THE SCIENTIFIC BASIS FOR SCEPTICISM ABOUT GLOBAL WARMING

Frederick C Bell BSc, MSc(Civil Eng), PhD

1.0 INTRODUCTION

As a recently retired scientist who has worked in advanced aspects of climatology and mathematical modelling, I am familiar with the scientific details of global warming*. Having been a consultant in this area in both the private and public sectors I also appreciate the dilemmas of decision-makers assigned to deal with potential problems of global warming (see Bell, 1989). Despite acknowledgement of its threats by most governments there is still much scepticism in the scientific and business communities about the significance of global warming and how much human activity has contributed to it. My aim in this paper is to review and assess the main grounds for this scepticism.

2.0 IPCC AND ITS CRITICS

The Intergovernmental Panel on Climate Change, or IPCC, has issued many documents detailing the scientific evidence and reasons for concern about global warming (see IPCC, 2007, under 'References' on page 11). Much of the evidence has been obtained from their internationally co-ordinated research involving several thousand climate scientists who have been working on the issue since the 1980s. This is now regarded as the largest non-military scientific research program ever undertaken and the authority of its findings has been accepted by an overwhelming majority of climate experts throughout the world. Nevertheless, a few climate experts and many other scientists (notably in geology and mining), together with large numbers of non-scientists, have been surprisingly critical of the IPCC and its work.

Some scientific critics of IPCC have formed a 'Nongovernmental International Panel on Climate Change' (NIPCC) and have recently issued a substantial report entitled 'Nature, Not Human Activity, Rules the Climate' (NIPCC, 2008). This explains most of the scientific reasons for scepticism about global warming. Further explanation and supporting evidence for some of the scepticism may be found in reports and books by the following authors (see 'References'):

Evans R., 2006.
Evans D., 2007
Kininmonth W., 2004
Lomborg B., 2008.
Robinson A.B. *et al*, 2007
Singer F., 2008.
Solomon L., 2008.

Most of these authors are scientists and members of NIPCC, but only two (Singer and Kininmonth) are regarded as experts in climate science.

3.0 MAJOR SCIENTIFIC REASONS FOR SCEPTICISM

It is noteworthy that NIPCC and all the above scientific sceptics actually agree with IPCC on two items: (a) the present warming trend is real, and has been occurring since 1970 or earlier, and (b) concentrations of CO_2 and other greenhouse gases in the atmosphere have continuously risen for at least 150 years. These should now both be regarded as established facts.

The most significant scientific sources of disagreement with IPCC are expressed or implied in the following statements:

1. It is futile to limit CO_2 emissions as other factors have greater effects on temperature.
2. The recent warming trend is within the variations expected from natural causes.
3. IPCC's predictions depend on unreliable global mathematical modelling.
4. IPCC's modelling does not adequately allow for the redistribution of radiated heat.
5. H_2O is a more important greenhouse gas than CO_2, and is neglected by IPCC.
6. IPCC's modelling does not adequately allow for the effects of clouds.

*The term 'global warming' is used in this paper for 'human enhanced greenhouse warming'. The term 'greenhouse warming' is used for the general or total warming effect through absorption and emission of solar energy by the earth's atmosphere, clouds and surface. This may differ from the terminology adopted in some texts and references but it is reasonably consistent with popular usage and with most of the cited references.

7. CO_2 from human activities is insignificant when compared with CO_2 in ocean and land storages.
8. Recent record-breaking extremes of cold weather refute global warming.
9. IPCC is biased towards adverse effects of global warming and ignores beneficial effects.

All these statements have some validity and collectively appear to provide a substantial basis for scepticism. Each will now be examined and discussed.

3.1 It is futile to limit CO_2 emissions as other factors have greater effects on temperature

Uncontrollable factors such as solar radiation, water vapour, clouds, and natural aerosols (from volcanic emissions, airborne soil etc) can all have large effects on global temperatures. As every climate scientist is thoroughly aware of this, however, much of the IPCC research, from its very start, has been to determine whether some of these factors may be responsible for the recent warming rather than CO_2. The data show distinctly that global temperatures from 1850 to 1970 generally tended to rise but there were several periods of cooling during that time (see, for example, Bell, 1989). These cooling periods have now all been convincingly explained by the detailed analyses of IPCC (2007, Chapter 9).

The analyses show that since 1970, only CO_2 has varied sufficiently to account for the continuing temperature rise. During this period the variations in the other factors have all been relatively small and in directions generally more consistent with global cooling than warming. The research on this particular question includes some of the most advanced scientific modelling ever undertaken. It involved ongoing studies from 31 independent global modelling centres in 12 different countries (see IPCC, 2007, Chapter 8). In every case the modelling simulations showed either no change or a small cooling trend after 1970 when CO_2 was held constant at various levels. The recent warming could be matched and explained only when the observed increasing levels of CO_2 were allowed for. Before 1970 there were significant periods of cooling and warming that could be simulated well with appropriate allowances for volcanic emissions, fluctuations in solar radiation, and increasing CO_2. Since then, however, increasing CO_2 and other greenhouse gases of human origin have clearly become the dominant influence on global temperatures.

Because many other factors have caused temperature changes in the past it is certainly possible that such factors could counteract the warming effects of CO_2 in the future. The probability of this occurring is well recognized by climate scientists, but considered small for two reasons:

- The present concentrations of CO_2 are higher than at any time during the past 800,000 years and the expected rates of temperature increase from such concentrations are now greater than any of the estimated counteracting rates of temperature change in recent millennia (IPCC, 2007, Chapter 6).
- Future persistent changes in other factors are more likely to intensify global warming than reverse it; this is inferred from research on glacial cycles indicating that global climates have not yet fully recovered from the most recent ice age and the natural factors causing the recovery are expected to maintain high temperatures for another 3,000 years or more (Petit *et al*, 1999; Epica, 2004).

Human actions to reduce CO_2 may turn out to be less successful than hoped, but there is no sound reason to assume they would be futile. If it is accepted that human actions can increase global temperatures, it is rational to assume human actions can, at least partly, reverse the effect.

3.2 The recent warming trend is within the variations expected from natural causes

There is reasonable scientific evidence to support this statement. Local and regional temperatures higher than present temperatures have been recorded at many weather stations in past times when CO_2 was considerably lower. There is also evidence that global temperatures during the 500-year 'Medieval Warm Period' from 800 AD to 1300 AD were possibly as high as today's. Sceptics have therefore concluded that (a) we should assume the recent warming is due to natural variations rather than to CO_2, (b) we should expect temperatures to eventually return to a more 'normal' state, and (c) human actions to reduce CO_2 are futile. Unfortunately, none of these conclusions is a logical consequence of the original statement, and good reasons for rejecting all three have already been given in 3.1.

As explained in 3.1, the assumption that recent warming is entirely due to natural variations has been invalidated by the findings of the large and thorough research effort for the IPCC. These findings show convincingly that human actions have changed temperatures in the recent past and are therefore capable of changing temperatures in the future. As also explained in 3.1, there is a possibility of temperatures soon returning to 'normal' levels through natural causes, but the probability is low.

Although today's temperatures may still be within the variations expected from natural causes, today's CO_2 concentration, at 385 ppm, is much greater than expected from natural causes. There is good evidence that during the past 800,000 years, the average concentration has been about 240 ppm and the highest only about 300 ppm (IPCC,2007, Chapter 3; Epica, 2004).

3.3 IPCC's predictions depend on unreliable global mathematical modelling

These days mathematical models are used for complex quantitative analyses in all advanced scientific work. Nevertheless, there are good reasons for mistrusting inexpert and indiscriminate uses of mathematical models because:

- the assumptions and conceptual simplifications necessary in most modelling are sources of error, uncertainty and bias that are often obscured by the complexities of the modelling structure;
- the outcomes of modelling may be deliberately 'fudged' by biased or marginal assumptions, and this is often difficult to detect and correct;
- the commercialization and marketing of user-friendly modelling programs have encouraged their inappropriate use by non-experts, and the many spurious and erroneous outcomes from this have tended to discredit modelling in general.

Scientists with expertise in modelling are very much aware of the above problems and the measures needed to avoid them. The modelling for IPCC is of the highest professional standard and the scientists responsible for it are unsurpassed in expertise. Knowing that the results of their particular work are confronting to many people, they have taken extraordinary measures to identify and minimize all likely sources of error, uncertainty and bias. These measures include:

- the use of 31 independently developed models in leading centres for mathematical modelling located in 12 different countries; 23 of the models are classified as AOGCMs (atmospheric-ocean general circulation models) and 8 are classified as EMICs (earth system models of intermediate complexity);
- validation and testing of every model by its close reproduction of contemporary climate changes as instrumentally recorded, and/or past climate changes as inferred from botanical and geological data (including, for EMICs, the climates of geologically recent glacial and interglacial periods);
- requiring all model parameters to have clear physical significance and values based on objective measurements or other scientific data;
- periodic scrutinising of each model by 18 'external' groups of experts not associated with any of the modelling centres, to ensure the model components are consistent with accepted physical principles and to ensure the model performance is within specified limits of accuracy in reproducing recorded and observed climate characteristics;
- open comparisons of the predictive performances of all models, detailed transparent investigations of any significant lack of concordance, and collective discourse to achieve consensus on the corrections and modifications needed to obtain reasonable compatibility of model outputs;
- frequent workshops and seminars of climate experts in different countries to examine and discuss the modelling developments at the 'component level', i.e with regard to individual processes simulated by the models and their comparative performances in particular regions of the earth.

It should be noted that each of the 31 models has been developed independently and has its own unique features. Because of the complexity and size of the global climate system, the models differ in factors such as the generalizing or grouping of processes, the time and spatial elements, and assumptions to allow for unmeasurable factors. Somewhat different outputs are therefore expected for each model, but good agreement has been obtained in the patterns and general magnitudes of output for all models.

A measure of the confidence that can be placed in the predictions of future conditions by a model is given by its success in reproducing a large range of recorded or inferred conditions of the past. By this measure, a high degree of confidence can be placed in future predictions by all 31 IPCC models. Nevertheless, the present and predicted future levels of CO_2 exceed any that have occurred in the past conditions for model testing, so some uncertainty is unavoidable in all model predictions of the future.

Despite the imperfections of mathematical models there are no other methods that could provide more reliable predictions of future climatic conditions. The essential function of modelling is to take all relevant factors into account as appropriately and objectively as possible, and there are no other satisfactory ways of doing this. In the development of models, expert decisions have to be made about what factors are relevant and the most appropriate ways of allowing for them. The IPCC has enlisted the

best people in the world for making these decisions. Although the reliability of their predictions still falls short of 100 %, the magnitude and quality of their efforts should be appreciated and respected.

3.4 IPCC's modelling does not adequately allow for the redistribution of radiated heat

Two sceptics who have made this criticism are the climatologist W. Kininmonth (2004) and solar expert D. C. Archbold (2008). The issue has revived an earlier controversy about the radiative heating effects of CO_2, following studies of seasonal fluctuations in temperature and CO_2 by C. Idso (1980). After much debate in the early 1980s, there was a general scientific consensus that Idso's claims were wrong (Schneider and Thomson, 1981, Schneider, 1984). In the more recent claims, Kininmonth considers the IPCC modelling overestimates the influence of greenhouse gases on surface temperatures by not adequately allowing for the redistribution of heat in the global circulation and convective processes. IPCC modellers have apparently dismissed this for three reasons.

Firstly, the IPCC modelling allows for the absorption, emission and redistribution of radiated heat in accordance with well established physical and meteorological principles while the suggested alternative treatments are less consistent with the principles. Secondly, the modelling cannot satisfactorily reproduce the recently recorded temperature increases (on both global and regional scales) if the influence of radiated heat from greenhouse gases is reduced. Thirdly, the horizontal and vertical temperature patterns given by the modelling show better agreements with satellite and radiosonde measurements than the patterns that would occur with the suggested alternative treatments (see Lambert, 2008).

Although the scientific basis for the criticism is not strong, it could still possibly be correct. This is because the arguments against it are not strong either, being largely dependent on the modelling itself.

3.5 H_2O is a more important greenhouse gas than CO_2, and is neglected by IPCC

Water vapour in the atmosphere is not well recognized as a major greenhouse gas but the suggestion that it has been neglected by IPCC is untrue. The small changes in water vapour that have apparently occurred on a global scale over the period of records can be very well explained as expected responses to continually increasing CO_2. It is therefore reasonable to assume the contributions of water vapour to global warming are indirect and secondary to the contributions of CO_2.

The suggestion by some sceptics that CO_2 is an insignificant greenhouse gas when compared with water vapour is misleading. The term 'radiative forcing' is used for the power (watts per square metre) of a greenhouse gas to increase the average global temperature (see IPCC, 2007, Chapter 2). By this measure, water vapour provides about 36% and CO_2 about 9% of the earth's natural greenhouse effect (Kiehl *et al,* 1997). But this is irrelevant to global warming which is human induced and results from the changes in contributing factors. Human actions directly change the CO_2 which is therefore the primary forcing factor.

In the IPCC modelling, water vapour is a variable 'feedback' component. Primary warming of the atmosphere by CO_2 increases the water vapour which then tends to further warm the atmosphere. If some of the increased water vapour condenses to form cloud, however, there may be compensatory cooling and little or no feedback effect. Although different models have allowed for these processes in different ways the overall results have generally been much the same for all models.

3.6 IPCC's modelling does not adequately allow for the effects of clouds

How to deal with the behaviour of clouds has been a controversial aspect of climate models for many years, and there is still some uncertainty about the most appropriate approach. The issue is currently receiving much attention by climate scientists and should be resolved soon (see IPCC, 2007, Chapter 8).

Depending on their altitude, depth, density and other characteristics, clouds can provide either cooling effects through the reflection of incoming solar radiation or warming effects through re-radiation of heat from the atmosphere and/or surface. The formation and properties of clouds are also complicated by interactions with aerosols, and possibly by cosmic radiation .

The IPCC models allow for these effects in a number of different ways and such treatments are now regarded as the most important source of differences in model outputs (IPCC,2007, Chapter 2). The differences are not large, however, and more refined treatments of this factor in future modelling are not expected to change any of the general conclusions and predictions.

3.7 CO_2 from human activities is insignificant when compared with CO_2 in ocean and land storages

Although this statement is correct, the large storages of CO_2 in ocean and land are not relevant to global warming. The most important factors for global warming are (a) the storage in the atmosphere, which is comparatively small, and (b) the rates of transfer of CO_2 between storages.

The statement seems to suggest that CO_2 emissions of human origin are an insignificant part of the transfer between storages but this suggestion is wrong. The present emissions of human origin are about double the net transfer rate from atmosphere to ocean and land each year, and this is why atmospheric CO_2 is continuously building up. Furthermore, the transfer rate is tending to decrease because the rate of absorption by the ocean declines as the water becomes warmer.

3.8 Recent record-breaking extremes of cold weather refute global warming

The global warming trend is expected to result in fewer occurrences of frost, snow, and cold weather and, in general, this is actually happening (see IPCC, 2007, Chapter 9). In a few places, however, recent record-breaking extremes of cold weather have occurred and these seem inconsistent with the general trend. They may be readily explained, however, as follows:

- In some regions the severity of cold weather is actually intensified by global warming because it results in increased thermal gradients and greater storm energy levels (IPCC, 2007, Chapter 8); vigorous outbreaks of cold air in violent storms therefore tend to penetrate further into temperate and subtropical areas than they would have penetrated without global warming.
- The paths and movements of severe storm systems (including those associated with extreme cold) are strongly influenced by the major patterns of ocean and atmospheric movements, notably the Thermohaline circulation (THC), El nino-Southern Oscillation (ENSO), and North Atlantic Oscillation (NAO); these patterns and their influences on storm systems are changing through global warming with the result that some severe storm systems are now occurring in areas where they were not previously recorded (see Merryfield, 2006; Wang and An, 2001).
- Very extreme events are due to rare combinations of factors, some of which are independent of global warming; such events could have occurred with or without global warming and some would have been even more severe without global warming.

Increased storm energy levels and changes in the patterns of ocean and atmospheric circulations are also changing the frequencies and intensities of other types of extreme weather. For example, there are more frequent droughts and higher bushfire risks in Australia due to disruptions of ENSO in the Pacific region (Karoly, 2001; Williams *et al*,2001). Another example is the increasing intensity of severe tropical cyclones in some coastal areas of North America and elsewhere (Elsner *et al*, 2008).

The differences between 'weather' and 'climate' are relevant to studies of extreme events. Individual occurrences of such events are studied by meteorologists and are regarded as 'weather' which is usually concerned with short-term phenomena having time scales measured in days, hours or less. In contrast, 'climate' and 'climatology' are concerned with average or normal or typical weather conditions, usually within periods of 10 to 100 years. Climatologists are therefore interested in how often extreme events occur in such periods (usually expressed as frequencies or probabilities), but regard the details of individual extreme events as relevant to meteorology rather than climatology.

As the IPCC models are climate models they do not, in general, reproduce or simulate individual weather events. A number of the models, however, can explain and predict the probabilities of weather extremes, and have been used to investigate the effects of global warming on the probabilities of extremes of low and high temperature, intense rainfall, droughts, tropical cyclones, and tornadoes. As expected, the results have been highly variable and quite different in different regions. Very detrimental effects are indicated in some regions with regard to heatwaves, droughts and cyclones but much less detrimental, and even beneficial, effects in other regions (IPCC, 2007, Chapters 8 and 9).

One of the problems with studies of extreme events is that, because of their rareness and erratic nature, most samples of data contain only small numbers of such events. This means that, although there may be substantial differences between samples, their statistical significance cannot be established with the level of certainty (usually 95%) required for scientific acceptance in this type of study. Firm conclusions about the effects of global warming on weather extremes have therefore not been issued to date by the conservative IPCC scientists, but much work is proceeding on this topic (see Elsner *et al*, 2008).

3.9 IPCC is biased towards adverse effects of global warming and ignores beneficial effects

Many beneficial effects have been identified by IPCC (see Houghton et al, 1990). The milder climates expected in parts of Canada, Russia and northern Europe should improve living conditions, increase the areas of arable land, and enable greater agricultural production in those regions. Greater agricultural production should also be possible in Mexico, Saudi Arabia, northern Australia, northern Argentina and Chile where higher and more reliable rainfall have been predicted by the modelling. Higher concentrations of CO_2 in the atmosphere are expected to 'fertilize' and stimulate plant growth throughout the world, and contribute to further increases in human food production* (see Idso and Idso, 2000).

Other benefits envisaged from global warming include:

- reduced energy requirements for heating in many countries throughout the world,
- longer ice-free periods for waterways and transport routes in higher latitudes,
- the opening of new shipping and trade routes in various places near the Arctic Circle.

From the beginning of its activities the IPCC has recognized and acknowledged all the above potential benefits of global warming. The main objectives of their climate scientists, however, have been to define the physical nature of global warming and predict the associated climate changes and general problems in different parts of the world. Detailed assessments of the economic, environmental, and social consequences of the changes, and how beneficial or detrimental they may be, have not been regarded as tasks for climate scientists, but for other professional people such as economists, agriculturalists, environmental scientists, politicians, and journalists. Many of these other people, in studying the predictions, have been shocked and alarmed by the adverse aspects which appear, overwhelmingly, to outweigh the beneficial aspects. The resulting focus, particularly in responses of the media and politicians, has been on the adverse aspects. If this has unduly diverted attention away from the beneficial aspects, the blame should be attributed more to the media and politicians than to the IPCC scientists.

Notwithstanding the above, most of the beneficial changes from global warming are likely to be more than offset by adverse changes. The expected areas of milder climate and increased agricultural production in many countries are exceeded by the likely increased areas of arid and semi-arid land in other countries as a result of climate zone shift towards higher latitudes. Also, detailed investigations for the Royal Society (2005) suggest the estimates of increased crop production from CO_2 fertilization have been exaggerated, and have ignored the likely decreases in plant growth in tropical and subtropical areas due to heat stress, effects on water and nutrient uptakes, and other factors (Reich, 2006; Chandler & Le Page, 2007). Reduced energy requirements for heating in many countries would probably be counteracted by greater energy requirements for air conditioning and cooling for the increasingly prosperous and demanding populations of India, China, Indonesia and elsewhere.

More disturbing, most beneficial effects become insignificant when balanced against the potentially disastrous effects of ocean level rise from global warming. Detailed observations and analyses have shown that such rises have been occurring since about 1920 and have accelerated to the present rate of about 2.5 mm per year (Church and White, 2006). Similar increases are occurring in the extreme high levels of storm surges and 'king' tides, with recent unprecedented damage from such events in some coastal areas. These changes in ocean levels are attributed partly to the melting of glacial and polar ice, and partly to the thermal expansion of ocean waters as temperatures increase (IPCC, 2007, Chapter 5).

From relatively simple calculations of ice-melt and thermal expansion, IPCC has tentatively predicted that ocean levels in 2100 will average between 50 cm and 80 cm higher than the 2005 levels. These are tentative predictions because the physical processes of ice-melt are complicated by multiple feedbacks such as the lubrication and transport of unstable sections, cracking and crevassing, variable albedo effects, and ablation by water and wind. Relationships between temperature change and ice-melt are therefore strongly non-linear and cannot yet be modelled in detail with a high degree of reliability. To avoid accusations of 'alarmism' the IPCC modellers have tended to underestimate, rather than overestimate,

*According to some agricultural scientists, such increases in production will actually be necessary to feed the growing world population and, if emissions of CO_2 from fossil fuels are reduced, there will be severe global food shortages by 2030 (Idso et al, 2006).

their predictions, and it is likely that the rise in ocean levels by 2100 will be higher than 80 cm. It is also likely that ice mass 'tipping points' will occur before 2100 if CO_2 concentrations are not reduced (Hansen, 2004; Church and White, 2006; Rignot *et al*,2006; Thompson *et al*, 2006).

The term 'tipping point' has been used by climatologists for a set of conditions in which a small change can trigger relatively large reactions that result in a significantly different set of conditions (see Pearce, 2008; Spratt and Sutton, 2008). Palaeoclimatological records have shown past occurrences of tipping points associated with volcanic eruptions, meteorites, and abrupt reversals of temperature during glacial and interglacial periods. As envisaged by the previously mentioned glacial experts, the possible tipping points from current global warming would result in one or both of the following :

- collapse of the extensively unstable West Antarctic ice mass, causing a rise in ocean levels of at least 5.5 metres over a period expected to be between 50 and 500 years,
- collapse of the similarly unstable Greenland ice mass, causing an additional 6.5 metre rise in ocean levels over a similar period.

Either of these events would result in inundation of many of the world's most densely populated areas, dislocating a billion or more people and eliminating much of the productive land needed to feed them. The definite possibility of such catastrophic changes is acknowledged by the IPCC (2007, Chapter 5) but with no attempts to assess their probabilities and impacts. As suggested by Hansen (2006) and mentioned earlier, continuing accusations of 'alarmism' by sceptics have made IPCC very reticent about reporting the progress of research in this politically sensitive but vitally important area.

4.0 OTHER REASONS FOR SCEPTICISM

Some other reasons for doubting global warning appear initially to have scientific justification but, on closer examination, are found to be based on misunderstandings about climate science, or based on aspects of global warming that are irrelevant to the main concerns. In many cases it is difficult to separate the scientific elements of the scepticism from economic, political, psychological and other influences. To follow are some examples.

4.1 Scepticism based on misunderstandings about climate science

Reasons for scepticism under this heading are typified by the following statements:

- human causes of global warming have not been scientifically proven;
- the IPCC modelling ignores chemical properties of CO_2;
- the IPCC modelling ignores the most important causes of climate change: solar output, continental movements, planetary orbital variations, tectonic activity and other 'great forces of nature';
- increasing global temperatures can be explained by increasing urbanisation and the 'heat island' effects expected in large cities;
- global warming could not be occurring because ice is getting thicker and places are getting colder in parts of Antarctica and Greenland.

The first of the above statements is countered by the fact that nothing is ever 'scientifically proven'. In good science, all principles, theories and hypotheses are regarded as provisional, and all may be superseded in the future when the observations are better explained by other principles, theories or hypotheses. Although for various scientific purposes a specified degree of certainty such as 95% may be required, 100% 'proof' is normally regarded as a theoretical ideal that can never be attained.

In applied sciences such as medical practice and engineering the testing of hypotheses is not usually relevant. Such sciences have specific objectives and in most cases the best available approaches to meet these objectives must be known and used, even if their reliability is considerably less than 95% (or some other ideal level). Global warming climatology is very much an applied science. The objectives are (a) to predict future global and regional climates in the light of recent trends in atmospheric CO_2 and global temperatures, and (b) identify possible problems resulting from the predictions (in general, but not in detail, as indicated in 3.9). To meet these objectives the best available approaches are selected, with recognition and allowances for their levels of reliability, but nothing needs to be 'proven'.

All the other reasons in the above list are examples of misunderstanding of climatology by other scientists. Climatologists need to analyse very complex phenomena with spatial dimensions measured in hundreds of km, and time scales measured in decades or centuries. It should be realized that the physical

behaviour of CO_2 over these scales of space and time is not directly comparable to its chemical behaviour in a laboratory with simple interactions and dimensions measured in cm and hours.

Similar comments apply to the sceptical attitudes of some geologists and mining scientists. Being so thoroughly adept with the concepts and objectives of their disciplines they do not appreciate the need for different concepts and approaches for analyses of phenomena with different time and spatial scales, and different objectives. For example, they apparently find it difficult to see how the 'great natural forces' relevant to their studies (solar radiation, continental movements, tectonic activity, earth's orbital alignment, etc) could be less important than a minor constituent of the earth's atmosphere such as CO_2. Of course the great natural forces cause the major climate fluctuations of interest to geologists, but these are over periods measured in millions of years. Over the relatively short periods of interest to climatologists, the effects of such forces are relatively constant, and lesser forces are responsible for the fluctuations and trends most relevant to the problems of global warming.

The final two reasons for scepticism in the above list are products of grossly simplistic assumptions about the science of climatology. The urban heat island effect is basic knowledge to every climatologist and appropriate corrections for it are normally made wherever necessary. This practice has certainly applied to all relevant data used for calculating global temperatures in the IPCC studies (it should also be noted that the greatest amounts of global warming have been measured in Siberia and Africa remote from all urban heat island effects).

It is also simplistic to assume that global warming means higher temperatures everywhere. Accumulating ice and decreasing temperatures in parts of Antarctica and Greenland are not inconsistent with the expected complex changes in climate interactions. In both case such effects would be due to increased precipitation (in the form of snowfall) as a result of higher evaporation and changes in the major patterns of ocean and atmospheric movements. This was explained previously in 3.8.

4.2 Scepticism based on irrelevant or minor aspects of global warming

Reasons for scepticism under this heading are exemplified in the following statements:

- life on earth has thrived in much higher concentrations of CO_2 in the past;
- polar ice floats on the ocean and whether it is liquid or solid makes little difference to ocean levels;
- global warming will not result in tropical diseases spreading into temperate areas, as claimed by IPCC, because these diseases are due more to poor living conditions than to climate;
- IPCC's claims about dangerous global warming are exaggerated as temperatures are no higher today than during the 'Medieval Warm Period' from 800 AD to 1300 AD when humans coped quite well.

The first statement above has no relevance to current global warming. To find a time of much higher CO_2 levels it is necessary to go back 56 million years to the Eocene epoch (Pearson and Palmer, 2000). At that time there were no ice caps, ocean levels were about 100 metres higher, the continental masses were in different positions, and life on earth had little resemblance to today's. Furthermore, almost all species of that epoch are now extinct. Throughout the much more recent period of human evolution and development (the Pleistocene epoch) concentrations of CO_2 have been significantly lower than today's.

With regard to the second statement, most of the volume of polar ice is not floating, but in the form of deep ice sheets on land. The three major ice sheets are East Antarctica,West Antarctica and Greenland. If the relatively unstable West Antarctica and Greenland ice sheets were to melt they would together add about 12 metres to ocean levels, as mentioned in 3.9. If the largest ice sheet, East Antarctica, were to melt it would raise ocean levels by about 70 metres. (see Hansen, 2006; IPCC, 2007, Chapter 5; Pearce, 2008; Spratt and Sutton, 2008).

The last two items in the list, on tropical diseases and the Medieval Warm Period, are both arguable and marginal issues. IPCC 's reporting and interpretations of the items were criticized by some scientists and this was given much unwarranted public attention by certain sceptics in deliberate attempts to discredit all work by IPCC. A prolonged public debate about the last item, called "the hockey stick controversy", was eventually defused by an expert scientific inquiry (see Christman and McRoberts, 2007). Both issues are quite minor aspects of global warming and no definite conclusions about either can be made with the data currently available. Whether or not these issues were correctly reported or interpreted by IPCC has no relevance at all to their main findings and recommendations.

4.3 Influence of economic considerations on scepticism

In discussions of global warming, former NSW Premier Morris Iemma was reported as saying (quite seriously) "there is no point in saving the planet if we ruin the economy doing it" (The Land, 2006). Not only does this assert that 'the economy' is more important than the consequences of global warming but the words 'saving the planet' tend to trivialise and fictionalise global warming with storybook and impersonal connotations. 'Protecting our children and grandchildren' would have been more realistic and honest than 'saving the planet', but would have weakened his rhetoric. It could also have weakened confidence in his government's resolve to satisfy the short term lifestyle expectations of NSW residents.

There is no denying that almost every aspect of our present lifestyles and material welfare is strongly dependent on the cheap and convenient energy provided by coal and oil. To try to change this quickly, as advocated by some global warming activists, would undoubtedly risk economic disruption and social turmoil, especially in coal-dependent NSW. Mr Iemma's short-term economic policies would aim to avoid such risks and his expressed attitude to global warming was consistent with this aim. Nevertheless, such an expression contributes to global warming scepticism, whether intended or not.

Much the same would apply to other political and business leaders throughout the world. They must give short-term economic objectives higher priorities than global warming objectives because of the realities of electoral and customer expectations and competition. These leaders are influential people whose attitudes, values and priorities are readily accepted and adopted by others. Their assignment of priorities does not necessarily mean they are all global warming sceptics, but their emphasis on short-term economic objectives is easier to justify with global warming scepticism; and vice versa.

Many scientists are amongst the people whose attitudes towards global warming have been influenced by economic considerations. Those in industries directly threatened (for example, by proposed carbon reduction measures) are aware of the possible economic implications of global warming to themselves, and have strong vested interests in finding good reasons to deny or doubt it. These personal motivations are stimulated and supported by the industry establishments, as exemplified by the widely reported scientific research sponsored by the energy industries to disprove or obscure global warming evidence (see Hamilton, 2007). Such sponsored work is the origin of some of the discredited reasons for scepticisms discussed previously.

Although it seems necessary for present lifestyle expectations and economic activities to change because of global warming, in the longer term such changes need not result in economic 'ruin' or social detriment. As suggested by Jochem and Madlener (2003), people who refer to the 'great cost' of mitigation measures usually fail to allow for the potential benefits of change. Also, they do not fully recognize that the consequences of not making the changes will almost certainly be worse.

The changes that seem necessary to mitigate global warming may also be necessary to forestall more immediate global problems, and to maintain longer term sustainability (see Beder, 1996). There is growing recognition that global warming is only one of a number of potentially disastrous global problems with apparently common and interrelated causes. These include the approaching, more immediate problems of widespread food, water and energy shortages, continuing threats of terrorism and war, highly organized global crime, and persisting global economic instability. The apparent common and interrelated causes are the physical limitations of global resources, continuing population growth, economic globalization, culturally-induced 'consumerism', and thwarted demands for equity within and between countries (see Leeb and Strathy, 2007; Large and Sisk, 2007; Glenny, 2008; Patel, 2008; Barlow and Clark, 2008). Proposed common solutions involve cultural changes to (a) reduce materialistic goals and (b) promote concepts of human progress in terms of social responsibilities, social harmony and stability. If appropriately implemented, such changes would mean less affluent lifestyles for many people, but with general benefits that should include more leisure and social time, better physical and mental health, longer life, greater personal safety, and positive feelings of confidence about the future (see Trainer, 1985; Hamilton, 2003; Hamilton and Denniss, 2005; Bell, 2008).

4.4 Influence of ideology and other factors on scepticism

The need to address and modify the direct and indirect causes of global warming is difficult to reconcile logically with the prevailing economic ideology that favours continuing economic and population growth, and the minimization of government controls. This difficulty seems to explain why so many mainstream economists were sceptics and deniers of global warming before 2007. More recently, however, increasing numbers of economists have accepted global warming as a reality, although there are still difficulties in

reconciling it with mainstream ideology. Evidently the major reasons for the change are authoritative reports by respected economists Sir Nicholas Stern (2006) and Professor Ross Garnault (2008). Both experts, after thoroughly investigating the available information, agreed that global warming is indeed a serious problem requiring urgent action, and that there are no reasonable grounds for denial or scepticism.

Following their professional advisors, politicians have also adopted mainstream economic ideology and their attitudes to global warming have been similarly influenced. Thoroughly indoctrinated politicians, such as George Bush and John Howard, have been notably indifferent towards global warming, and have been willingly duped by the energy industries into opposing or indefinitely delaying mitigation measures. Large numbers of other right-leaning people have become committed sceptics, influenced irrationally by the fact that their political opponent, Al Gore, has vigorously promoted global warming action.

Another source of irrational scepticism is the 'shoot-the-messenger' syndrome which occurs when unwelcome information causes anger that is directed back at the people delivering the information. This has probably contributed to, or amplified, some of the previously discussed expressions of scepticism. One form of 'shoot-the-messenger' syndrome with potentially dangerous consequences, is the labelling of climatologists 'alarmists' (mentioned previously in 3.9). Such taunts are particularly distressing to scientists who are trained to be scrupulously objective and honest in their work, and whose reputations depend on these qualities. The IPCC scientists have consequently become unduly conservative in the reporting of very adverse findings, increasing the risk that the most serious problems will not be adequately recognised until it is too late to take effective action.

Attitudinal and psychological sources of scepticism appear to drive some people to seek and defend scientific support for their positions, no matter how weak or wrong. These sources of scepticism would include intuition, aversion to pessimism, irrational optimism, defending prior commitments, and mistrusting anything not understood. All are beyond the intended scope of this paper.

5.0 SUMMARY AND CONCLUSIONS

Many of the reasons given for scepticism about global warming appear initially to be scientifically sound, but closer examination reveals them to be irrelevant or inappropriate. The following reasons for scepticism, however, cannot be completely dismissed and should be given some recognition:

- global warming is likely to be counteracted or reversed by a decline in solar radiation, the eruption of one or more very large volcanoes, or some other unforeseen cataclysmic occurrence (see 3.1);
- the predicted higher temperatures will fail to occur because all 31 models have underestimated the redistribution of heat reradiated from greenhouse gases (see 3.4);
- global warming will be counteracted or reversed by extensive and persistent cloud cover in negative feedback effects grossly underestimated by the 31 models (see 3.6).

Although these are definite possibilities, the probability of any one or more applying within the next 100 years would be low (< 10%), as inferred from a number of investigations .

Some scepticism is based on the fact that global temperatures and some other climate elements are still generally within the expected ranges of natural variability. The present atmospheric concentration of CO_2, however, is well beyond the expected natural range. It is about 50% higher than the average during the past 800,000 years and 25% higher than the maximum during that period.

Many sceptics are critical of IPCC's findings because of their dependence on mathematical modelling which is regarded as unreliable. Most of these sceptics seem unaware that the modelling is only one part of an enormous international research effort by the world's leading climate scientists. The modelling is also the most advanced, non-military modelling work ever attempted, and IPCC have taken extraordinary measures to minimise errors and uncertainties. With 31 different, independently developed models, and a large team of experts scrutinizing the highly transparent operations and outputs, no better approach could be expected or envisaged.

Some scepticism seems to be supported by recent occurrences of record-breaking extremes of cold weather and increased ice build-up in certain places. Such occurrences are not unexpected by climatologists and may be readily explained as the consequences of patterns of air and water circulation disrupted by global warming. Higher precipitation and severe storms with cold air outbreaks are therefore occurring now in some areas where they were not previously experienced. The intensification of storms and other weather extremes is also occurring because of the increased thermal gradients and higher energy inputs produced by global warming.

IPCC has been criticized for emphasizing the adverse effects of global warming and giving little attention to the beneficial effects. It is true that the climates of cold countries such as Russia and Canada could improve with global warming but all the beneficial effects are insignificant when balanced against the potentially adverse effects. The worst of these is the risk of a disastrous collapse of the unstable Greenland and/or West Antarctic ice masses. Either occurrence would result in the inundation of many of the world's most densely populated areas, dislocating a billion or more people and eliminating much of the productive land needed to feed them.

Much of the scepticism expressed by scientists, economists, politicians and others is not based on science but is generated by economic, political, psychological and other concerns. In particular, the mitigation measures that seem necessary to address global warming are difficult to reconcile with mainstream economic ideology. As the measures appear to require significant industrial and social changes there are fears that they would result in 'economic ruin'. The consequences of not making the changes, however, are likely to be worse. Furthermore, if appropriately implemented, the benefits from the changes could include the forestalling of related, more immediate global problems, namely widespread food, water and energy shortages, continuing threats of terrorism and war, highly organized global crime, and persisting global economic instability.

REFERENCES

Archibald D.C., 2008. *Solar Cycle 24.* International Conference on Climate Change, March 2004, Heartland Institute, Chicago (30pp).

Barlow M. and Clarke T., 2008, *Blue Covenant: The Global Water Crisis and the Coming Battle for the Right to Water*. New Press (288 pp).

Beder S., 1996 (2nd edn). *The Nature of Sustainable Development.* Scribe Publications (311pp).

Bell F.C., 1989. *Possible Climate Changes Relevant to Electricity Generation in New South Wales,* Consultants' Report, University of New South Wales (47 pp).

Bell F.C., 2008. *Introducing Pronomics (Applied Sustainability Science)* http://pronomics1.com/

Chandler D. and Le Page M., 2007. Climate myths: higher CO_2 levels will boost plant growth. *New Scientist,* 16 May, 2007.

Christman M.C. and McRoberts R.E., 2007. Notes from the Chair. Notes from the Editor. *American Statistical Association Newsletter,* Vol 9, no.1 (Spring 2007).

Church, J.A., and N.J. White, 2006: A 20th century acceleration in global sea-level rise. *Geophys. Res. Letters*, 33, L01602.

Elsner J. B., Kossin J.P., and Jagger T.H., 2008: The increasing intensity of the strongest tropical cyclones,.*Nature*, 455: pp 92-95.

Epica (Augustin et al), 2004. Eight glacial cycles from an Antarctic Ice Core, *Nature* 429: 623-628.

Evans D., 2007. *I was on the Global Warming Gravy Train.* Ludwig von Mises Institute, http://mises.org/story/2571

Evans R., 2006. *Nine Lies About Global Warming.* The Lavoisier Group (13 pp).

Foukal P., Fröhlich C., Spruit H.and Wigley T.M.L., 2006, Variations in solar luminosity and their effects on the earth's climate. *Nature* 443: 161-166 (September 2006).

Garnaut R., 2008. *The Garnaut Climate Change Review* (Draft). Commonwealth of Australia (530pp).

Glenny M., 2008. *McMafia: Crime without Frontiers.* The Bodley Head Ltd (432 pp).

Hamilton, C., 2003. *Growth Fetish*. Allen and Unwin (262 pp).

Hamilton, C., 2007. *Scorcher: the dirty politics of climate change*. Black Inc (266 pp).

Hamilton, C. and Denniss, R.,2005. *Affluenza.* Allen & Unwin (224 pp).

Hansen J., 2004. Defusing the global warming time bomb. *Scientific American*. V.290 No.3 68-77.

Hansen J., 2006. Scientific reticence and sea level rise. *Environmental Research Letters 2*.024002.

Houghton J.T., Jenkins G.J., and Ephraums J.J.,(Ed), 1990. *Climate change. The IPCC scientific assessment.* Cambridge U. P. (365 pp)

Idso C. and Idso K., 2000. Forecasting World Food Supplies: the impact of the rising atmospheric CO_2 concentration. *Technology* 7S: 33-56.

Idso S., 1980. The climatological significance of a doubling of earth's carbon dioxide concentration, *Science* 207: 1462-1463.

Idso S., Idso K. and Idso C., 2006. Can the world produce 40% more rice by 2030 ? CO2 Science, *Vol 9 No 9*, March 2006.

I.P.C.C., 2008 (Intergovernmental Panel on Climate Change), *Climate Change 2007,* 4th Assessment Report,WMO (Geneva).
Jochem E. and Madlener R., 2003. *The Forgotten Benefits of Climate ChangeMitigation: Innovation, Technological Leapfrogging,* OECD Publication (25 pp).
Karoly D., 2001. *Understanding the Climate of Australia and the Indo-Pacific Region*. Research Report No. 84, pp 49-52. Bureau of Meteorology, Australia.
Kininmonth W., 2004. *Climate Change: A Natural Hazard,* Multi-Science Publishing (310pp).
Kiehl J.T. and Trenberth K.E., 1997, Earth's Annual Global Mean Energy Budget, *Bulletin of the American Meteorological Society*, 78:2 197-207
Lambert T., 2008, http://scienceblogs.com/deltoid/2008/07/the_australians_war_on_science_16.php.
Large J. and Sisk T.D., 2007, *Democracy,Conflict and Human Security.* International Idea (244 pp).
Leeb S. and Strathy G., 2007, *The Coming Economic Collapse,* Business Plus, USA.(224 pp).
Lomborg, Bjorn, 2008. *Cool It: The Skeptical Environmentalist's Guide to Global Warming, Vintage Reprint,* (272 pp).
Merryfield W., 2006. Changes in ENSO under CO_2 doubling in a Multimodel Ensemble, *Journal of Climate* Vol 19 No 16 p.86.
N.I.P.C.C., 2008. (Nongovernmental International Panel on Climate Change), *Nature, Not Human Activity, Rules the Climate,* F.Singer (ed), The Heartland Institute (50pp).
Patel R., 2007, *Stuffed and Starved*. Portobello Books P/L, (438pp).
Pearse F., 2008. *With Speed and Violence: why scientists fear global warming.* Bacon press (304 pp).
Pearson P.N. and Palmer M.R., 2000. Atmospheric carbon dioxide concentrations over the past 60 million years. *Nature* 406: 695-699.
Petit, J. R. et al., 1999. Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica. *Nature* 399, 429–436.
Reich P., 2006. Higher carbon dioxide & lack of nitrogen limit plant growth. *Science News.* (April 13).
Rignot E., Bamber J. & 5 others, 2008. Recent Antarctic ice mass loss from radar interferometry and regional climate modelling. *Nature Geoscience.* 102 (13 January).
Robinson A.B., Robinson N. E. and Soon W. 2007, Environmental Effects of Increased Atmospheric Carbon Dioxide, *Journal of American Physicians and Surgeons* 12: 79-90.
Royal Society, 2005. *Food Crops in a Changing Climate.* Royal Society Policy Document 10/05 (15pp).
Schneider S.H., 1984. *The Coevolution of Climate and Life.* Random House (563 pp).
Schneider**,** S.H. and Thompson S. L.,1981**,** Atmospheric CO2 and climate: Importance of the transient response,. *J.Geophys. Res.* 86: 3135-3147.
Singer F., 2008. *Unstoppable Global Warming: Every 1,500 Years.* Rowman & Littlefield, (264 pp).
Solomon, Lawrence, 2008. *The Deniers,* Vigilante Books (240 pp).
Spratt D. and Sutton P., 2008. *Climate Code Red*. Scribe (304 pp).
Stern N., 2006, *The Economics of Climate Change.* Cambridge U.P. (689pp).
Trainer F.E., 1985. *Abandon Affluence !* Zed Books Ltd (308 pp).
The Land, 2006. Article on Morris Iemma, 28/08/06, page 24 (Fairfax Newspaper, Richmond NSW).
Thompson L., Mosley-Thompson E. & seven others, 2006. Abrupt tropical climate change: past and present.*Proceedings of National Academy of Sciences of USA*, 103: 11437-11439 (July 25).
Wang, B. and An S., 2001: Why the properties of El Niño changed during the late 1970s. *Geophys. Res. Lett.*, **28,** 3709–3712.
Wikipedia, 2008. *Scientific Opinion on Climate Change.*
Williams A.A., Karoly D.J. and Tapper N., 2001. The Sensitivity of Australian Fire Danger to Climate Change. *Climate Change*, 49: 171-191.