic consequences.

development now seems costly, and an unsure outcome is likely to be delayed beyond the middle of the century.

On the other hand much focus and expenditure on carbon sequestration and ‘clean coal’, is counter indicated by what will be the long term increasing exhaustion of global coal stocks. Such a focus would divert resources from the development of longer term alternative energy solutions. Geo-engineering sunshades may temporarily cool the earth, but would allow $CO^2$ to continue rising, and contributing to yet more ocean acidification. Such sunshades would then become a permanently locked in requirement.

**Global co-operation is needed.** Climate change represents the most globalized impact of humanity on nature in our history. It is certainly also occurring in a period of unprecedented global awareness and the beginnings of planet wide attempts at mitigation. To varying degrees, all human societies contribute to the causes of global warming through emissions, agricultural and livestock rearing practices and deforestation. All will also feel the consequences, and the contributions and agreement of developed and developing countries, and of populations around the world, will be needed to prevent catastrophe.

Since all greenhouse gases combine to circulate the whole globe, there is no direct causal link or proportionality between the emissions made by one nation or group and their vulnerability to the consequences. The specific unpredictability of the timing and location of impacts is in fact a saving grace, since none can consider themselves immune or protected.

An imposed or seemingly unjust solution will lead to illegal evasion or sabotage or rebellion and a short life for the remedy. Conflict within or between countries or regions, on this issue, will undermine the universal legitimacy on which it must depend. The agreement of China and the United States as the two biggest emitters, is indispensable, otherwise everyone else will find excuses for inaction, as happened after the log jam at Copenhagen in 2009.

This may be a more important reason to reject a nuclear solution than any actual risk assessment. In Japan itself a public opinion survey conducted since the disaster found 70% opposed to the continuing use of nuclear power.

Some remedies may lead to the coming together of several ethical ends, but at other times the needs of mitigation may clash with other values or interests, which will need to be accommodated or compensated. The offer of aid for adaptation, to poor developing countries, in return for them mitigating their emissions, by reducing deforestation and using cleaner technology for their new industries, can bring convergent benefits to both sides of the bargain. The development of solar energy in the Sahara or central Australia can provide electricity and jobs for desert tribes (Lever-Tracy and Pittock 2010: 9). On the other hand, projects for massive new hydro electric projects on the Mekong or in central Africa may displace many poor peasants and flood wild habitats, and require substantial compensation to avoid undermining the unity, but still might be justified by long term climate priorities.

We can't escape all uncertainty about the scale, timing and precise location of the risks of climate change, but there can be no doubt that humans are having intolerably dangerous effects on the climate. The three primary considerations listed above will often pull in different directions. Can they be reconciled sufficiently to prevent the worst? It is, as Ross Garnaut said, 'a wicked problem'. Neither the precautionary principle nor any short term cost benefit analysis will supply ready answers, yet substantial, costly and indeed risky action must be undertaken, and preferably sooner rather than later. It must also be politically sustainable globally over the long term. Not being a gambling woman, I won't try to calculate our chances.

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**<u>Appendix</u>**.

**Have we been asking the wrong questions about climate science? Why strong climate change ethical duties exist before scientific uncertainties are resolved. (Extracts reproduced with permission of the author).**

By Donald A. Brown

The reasons why we have long ago passed a level of threshold knowledge about climate change that ethically should shift the burden of proof to skeptics... include :

1. We have known for 150 years if we add ghg to the atmosphere that there would initially be some positive forcing (that is change in the Earth's energy budget that would initially increase warming) even if we admit that we don't fully understand feedbacks quantitatively.

2. We have known since the late 1950s that ghg are increasing in the atmosphere in direct proportion to increases in human use of fossil fuel, known land use changes, and several other human activities.

3.If ghg increase due to human action, basic physics says that higher concentrations of atmospheric ghgs will cause some initial warming with high levels of confidence about what that initial forcing is. Yet because we need to understand feedbacks in the climate system before we can actually predict temperature changes at equilibrium there has been and remains some uncertainty about timing and magnitude of climate change impacts. Nevertheless, there has never been any uncertainty that if you add known amounts of ghg to the atmosphere, these gases will initially trap and re-radiate heat in a precise amount. The basic physics of this simply has never been in question in the 20th let alone the 21rst Century.

4. Every scientific attempt to define what is likely climate sensitivity since the 1960s has been in the 1.5 and 5 degree C range with upper tails sometimes reaching 9 degrees C . Climate sensitivity is the warming that the Earth will experience at equilibrium (from doubling ghg in the atmosphere to 560 ppm CO2 from pre-industrial concentrations of 280 ppm CO2) The US Academy of Science estimated in 1979 that climate sensitivity was 3 degree C. Notice we are not saying the Academy of Science proved what climate sensitivity is but claim this estimate was relevant to whether duties existed to reduce dangerous behavior.)

5. Particularly worthy of attention are attribution studies including many different types of fingerprinting studies-- all giving strong support for human attribution of climate change. The fingerprinting on the differences between the temperatures of upper and lower atmosphere, measurements of increasing absorption of and re-radiation of heat with a corresponding decline in heat leaving the atmosphere, the increase in heating in the night time compared to daytime, how oceans heat, etc. are very strong evidence of human causation. This evidence is particularly strong and led the IPCC in 1996 to conclude, the scientific community could discern the human influence on the climate system despite natural variability.

6. Most recent studies of climate change scientists that actually published research in the field conclude that above 95% agree that humans are causing climate change.

7. Most of the CO2 we find in the atmosphere we know comes from old fossil carbon not new carbon that would be driven by natural force by measured carbon isotopes.

8. Almost every major scientific organization with expertise over climate science has issued statements in support of the IPCC consensus view.

9. Also every Academy of Science in the world that has taken a position on climate change has supported the consensus view.

10. A letter from 18 scientific organizations to the US Congress says:

Observations throughout the world make it clear that climate change is occurring, and rigorous scientific research demonstrates that the greenhouse gases emitted by human activities are the primary driver. These conclusions are based on multiple independent lines of evidence, and contrary assertions are inconsistent with an objective assessment of the vast body of peer-reviewed science.(Letter to US Congress, 2009)
(See Skeptical Science, 2010, for links to all of the above)

11. Although some skeptics, playing the role that good skeptics should play have occasionally initially raised issues worthy of consideration, they have not proven in peer-reviewed literature that the consensus view is false. In fact, most of the issues initially pushed by the skeptics including such things as the claim that the upper atmospheres is warming, the sun is the cause of the problem, etc, have not withstood any serious scientific scrutiny.

12. Even though one should be suspicious of climate models because there are likely to be thresholds in the climate system that are not fully understood that could result in rapid non-linear climate response, all models indicate warming and some have been successful in making natural forcing, predicted future forcing, and observations align. (This does not prove the models are correct but simply gives reasons why they are entitled to respect) In fact the models that best predict actual observations are those that quantitatively put the natural forcings that we are aware of into the models. Again this does not prove the models should not be questioned, it simply demonstrates that their results are entitled to be respected as part of the evidence of human causation of climate change. .

13. What we know about natural forcing leads us to conclude that we should be cooling the Earth now, not heating. Yet the evidence contradicts this.

14. Although there is some possibility that we will yet discover unknown negative feedbacks in the climate system, there is at least equal, if not greatly more respectable reasons to be worried about unknown positive feedbacks that will lead to rapid, non-linear climate change outside the IPCCs quoted climate sensitivity scale. (These are simply 14 reasons among many others) for concluding that human-induced climate change is dangerous and that large emitters are putting others at risk from their behavior.

Without doubt, there is a clear scientific consensus that humans are changing the climate and threatening great harm to some of the poorest people around the world. But even if one assumes, for the sake of argument, that there is more scientific uncertainty about human causation of climate change impacts than recognized in the above statements of scientists around the world, there is a strong ethical duty to avoid the huge potential harm entailed by human-induced warming. In other words, ethics would not allow non-action on climate change simply because the potential harms have not been proven.

After reaching some level of scientific consensus that serious harms are possible, ethics would shift the burden of proof to those who want to continue risky behavior. This fact about climate change has been lost in the U.S. climate change debate (and in other parts of the world) The U.S. climate change debates have sometimes unfolded as if absence of proof equals absence of obligation. This position sometimes has been fortified by arguments that imposing the costs entailed by needed reductions of climate change emissions are great compared to dubious benefits from actions to reduce these impacts. (We will not examine here many specious ethical elements in this position but have done so many times on ClimateEthics) Yet this argument also ignores duties, obligations, and responsibilities to others that must ethically be considered in making cost arguments in support of non-action (See Ethical Issues in the Use of Cost-Benefit Analysis of Climate Change Programs)

The ethical duty to avoid risky behavior is proportional to the magnitude of the potential harm. Because climate change is likely to cause death to many, if not tens of millions of people, through heat stroke, vector borne disease, and flooding, annihilate many island nations by rising seas, cause billions of dollars in property damage in intense storms, and destroy the ability of hundreds of millions to feed themselves in hotter drier climates, the duty to refrain from activities which could

cause global warming is extraordinarily strong even in the face of uncertainty about consequences. The duty to be careful and take preventative action is particularly strong in cases where:
a) if you wait to act until all uncertainties are resolved, it may be too late.
b) The burdens of waiting until the uncertainty is resolved are most harshly felt by potential victims,
c) the victims have not consented to be put at risk, and
d) the longer one waits the more dangerous the problem becomes.
e) there is strong evidence that worse-case could be truly catastrophic for large parts of the planet.
All of these are particularly true of human-induced climate change

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http://rockblogs.psu.edu/climate/2010/07/have-we-been-asking-the-wrong-questions-about-climate-change-science-why-strong-climate-change-ethic.htm

Climate change is complex. But understanding uncertainty can help us prepare for the unknown.Â  This is also true for climate change. It is certain that climate change is happening and driven by human factors. But its inherently complex nature makes it less clear what the impacts will beâ€”including when and where they'll happen, or to what degree. The uncertainty of future climate policies, greenhouse gas emissions, complex climate and socioeconomic feedback loops, and unknown tipping points all further complicate our projections. But this doesn't mean we can't or shouldn't act to try to reduce risk. Indeed, it would be disastrous not to. Scientific uncertainty will al The steps in climate change impact and adaptation assessment are shown in figure 9.1. Several types of national health impact assessments have been undertaken. A basic assessment identifies the types, but not much about the magnitudes, of potential impacts. In contrast, comprehensive well-funded and well-supported assessments are undertaken. For example, in the United States assessment, published in 2000, population health was one of the five target sectors included in the 16 detailed regional assessments and in the overall assessment.Â  The large uncertainty surrounding these estimates was acknowledged. The main conclusions of the report were the impact of increases in river and coastal flooding, and severe winter gales.