The impacts of climate change

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Introduction

1. I was educated at UCT in chemical engineering, graduating with a PhD in 1961. In 1962, I did doctoral studies in nuclear physics at MIT via an International Atomic Energy Agency fellowship. From 1965 to 1967, I worked for the SA Atomic Energy Board at their Extraction Metallurgy Division at the University of the Witwatersrand. In 1967, I joined the Metallurgy Laboratory at the Chamber of Mines Research Organisation in Melville, Johannesburg, and in due course became its Director. In 1983, I joined Murray and Roberts as Director of Engineering Management Service. In 1988 I moved to EL Bateman, first as Technology Manager, and then as Director of Industrial & Petrochemical Consultants [IPC]. In 1994, I resigned and bought IPC, of which I am still owner and director. Also in 1994, I was appointed Professor in Environmental Chemical Engineering at the University of the Witwatersrand. In 1999, I moved to University of Cape Town and became a Senior Research Fellow in the Energy Research Centre. In 2009, I became Adjunct Professor in the Energy Institute at the Cape Peninsula University of Technology [CPUT]. In 2017, I also became an Adjunct Professor at the Beijing Agricultural University.
2. I am a Fellow and Past President of the SA Institution of Chemical Engineers; a Fellow and past Gold Medallist of the SA Institute of Mining and Metallurgy; an Honorary Fellow of the SA Academy of Engineers; and a Member of the SA Chemical Institute. Awards have included being one of Four Outstanding Young South Africans (1976), a certificate recognizing my contribution to the award of the Nobel Peace Prize to the Intergovernmental Panel on Climate Change [IPCC] (2007); Annual Energy Award, SA National Energy Association (2010); and Africa Intellectual of Year, Conrad Gerber Foundation (2012). I presently serve on the Energy Committee of the Council of Academies of Engineering and Technological Societies and on Working Groups 1 and 2 of the International Standards Organisation Technical Committee 285, Clean Cookstoves
3. I have been involved in the study of climatology since 1994. I have contributed several professional papers on the topic, probably the most important of which was "An estimate of the centennial variability of global temperatures." *Energy & Environment*, 26(3), pp. 417–424, 2015 which, according to *Academia,* had had over 900 downloads by February 2017. It provided an answer to how much of the observed warming was likely to be natural in origin. I was a Co-ordinating Lead Author for the IPCC Special Report on Carbon Capture and Storage (2004) and a Reviewer for the Third and Fourth IPCC Assessment Reports. I have lectured extensively on climate change in both academic and open public circles.
4. I have been requested by the owners of the Colenso Power Station Project to assist them in providing input into the assessment of the climate change impacts that may possibly arise from the implementation of the Project.

Climate Change

5. There are two definitions of climate change employed in the official literature[1]:
    a. Climate change in IPCC usage refers to any change in climate over time, whether due to natural variability or as a result of human activity.
    b. Climate change in the United Nations Framework Convention on Climate Change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods.
6. Because any impacts of climate change are very difficult to attribute to human activity *a priori*, I shall employ the IPCC definition to establish a baseline of climate change against which any future changes which might be caused by the Project may be measured.
7. Webster's *New Twentieth Century Dictionary* defines climate as "The prevailing or average weather conditions of a place, as determined by the temperature and meteorological changes over a period of years". Note the recognition that the weather is constantly changing, and that it is possible to average those changes over many years to determine the climate of a place. This in turn implies that it is necessary to determine the average over many more years to be certain that the climate is indeed changing.
8. Figure 1 shows two measures of changes in global temperatures[2]. The first is the HADCRUT 4 series, showing "temperature anomalies" for the globe on a basis of the 1960-1990 average temperatures. A temperature anomaly is the difference between the average temperature ((maximum + minimum)/2) at that place on a given calendar day and the temperature on that day averaged over the period 1960-1990. The second is the UAH 6 satellite estimate of the temperature of the troposphere, where the baseline is the 1981-2011 average temperature. Because the comparison is between anomaly values, the change of baseline period has no impact.

Temperature anomaly, deg C

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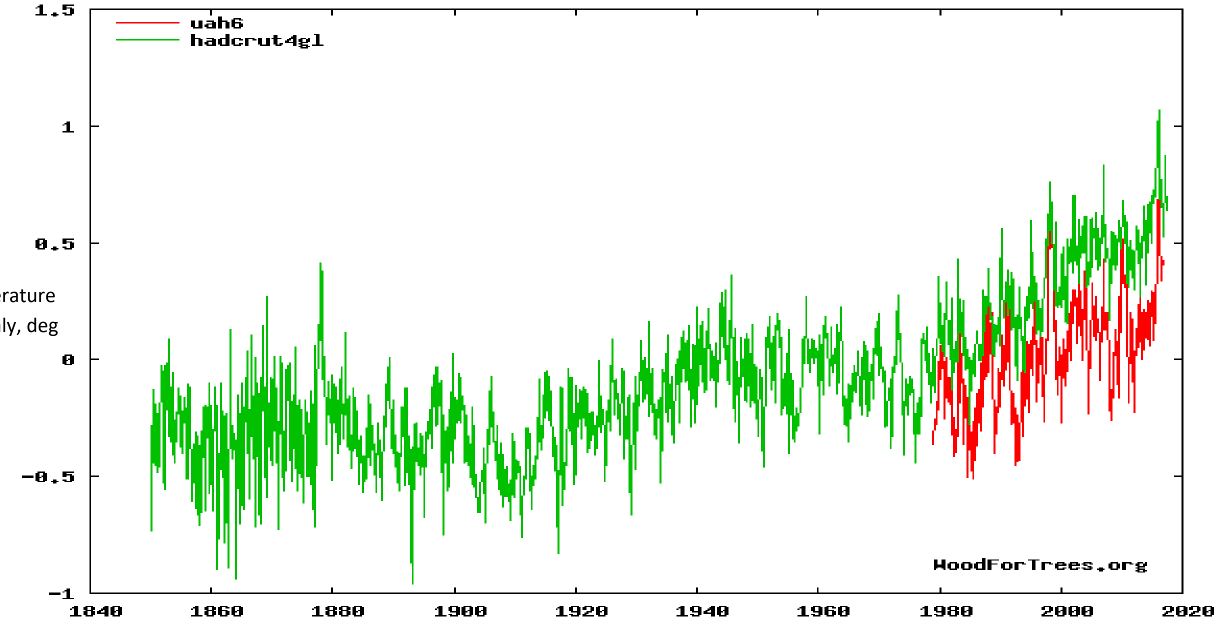

Figure 1 Comparison of global measurements of temperature (HADCRUT) and satellite (UAH)

9. While the data of Figure 1 appear to show a strong warming trend, some caution is essential. First, it has to be recognized that the annual variation in temperature, between the warmest summer's day and the coldest winter's night, is of the order of 20°C. It is less in the tropics, and more in the high latitudes and mid-continent. Figure 2 illustrates the annual range for a temperate southern-hemisphere city (Cape Town).

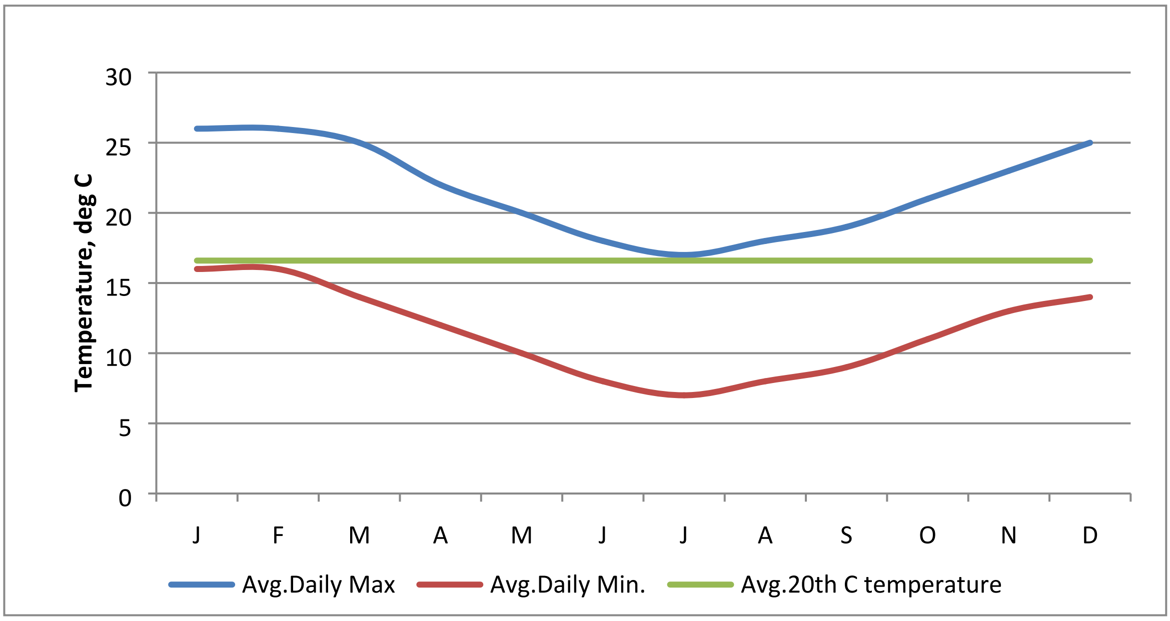

Figure 2 The diurnal and seasonal change in Cape Town temperature.

Figure 1 can be replotted on a scale comparable to the diurnal and seasonal variation, as shown in Figure 3.

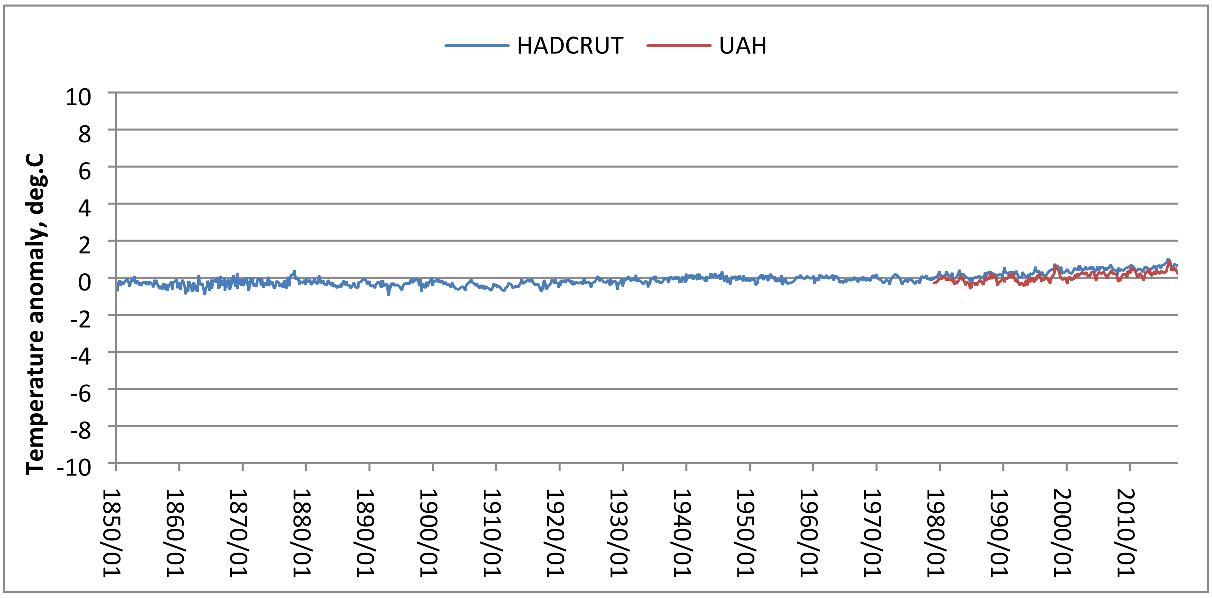

Figure 3 Replot of average global temperatures on a scale comparable to seasonal changes

There is thus evidence that the world has warmed since 1850, but the extent of warming is scarcely detectable compared to natural variation in temperature.

10. Secondly, the sheer difficulty of estimating an average global temperature has to be noted. There are several thousand measuring stations around the world, both on land and at sea. It is challenging to obtain a consistent set of measurements at all of these stations all of the time. There is a good description of the land-based challenges in Jones et al[3]:

"The most important causes of inhomogeneity are (1) changes in instrumentation, exposure, and measurement technique; (2) changes in station location (both position and elevation); (3) changes in observation times and the methods used to calculate monthly averages; and (4) changes in the environment of the station, particularly with reference to urbanization that affects the representativeness of the temperature records. All of these have been discussed at length in the literature."

By "inhomogeneity" the authors mean the effects of the cited changes. In some cases of missing data, data from nearby stations are used to estimate the missing data. "Nearby" in this context weights stations according to their proximity to the station that is missing data. The weighting function drops off with distance, reaching zero at 1200km

11. There are various homogenizing processes used by different groups. The first step is usually taken by the Global Historical Climate Network [GHCN] maintained by the US National Oceanic and Atmospheric Administration [NOAA], which gathers data from several thousand land-based stations around the world. This step is not without challenges, which may be illustrated by the data for Cape Town[4], shown in Figure 4.

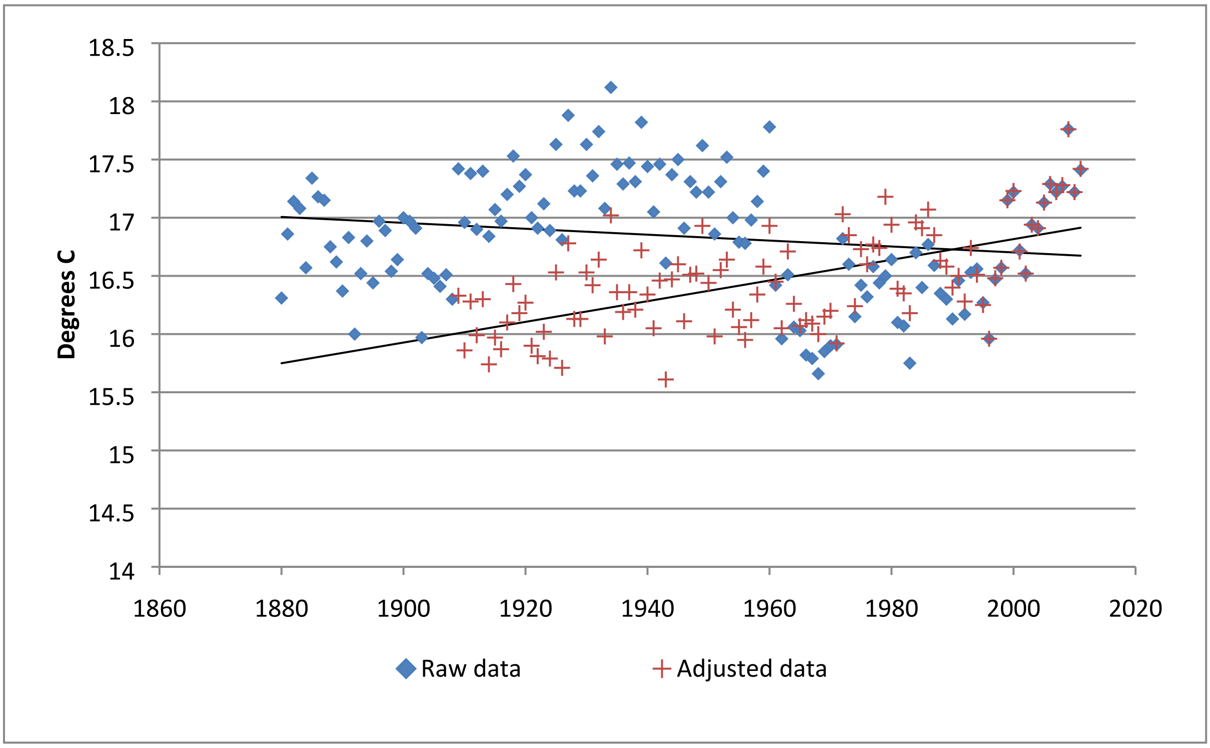

Figure 4 Raw data for Cape Town and data homogenized ("Adjusted") for GHCN V3.

All the raw data before 1910 was ignored. No reasons have been given for this. All the data between 1910 and 1960 was adjusted downwards by 1.2°C. This is apparently because the station was moved from the South African Observatory to the Cape Town airport. There appears to be a statistically significant break in the data when this occurred. However, the Observatory site is on a river delta close (2.6km) to a cold sea, whereas the airport is in a dry, sandy area 9.5km from the nearest sea, and is generally warmer, not cooler than the Observatory site. It is therefore unlikely that the artificial adjustment of the Observatory data to make it cooler than the airport data is valid.

13. This is a general problem with the "official" temperature records – historical data are being changed. In one well-documented investigation[5], the monthly records of the global temperature anomaly were altered eight times between 2010 and 2015. The total effect of the changes is illustrated in Figure 5:

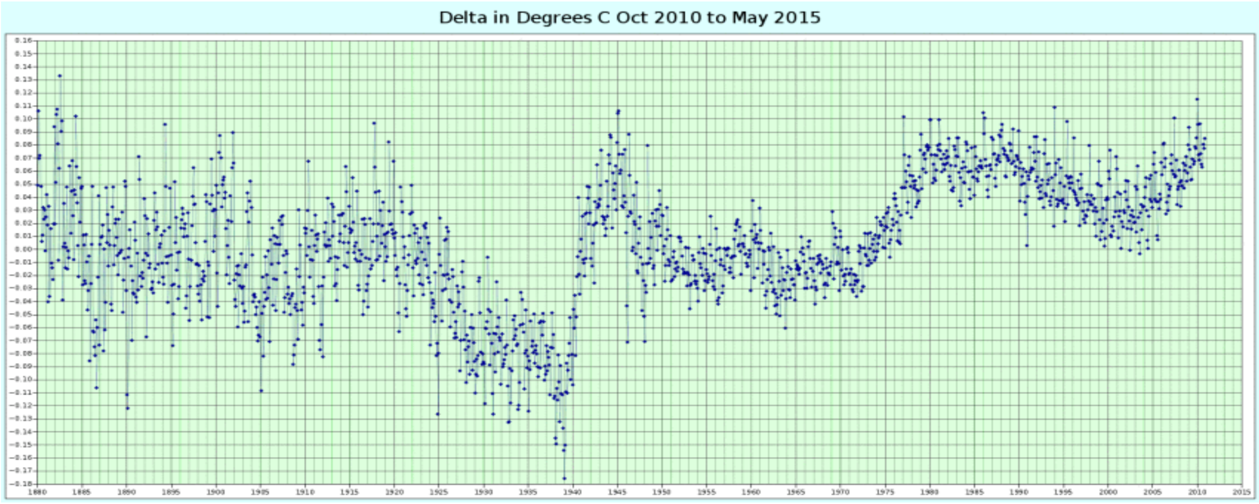

Figure 5 Cumulative changes in NOAA historical data between 2010 and 2015

Some of the 1880's data was increased by as much as 0.13°C over this period, while some of the 1940's data was decreased by 0.18°C. It is difficult to find a rational explanation for the need to make changes to historical data in this way.

14. Because these changes to historical data are difficult to justify, there is a high level of scepticism in many scientists about the true extent of global warming. There is reasonable agreement that there has been warming since the mid-1970's, but no agreement on the magnitude of such warming.

15. Fig.6 shows the same basic record as Fig.1, published by the IPCC in its First Assessment Report[6]

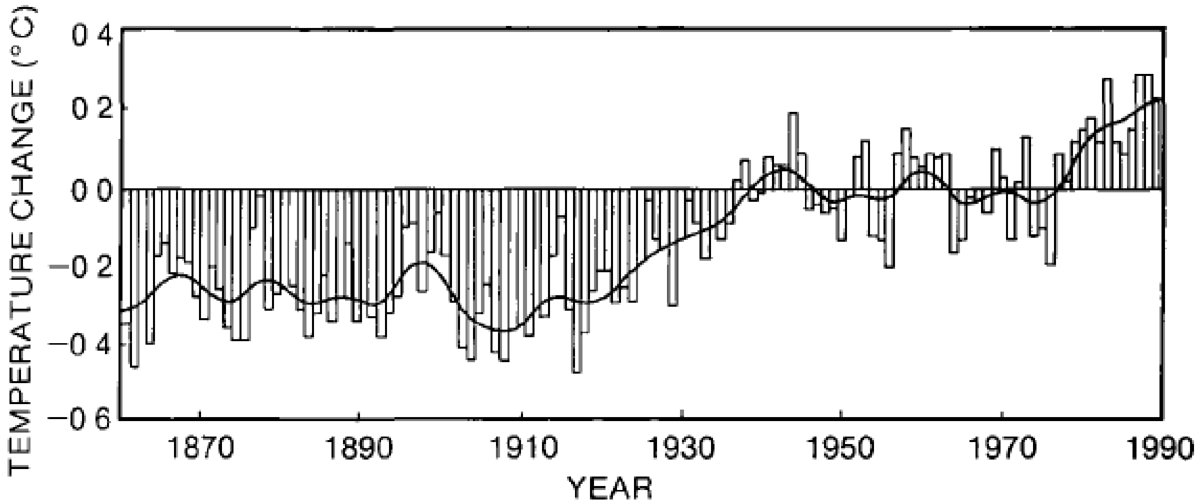

Figure 6 Global temperature record as published in 1990

This should be compared to Figure 1. There are many differences, but the most striking is probably the change of scale. Figure 1 is from -1.0 to +1.5°C; Figure 6 from -0.6 to +0.4°C. This is probably due to the cumulative effect of the "homogenization" of the raw data, which has consistently cooled the past.

16. There are, of course, signals of warming other than thermometers. The Arctic ice, for instance, appears to be less in area year by year, but the Antarctic ice is growing both in thickness and extent except in a few regions of the continent. Many glaciers are retreating, but as they do, they are revealing that they had been growing until recently. For instance, plant remains have been exposed that have been dated to a thousand years ago[7]. There are reports of plants blooming earlier in the year than they used to, but I have not been able to find hard scientific evidence to support this.
17. The oceans appear to be warming. I say "appear" because measuring the temperature of the oceans is even more challenging than measuring the temperature of the land. Over the first few hundred metres of depth, the temperature drops off rapidly. Then it reaches about 4°C, after which it cools very slowly. The depth at which it reaches 4°C varies with the season, and may also change with changes in currents and even with wind conditions over the ocean. Most measurements are made on the surface water. What is "surface" varies according to the measurement method used, but ranges from 1 millimetre to 20 metres depth.
18. For a long while, ocean surface temperatures were determined from ships, using a bucket to take a sample. However, careful experiments showed cooling took place by evaporation in the time between taking the sample and measuring the temperature. The rate of cooling varied with the material from which the bucket was made. In the 1960's, the temperature started to be measured at the intake of water for cooling the engine, but this was found to bias the temperature about 0.6°C high due to heat from the engine. Since the 1980's a fleet of buoys has been deployed around the world with a temperature measured at 3m depth, and radioed to a recording station. More recently, buoys that rise to the surface then fall to 1000m depth before returning to surface have been used to take temperature profiles. Satellite measurements are reported, but these reflect only the temperature of the uppermost millimetre, which correlates poorly with the measurements at depth.
19. From this discussion, it is clear that absolute measurement of ocean temperatures is very difficult. This needs to be born in mind when assessing the IPCC records[8] shown in Fig.6. All the data before 1960 has been warmed to correct for evaporative cooling. All the data from 1960-mid 1980's has been cooled to correct for warming from the engines. The only raw data is that from the mid 1980's until the present.

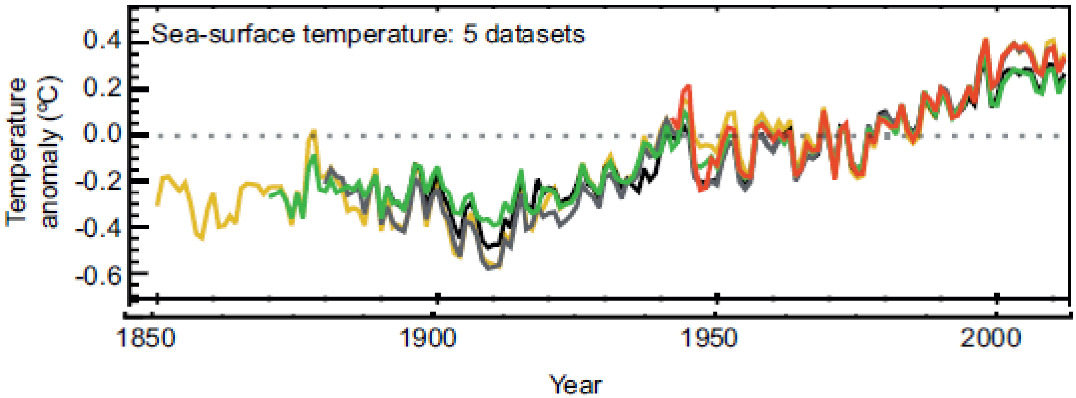

Figure 7 Sea surface temperature records

So when the IPCC says: "It is virtually certain that the upper ocean (above 700 m) has warmed from 1971 to 2010, and likely that it has warmed from the 1870s to 1971" (Ref.6, p38), it is essential to treat the statement with caution. Figure 7 shows the sea surface temperature, about 3m deep, not the temperature averaged to 700m. The warming, relative to a 1960-1980 baseline is about 0.3^{o}C, but much of the data over the period 1960-1980 has been manually adjusted downwards by about 0.6^{o}C. It is **not** "virtually certain" that the sea surface has warmed. A very recent finding [9] is that the total warming over the past 50 years is about 0.1^{o}C.

20. An unanswered question is why there are signs of global warming. One possibility is that the global thermostat is imperfect, and that there are natural variations. Certainly, on long timescales there are massive natural variations.

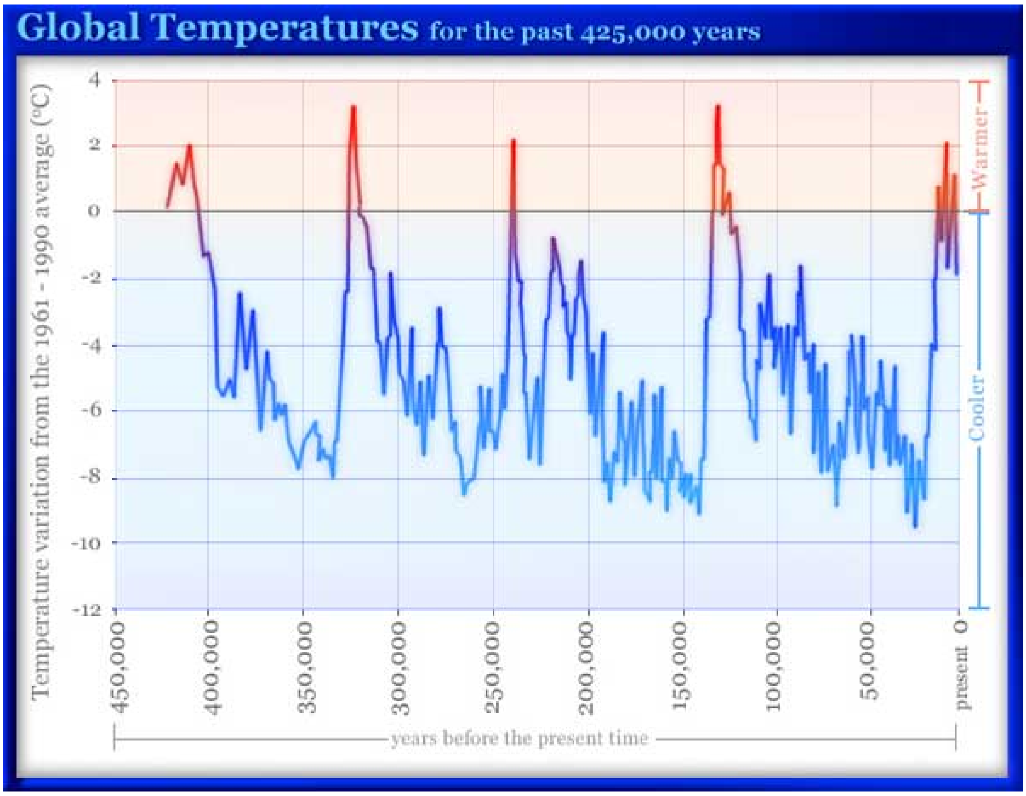

Figure 8 Variations in temperature over past 450 000 years

During the past 450 000 years there have been four cycles where the world warmed rapidly from about 10^{o}C colder than today, stayed warm for about 10 000 years, then drifted back to a glacial state for about 120 000 years. We are presently in one of the interglacial states, having emerged from the previous ice age about 11 000 years ago.

21. We know this because of the ice caps over Greenland and Antarctica. Holes drilled into this ice show layers of dense and less dense ice. The denser layers arise from the melting of the ice during summer sun; the less dense ice comes from the compression of unmelted winter snow. It is therefore possible to tell the age of the ice at a certain depth by counting the number of layers above the layer of interest. There are various ways to estimate the temperature when the ice was formed. The most popular uses the amount of deuterium in the water. Deuterium is a heavy isotope of hydrogen. Water made of deuterium evaporates slower than water made of hydrogen, so the amount of deuterium in a sample of ice is a good guide to the temperature when it was formed.

22. I studied[10] how the temperature changed in samples about 100 years apart, from four ice cores. There were about 700 such pairs over the past 8200 years – about 8200 years ago there was a sudden cooling and change of climate for about 400 years[11]. During the past 8200 years, the standard deviation of the temperature change over a century was 0.98±0.20^{o}C. In layman's terms, this means that there is about a 95% chance that, over a century, the temperature will vary by less than ±2^{o}C. In practice, (see Fig.1) the temperature over the past century has changed by about +0.8^{o}C. This is well within the ±2^{o}C expected from the behaviour over the past 8200 years. There is therefore an excellent chance that most if not all of the observed warming is natural, though we cannot exclude the possibility that some of it may be caused by human activity.
23. An alternative hypothesis for the observed warming is that it is due to human activity, specifically the release of "greenhouse gases" [GHGs] into the atmosphere. GHGs are molecules that scatter infrared radiation. The theory is that heat picked up from the sun by day is radiated into space at infrared energies, so ensuring a balance between incoming and outgoing heat and keeping average global temperatures reasonably constant. If the outgoing radiation is scattered and prevented from radiating into space, then the heat balance will be disturbed and the earth will warm.
24. The most significant GHG is water vapour, but its effect appears to be offset by the formation of clouds when there is an excess. The effects of cloud are not clear at present. The IPCC notes "Although trends of cloud cover are consistent between independent data sets in certain regions, substantial ambiguity and therefore low confidence remains in the observations of global-scale cloud variability and trends." (Ref 6, p40)
25. Carbon dioxide is the next most important GHG. The wavelength at which it scatters happens to coincide with a wavelength at which water vapour does not scatter, around 15µm. It is for this reason that the impact of carbon dioxide is far greater than it would be if water vapour were not present.
26. It will be noted that I speak of "scattering". There is a very prevalent misconception that carbon dioxide absorbs the infrared photon and is thereby heated. This is not true. It is true that the carbon dioxide and the photon interact, but the effect is more one of the photon bouncing off the carbon dioxide, i.e. changing direction. The scattering prevents the photon energy escaping directly to space. An analogy is driving a car at night into a fog. Instead of illuminating the road ahead, the light is scattered, much of it back towards the driver.
27. There is concern that the trapped infrared will cause warming, which will increase the evaporation of water, which will trap more infrared and so lead to a runaway heating of the earth. There is, fortunately, little evidence for such a phenomenon. The global humidity appeared to rise in the latter part of the last century, but has fallen back in this century.
28. There are several other gases in the atmosphere that scatter infrared photons and contribute to the GHG effect. Methane is the most prominent of these. However, their combined effect is less than half that of carbon dioxide.
29. The carbon dioxide concentration of the atmosphere has been increasing. The pre-industrial level was about 280 parts per million [ppm] of air. Continuous measurements have been made since the 1960's, and show an ongoing increase:

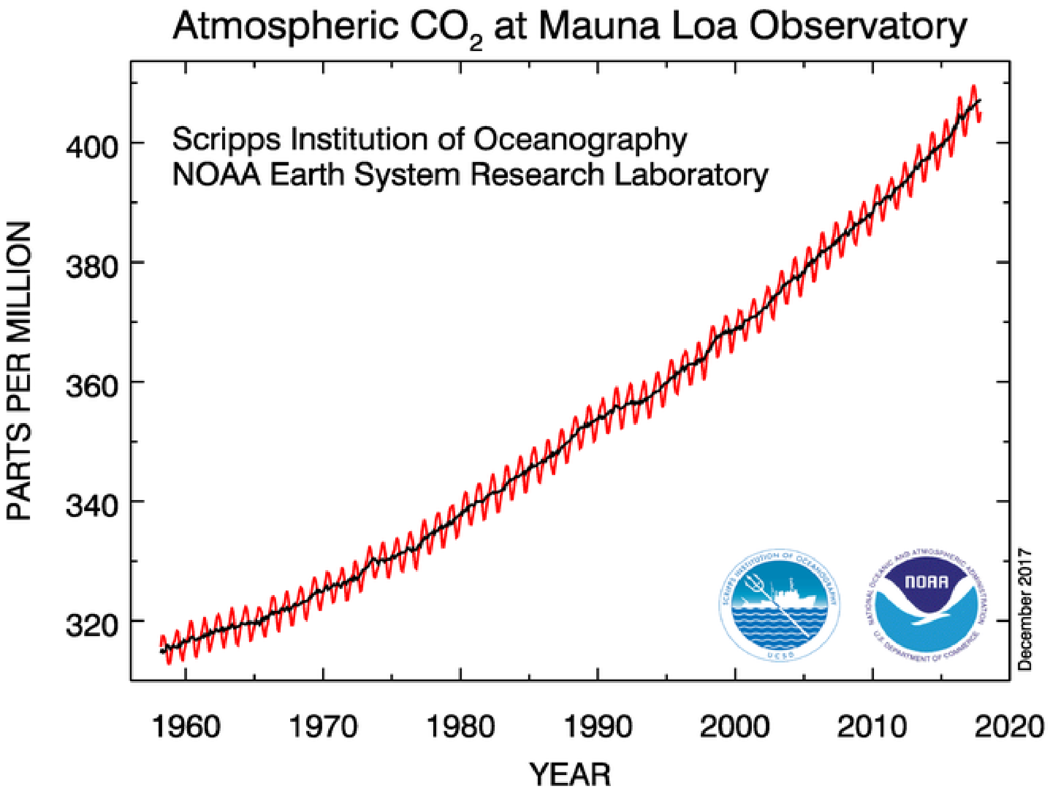

Figure 9 Growth in carbon dioxide concentration

The zig-zag pattern is due to carbon dioxide absorption by plants and trees during the northern hemisphere summer. As the land mass of the southern hemisphere is far less, the carbon dioxide concentration increases during the southern summer. The concentration is approaching 410ppm, about 130ppm above the preindustrial level.

30. There is no doubt that this increase is caused by the combustion of fossil fuels. They contain hydrocarbons that burn to produce carbon dioxide and water. Fossil fuel use surged after World War 2 as motor vehicles became more widespread and the demand for electrical energy grew. The carbon dioxide concentration in the atmosphere grew slowly between 1800 and 1850; grew somewhat faster but linearly from 1850 to 1950; but has grown exponentially since 1950:

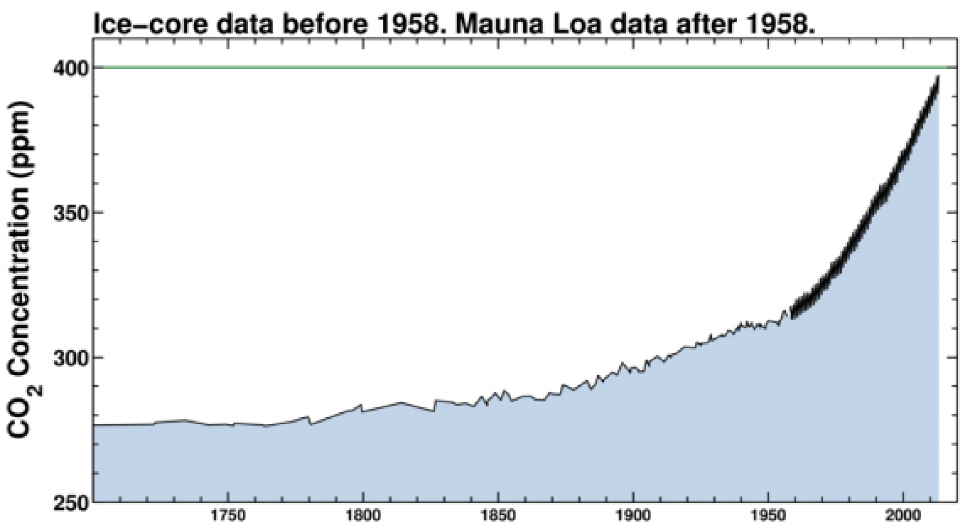

Figure 10 Long-term change in carbon dioxide concentration

31. The IPCC explicitly recognizes that there was a significant change in the earth's climatic behaviour after 1950 "Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia." (Ref 1, p.4). But a comparison with Fig.1 soon shows that the link between carbon dioxide concentration is not direct. For instance, between 1910 and 1950, both concentration and temperature increased, but between 1950 and 1980, concentration increased while the temperature decreased. Indeed, the cooling that was observed gave rise to the hypothesis that the earth was heading for another ice age, although there was no consensus on this[12,13]. From 1980 to 2000, both temperature and concentration increased. Since 2000, it has been warm, exacerbated by two El Niño events, but the concentration has increased markedly.
32. Even if the hypothesis that GHGs cause global warming is accepted, it is clear from the record that there are temperature changes that are entirely natural, which are occurring at the same time as those caused by GHGs.
33. One of the challenges to climate science is to understand the drivers of natural change. It is known, for instance, that large volcanic events can cause temporary cooling. Similarly, El Niño events can cause global warming. But we have no explanation for long-term cooling events such as that which appears to have occurred between 1950 and 1980, or the decade of heat of the 1930's best recorded in the USA.
34. There are attempts to attribute climatic changes to the effect of GHGs and only GHGs. These attempts take into account the known natural causes such as volcanic eruptions, but obviously cannot take into account the unknown factors behind the natural variation.
35. The IPCC concludes that, considering all the evidence "it is *likely* that anthropogenic forcings, dominated by GHGs, have contributed to the warming of the troposphere since 1961." (Ref 8, p66). *Likely* means that the IPCC believes the probability of the outcome to be better than 66%.
36. However, the IPCC concedes that "Uncertainties in radiosonde and satellite records makes assessment of causes of observed trends in the upper troposphere less confident than an assessment of the overall atmospheric temperature changes." (Ref.8, p66) This is a reference to a long-term debate regarding the increase in temperature in the troposphere. According to the models of the climate on which the IPCC relies, the upper atmosphere between the two tropics should be warming far faster than at ground level. Multiple measurements over as long as 50 years using weather balloons carrying thermometers, and support measurements inferring temperatures from satellite measurements, agree with each other to a large extent, but increasingly diverge from the predictions of the models

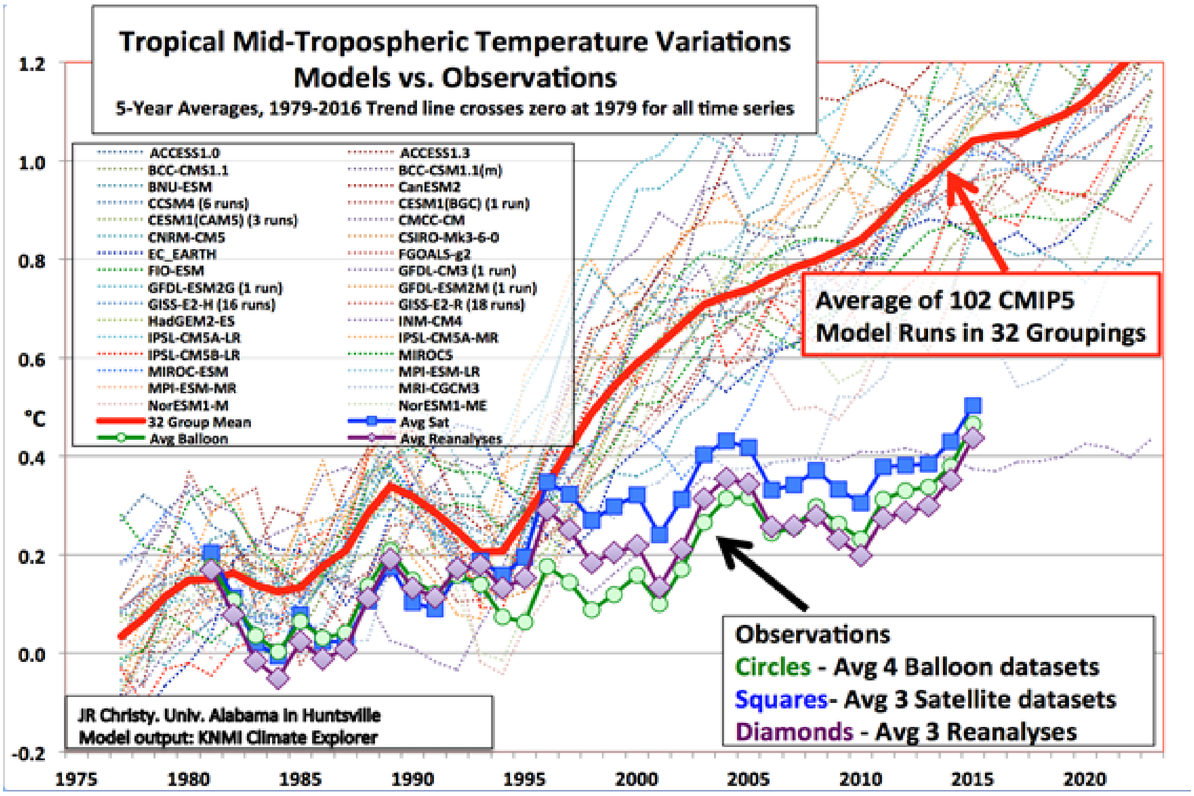

Figure 11 Comparison of measurements of tropospheric temperature anomaly with CIMP model predictions

Only one of the 102 model runs approximates the observations. The average of the models is presently about 0.6°C too warm

37. Scientifically, this destroys the credibility of the model's predictions. Any set of observations that deviates significantly from the underlying mathematical representation of a phenomenon proves the mathematical representation to be false. This is a fundamental philosophical constraint on all science[14]. Physical measurements of balloon-born thermometers and temperatures inferred from satellite observations are in essential agreement; the theoretical calculations diverge from these measurements. It follows that there are unknown errors in the theoretical calculations, and its predictions cannot be relied on.
38. A possible explanation for the errors in the models has recently been reported. The models are highly complex. They have to be fed a set of initiating values that allows them to match the observed climate of the past, a process known as "tuning". As Figure 11 illustrates, up to about 1998 it is possible to track the past climate reasonably well if the base date was 1979. However, it has been shown[15] that the assumptions make the extrapolation of past climate into the future highly questionable. "Optimization of climate models raises important questions about whether tuning methods *a priori* constrain the model results in unintended ways that would affect our confidence in climate projections."
39. In addition, the models fail to take into account some phenomena that are known to affect the weather dramatically. For instance, they do not, take into account El Niño effects, yet there is a strong correlation with global temperatures sufficient to believe that El Niño is the cause. The models do not take into account the energy dissipated in the average tropical cyclone. The condensation of moist air alone in the average cyclone dissipates about 50EJ/day, some 200 times the amount of electrical energy produced worldwide[16]. It is about eight times the total energy of

the global wind, and 0.5% of the total sunlight reaching the earth's surface. Note that this is for just one cyclone, and there are of the order of 50 cyclones each year, some of which will be significantly more energetic.

40. In summary, climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity. I have shown that one measure of climate, the average temperature of the earth, has changed over the past 180 years (Figure 1) but that when compared to diurnal and seasonal temperature changes, the changes are small (Figure 3). Moreover, there is doubt about the magnitude of warming because the raw data has been repeatedly modified by processes that are not clear and by amounts that suggest arbitrary adjustments (downwards by 1.20°C for Cape Town's data between 1910 and 1940, Figure 4, for instance). I have further shown that there is a high probability of the global temperatures varying by as much as 2°C over a century due to natural effects, which means that much if not all of the apparent change of ~0.8°C which has been observed could be natural rather than driven by man's activities. The alternative hypothesis, that increasing levels of GHGs are responsible for the observed warming, relies on models of atmosphere and ocean physics which are complex and extensive, but do not appear to have the predictive power necessary to show the claimed effects of GHGs.
41. There is a very large body of public opinion that finds it difficult to accept the facts that I have used in support of my argument. Many are believers rather than analysts. It seems amoral not to be concerned that human activities are changing the composition of the atmosphere. I am concerned, and express my concern by examining the evidence for the effects of climate change. I know the benefits that having sufficient energy provides. I have studied the relationship between energy consumption and life expectancy, and it is a strong relationship. The poor use an amount of energy X per capita, and their life expectancy at birth is <50 years; wealthier societies use >3X per capita and their life expectancy at birth is >70. This holds true for 50 years of growth in China, India, Indonesia, Pakistan, Brazil and Nigeria, cumulatively over half the world's population[17].
42. There is a hypothesis that 97-98% of all scientists support global warming[18]. Unfortunately, soon after it was published it was shown to rely on a badly phrased question; not to report the opinions of the scientists themselves, but to use the interpretation by others of what the scientists had written; and to be riddled with faulty statistics – e.g.[19]
43. A group of German scientists have undertaken a biannual survey of scientific opinion. They take care to pose neutral questions, and they interview only scientists who have written about climate change in major respected scientific journals in the past two years The results of their latest survey [20] showed that:
    - in answer to the question "How convinced are you that climate change, whether natural or anthropogenic, is occurring now?" over 79% of all scientists were absolutely convinced; just over 20% had some doubts
    - In answer to the question "How convinced are you that most of recent or near future climate change is, or will be, the result of anthropogenic causes?" over 52% of all scientists had some doubts; less than half were absolutely convinced

    This is a result that those who have strong beliefs find difficult to even comprehend. Yet for the past five surveys, the percentage of scientists who doubt that "most of recent or near future climate change is, or will be, the result of anthropogenic causes" has increased steadily. Doubting scientists now make up the majority. The science is not yet settled.
44. Thus far, we have only considered the signal of global warming as showing climate change. There are a number of other signals that confirm warming. For instance, nights have tended to be

warmer. As noted in para.16 above, many glaciers are retreating to levels previously seen as much as millennium ago. The Arctic coverage of ice is shrinking and the ice itself is thinning. There is some evidence that this behaviour is cyclic, but the only really hard data is satellite data starting in the mid 1970's. It is too soon to confirm any cyclic nature. In contrast, the Antarctic ice is growing in extent and in many places thickening, so that the global sea ice coverage varies with no discernible trend:

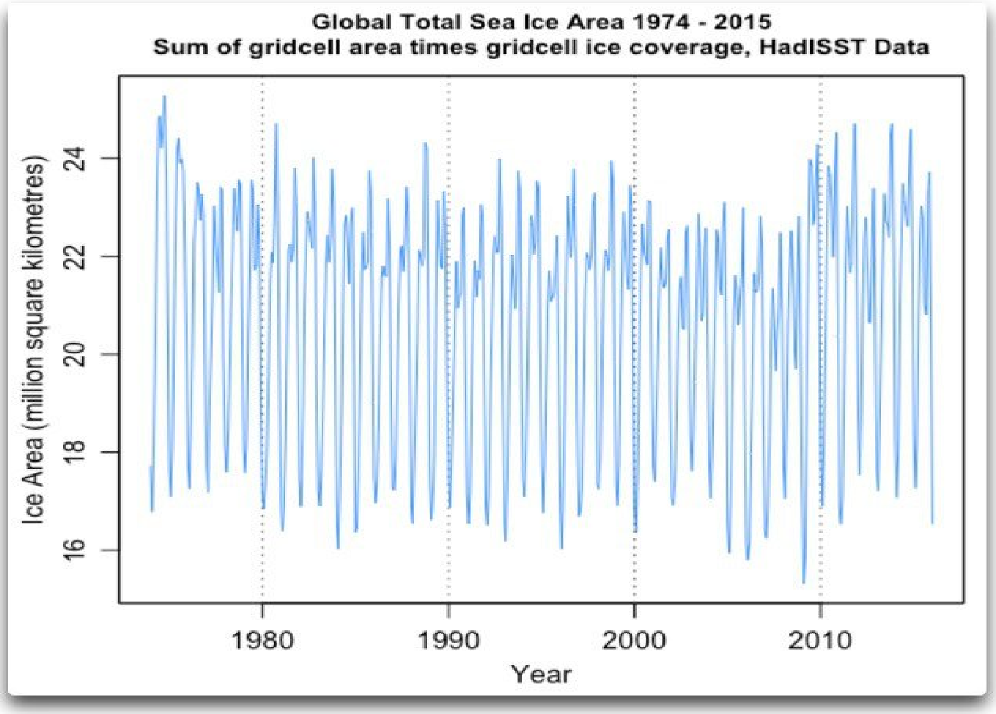

Figure 12 Sum of Arctic and Antarctic coverage of sea ice.

The ice cover of Greenland is reducing by as much as 10cm per year over much of the south western area. In contrast, most of Antarctica is growing at several cm per year, although a small area to the south of the Antarctic Peninsula is reducing by as much as 10cm per year.

45. These phenomena are to be expected in a warmer world – they are the result of warming! They do not show that GHGs are the root cause of the phenomena observed. We must now consider other phenomena where the cause-and-effect link is not so obvious.

46. The first of these is the question of the rise in sea level. There is little doubt the seas are generally rising. We know this because there is over a century of records from tide gauges around the world. There is an international organisation, the Permanent Service for Mean Sea Level [PSMSL], with data[21] from over 2300 coastal locations around the world. Not all stations have continuous records, and few date to before 1900.

47. A selection of stations from around the world was made, using as selection criteria the length and completeness of the record. An attempt was made to cover all continents, but data were lacking over most of Africa and South America. The raw PSMSL data were first checked, and -99999 entries removed as indicating no data. The data were plotted to check for gross anomalies, and then a regression analysis performed to determine the trend. The analysis gave an estimate of F for the trend, which had a confidence limit of <0.1% in every case, and also gave the standard

deviation on the estimate of the trend. Figure 13 shows an example of the data for Wismar, Germany, on the Baltic Sea.

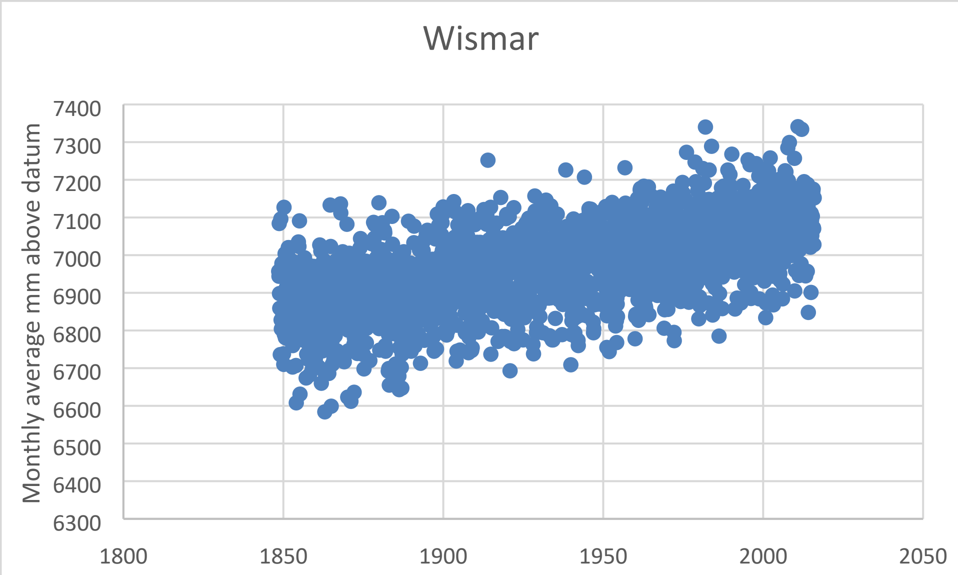

Figure 13 Tide gauge data from 1850 to present for Wismar, Germany

This site showed 100% complete data from 1850 to the present. The trend was for an increase of 1.418mm per year with a standard error of 0.042. There is clearly a lot of scatter about the trend line, partly due to the mismatch between the calendar and lunar months, partly due to storm surges, and partly due to seasonal changes. In spite of these sources of "noise", the volume of data is sufficient to give a robust estimate of the trend. There was a total of 2008 records, and the likelihood of the trend resulting from random events was essentially zero.

48. The result for some 15 gauges around the world, chosen according to the criteria given above, are summarised in Table 1, where they are arranged in ascending order of rate of sea level rise.

Table 1 Rate of sea level rise at various locations around the world

Tide Gauge	Sea Level mm/year	Station ID:	Latitude :	Longitude :	Country:	Time span of data:	Completeness (%):
Oslo, Norway	-3.1+/-0.24	62	59.91	10.73	Norway	1885 – 2016	78
Quequen, Argentina	0.82+/-0.33	223	-38.58	-58.70	Argentina	1918 – 1982	98
Aden, Yemen	1.27+/-0.19	44	12.79	44.97	Yemen	1879 – 2013	50
Cascais, Portugal	1.33+/-0.10	52	38.68	-9.42	Portugal	1882 – 1993	93
Wismar, Germany	1.42+/-0.08	8	53.90	11.46	Germany	1848 – 2015	100
Cochin, India	1.43+/-0.27	438	9.97	76.27	India	1939 – 2013	89
Honolulu	1.44+/-0.10	155	21.31	-157.87	United States	1905 – 2016	100
San Francisco	1.45+/-0.07	10	37.81	-122.47	United States	1854 – 2016	100
Fremantle, Australia	1.68+/-0.17	111	-32.06	115.74	Australia	1897 – 2016	92
Venice, Italy	2.44+/-0.21	168	45.43	12.33	Italy	1909 – 2000	94
New York Battery	2.85+/-0.09	12	40.70	-74.01	United States	1856 – 2016	90
Halifax, Newfoundland	3.18+/-0.12	96	44.67	-63.58	Canada	1895 – 2014	79
Aburatsu, Japan	3.69+-0.19	814	31.58	131.41	Japan	1960 – 2016	100
Galveston Pier II	6.41+/-0.19	161	29.31	-94.79	United States	1908 – 2016	99
Tomi, Georgia	6.66+/-0.13	41	42.17	41.68	Georgia	1874 – 2015	94

In Oslo, the sea is actually receding at a little over 3mm per year. This is believed to be due to the sub-continent rising as a result of the melting of a thick layer of ice which used to cover Norway. The melting has taken about 20 000 years, and the weight due to several km thickness of ice has allowed to sub-continent to "float" on the hot, dense rock deep in the earth. There are then eight stations that statistically average about 1.5mm per year rise in sea level. They cover the Pacific, Indian and Atlantic oceans, and therefore probably represent the average sea level rise quite well. Then there is a group that includes Venice, where the slow flooding of the ancient city is well-known. Here it would appear that the land is sinking – because the sea is rising faster than average. This is only too apparent along the Gulf Coast of the US, where the sea is rising so fast that there are significant differences between 1940's and present day coastlines. Another example is in Georgia, on the Black Sea, where again tectonic forces appear to be submerging the land.

49. The tectonic drop in New York and Halifax shown in Table 1 is surprising in view of the fact that much of North America was laden with kilometre-thick ice until quite recently (in geologic terms) and therefore might be expected to be rising like Norway rather than sinking. There is confirmatory evidence[22] from satellite observations that the east coast of North America is indeed sinking, while the Hudson Bay – Great Lakes area is rebounding as expected.

50. A different view emerges from satellite estimates of the mean sea level, as shown in Figure 14[23]. When not apparently affected by tectonic movement, tide gauges show about 1.5mm per annum rise in sea level, the rise reported from satellite measurements is about 3.4mm per annum. However, the measurements only started in 1993; some tide gauge data dates from as long ago as 1848, so should be a more reliable baseline. The discrepancy is unresolved. The IPCC reports "GMSL has risen by 0.19 [0.17 to 0.21] m, estimated from a linear trend over the period 1901–2010, based on tide gauge records and additionally on satellite data since 1993. It is very likely that the mean rate of sea level rise was 1.7 [1.5 to 1.9] mm yr–1 between 1901 and 2010. Between 1993 and 2010, the rate was very likely higher at 3.2 [2.8 to 3.6] mm yr–1; similarly high rates likely occurred between 1920 and 1950. The rate of GMSL rise has likely increased since the early 1900s, with estimates ranging from 0.000 [–0.002 to 0.002] to 0.013 [–0.007 to 0.019] mm yr–2."[8]

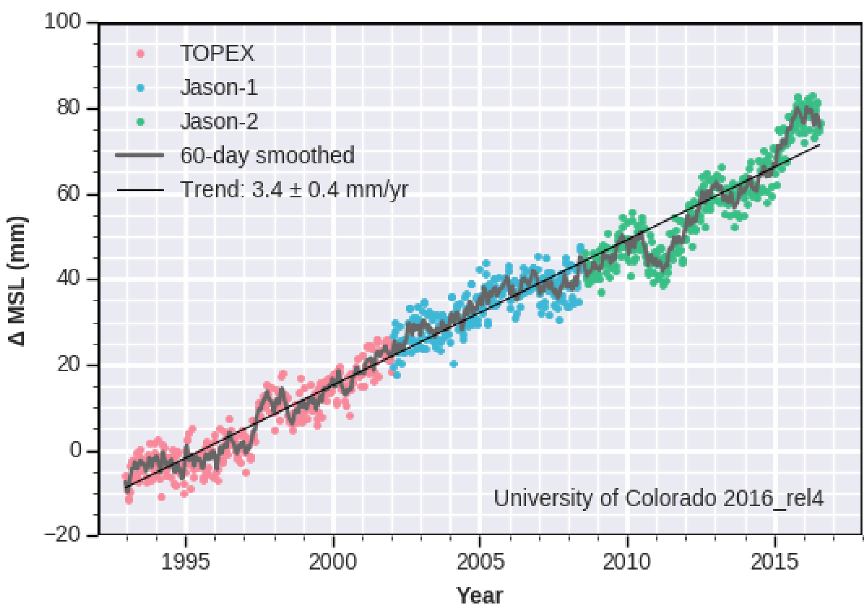

Figure 14 Satellite estimates of Mean Sea Level [MSL]

51. Whether the rate has truly increased between 1993 and the present is doubtful. Tide gauge trends from 1993 to present were determined. Of the 15 cases in Table 1, four showed a statistically significant increase, seven showed no statistically significant change, and there was insufficient data to analyse four (some records ended before 1993, for instance). However, in each case there were only about 300 records to analyse, and the trends determined had large (>20%) relative standard deviations.
52. Figure 15 gives the 24 000-year view of sea level, as shown by geological studies.[24]

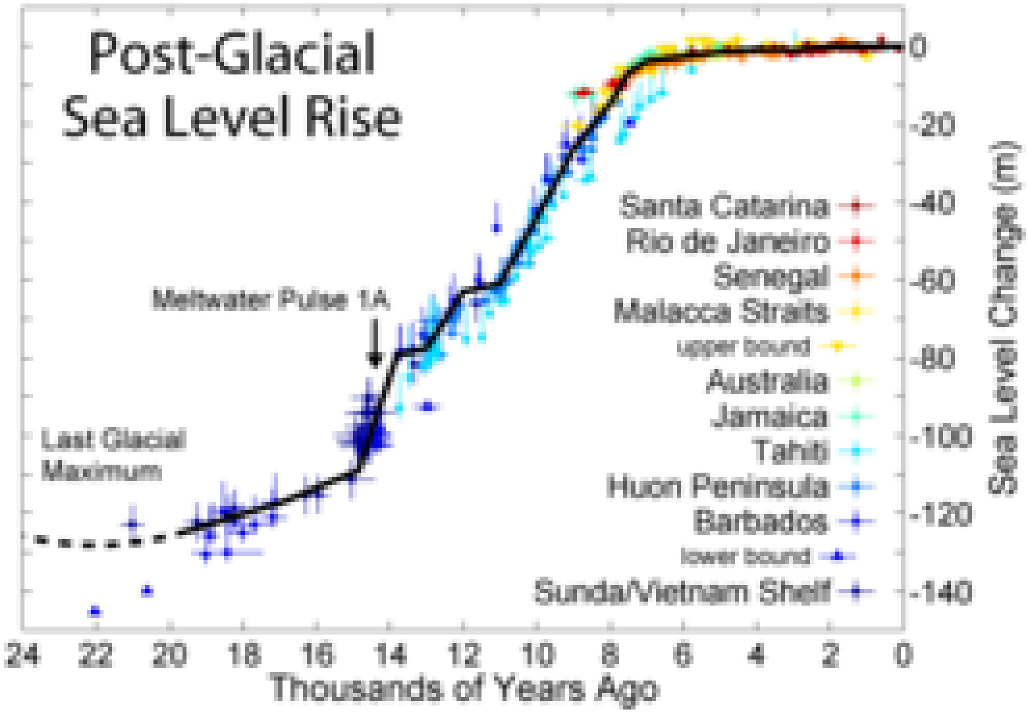

Figure 15 Rise in sea level over past 24 000 years

53. The temperature rose about 20 000 years ago, and reached present day levels about 11 000 years ago. It caused the huge ice sheets that covered much of the world to melt, and the sea level rose by about 130m. Since about 8 000 years ago, the ice still stored on land has been slowly melting but at a much slower rate than previously. There seems to be a reasonable likelihood that this slow rise will persist – the massive stores of ice left after the last ice age have gone, and the ice cores show that the ice cover of Greenland and Antarctica has persisted through past warm interglacials (Figure 8).
54. There is some evidence that the satellite estimate of sea-level rise of over 3mm per year is unlikely. Comparison of Figures 16 and 17 indicates the 30m retreat of the coastline in Galveston Bay, where the tide gauge indicates a change of sea level of over 6mm per year, over a period of some 73 years. This suggests a rate of retreat of about 0.4m per year. A sea-level rise of 3mm per year, as suggested by the satellite data, would already be showing graphic evidence on our coastlines. I have failed to find any.
55. It may be concluded that the slow rise in sea levels that has persisted for the past 150 years is likely to continue, and that the rate is unlikely to increase significantly. There does not appear to be any linkage to carbon dioxide levels in the atmosphere – tide gauge records assessed over the period prior to 1950 are statistically identical to those recorded since 1950. There is a hypothesis

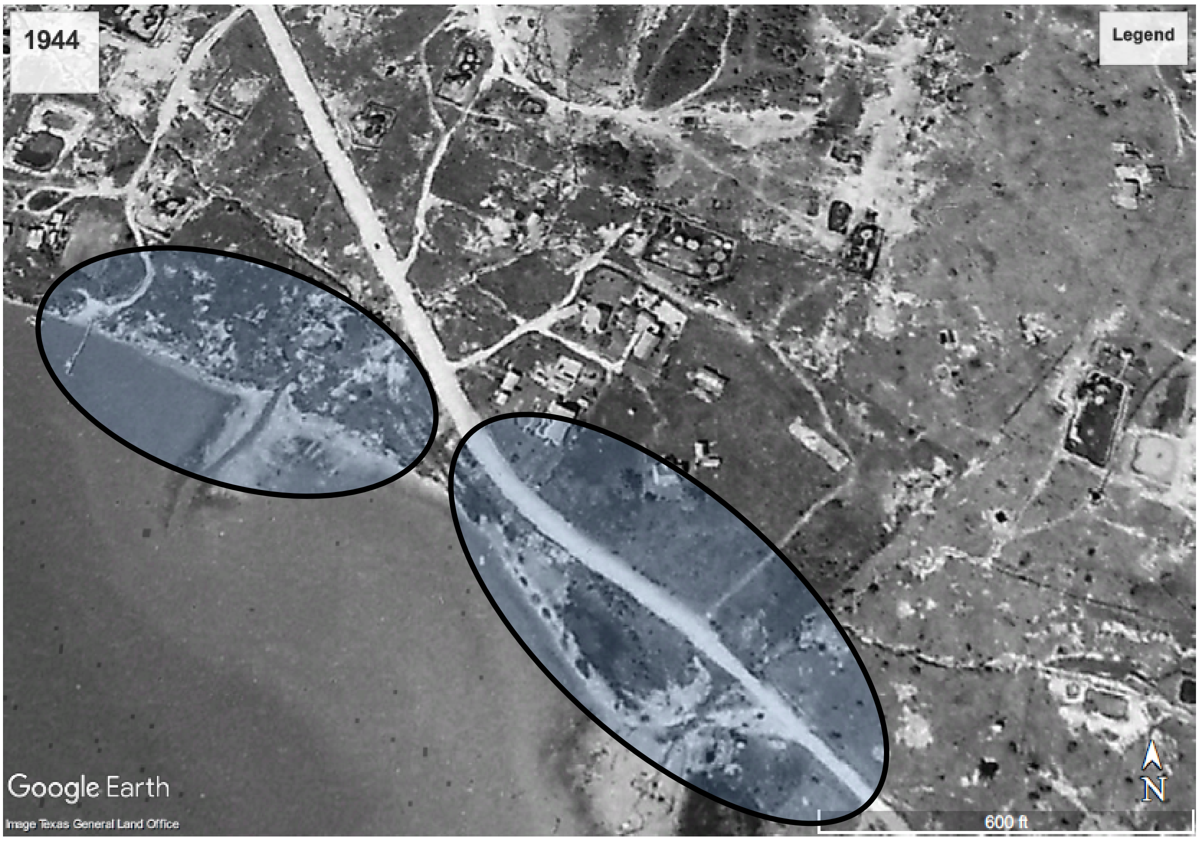

Figure 16 Aerial view of a section of Galveston Bay in 1944

Figure 17 Aerial view of a section of Galveston Bay in 2017

that the increased temperature of the upper 700m of ocean has caused expansion of the oceans sufficient to raise the sea level faster than previously. As discussed in Para.19, it is unlikely, because we have no reliable information about temperature changes in the upper 700m.

Extreme Events

56. A possible impact of climate change is extreme weather events. These changes may take several forms – there may be an increase in the frequency of such events, or in their intensity, or in the area impacted, or in the duration. The impacts can also take many forms – they may be in terms of damage to physical property or infrastructure, or in terms of loss of life, or pure economic cost. Assessing such a multidimensional phenomenon is not simple. It requires clear thinking and an understanding of basic statistics.
57. The first issue to address is the fact that the impact is the result of two prime factors, namely the probability of the extreme event occurring and the consequences of its occurrence. We will consider first the probabilities.
58. In order to work out probability of an extreme event, one needs to know the distribution of all such events. For example, if you were trying to find out what the driest and wettest years in the past had been, you would put the data on annual rainfall in ascending order. You could then see how many years fell below a chosen lower value, and how many above a chosen upper value.
59. Table 2 is a table of such values, drawn up for the 252 years of data for the rainfall over England and Wales[25].

Table 2 Distribution of annual rainfall, 1766-2017, England and Wales

Rain, mm	*No. of years with less rain*
700	5
750	13
800	20
850	39
900	37
950	42
1000	33
1050	29
1100	18
1150	9
More	7

A graph of these data is a bell-shaped curve, which comes close to what is known as a "normal" distribution. It is shown in Figure 18. The "normal" distribution has known properties. For instance, the most likely value is the average value, which occurs at the peak of the curve, somewhere between 900 and 950mm (arithmetically it is 918mm). The width of the "normal" distribution is measured by a parameter called the standard deviation. About 66% of the data will be within one standard deviation of the average value, and 95% of the data will be within two standard deviations. The England and Wales rainfall data have a standard deviation of 119mm.

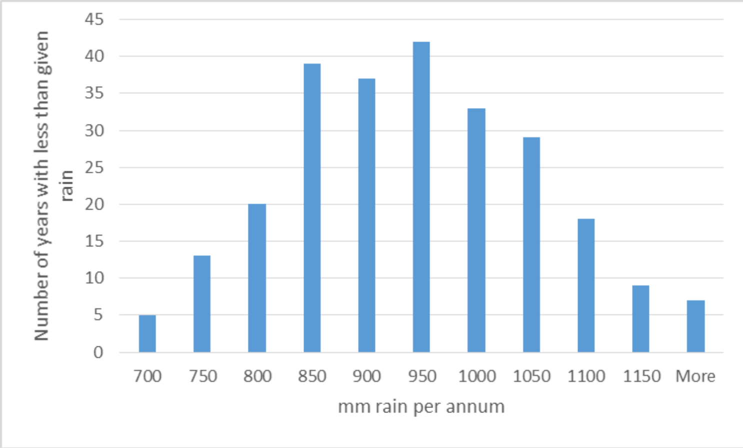

Figure 18. Distribution of England and Wales annual rainfall, 1766-2017

60. Any limit could be placed on what we wish to call an extreme event. A common assumption is an event which lies outside 95% of all events. That is, if we are dealing with annual data, an extreme event would occur once every 20 years on average, and it could be extremely positive – a flood – or extremely negative – a drought.
61. Figure 19 shows the rainfall data for England and Wales, along with the linear trend through the data and the upper and lower 95% bounds. The average rainfall appears to have increased by about 48mm over the period, which may be a reflection of a warmer, moister world. There are seven years at or above the upper 95% and four at or below the lower 95% bound, or a total of eleven extreme events in 250 years. 5% of the years, or 12.5 years, were expected to be extreme, so the observation of 11 is reasonable. But note that it has taken 250 periods to estimate the rate to within 12%, and that is the error on the rate. It is not possible to say whether there has been a change in the rate. The gaps between flood years, for instance, was 94, 20, 31, 51, 40, and 12 years, and it is 84 years since there was a drought. The average gap between floods is 41 years, close to the expected average of 40 years. However, the standard deviation on this average 41 years is 29, which means there is a 95% chance of the next event occurring anywhere between a year later and a century later, neither of which bounds is exactly helpful!

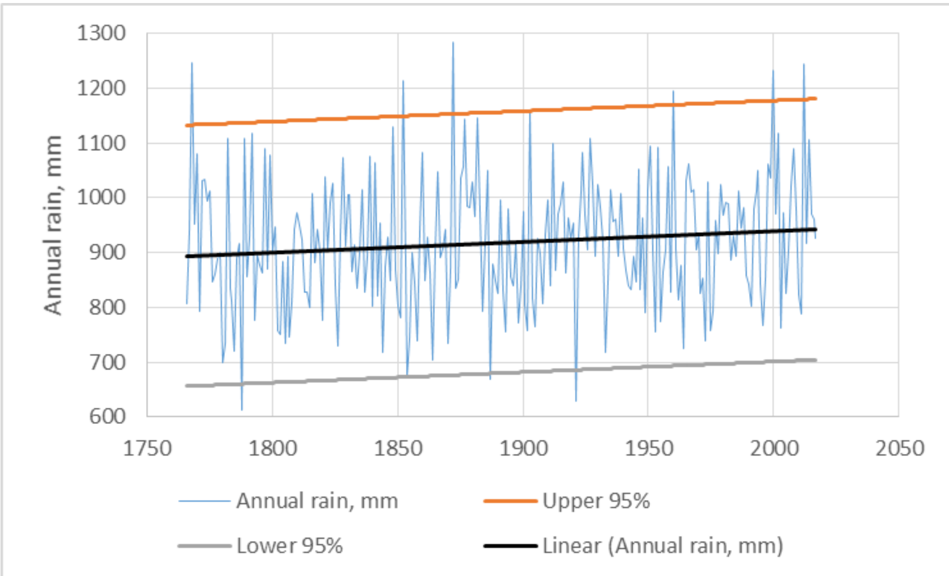

Figure 19 Rainfall over England and Wales, 1766-2017, with linear average and two-standard-deviation limits

62. This illustrates the problem of all claims regarding extreme events. By definition, extreme events are comparatively rare. They are also random. So it takes a lot of data to estimate the rate at which they occur, and about ten times as much data to detect any shift in the rate. Very few of the measures of climate are of sufficient duration to estimate the rate with any accuracy, and none of the very few extend long enough to find changes in the rate.
63. For instance, I studied[26] the rainfall at 154 stations in the National Acid Precipitation Assessment Program. It was continuous weekly data for 24 years, about 1250 data points at every station. Statistically significant trends were found at most stations, and showed an average of 21±12mm increase in rainfall over the whole period. However, attempts to determine the frequency of extreme events failed. For instance, there was weekly data since 1984 at site OR18, Starkey Experimental Forest, 45.2247N 118.5130W[27]. During the period 1984-2000, there were 21 high rain week and 42 low rain weeks; during 2001-2017 there were 17 high rain weeks and 50 low rain weeks. The 5% limits were a total of 68 events; the distributions were somewhat skewed, which was why there were more low then high events observed. There was no statistical difference in the rainfall over the two periods – a T test showed a >99.999% probability that they were identical.
64. It can only be concluded that the first parameter in the assessment of risk, namely the probability of an extreme event occurring, can be estimated from historical data, but that there is no *a priori* knowledge of when it might occur. Claims of increased frequency have no scientific basis.
65. This finding explains why, even though the world has been warming for the past 150 years or more, it has not been possible to find clear evidence of a change in the rate of extreme climatic events. There have been many predictions of such a change, but none have been identified.
66. A further challenge to the identification of the rate of change is that the technology underlying measurements has changed over the years. There was earlier (para.18) the example of the measurement of the temperature of sea water. A further example comes from the study of hurricanes[28]. As shown in Figure 20, in 1933 there were no observations in a large area of the Atlantic because there was little shipping in the area. By 2005, satellites were able to observe and track hurricanes that would not have been observed 80 years earlier.

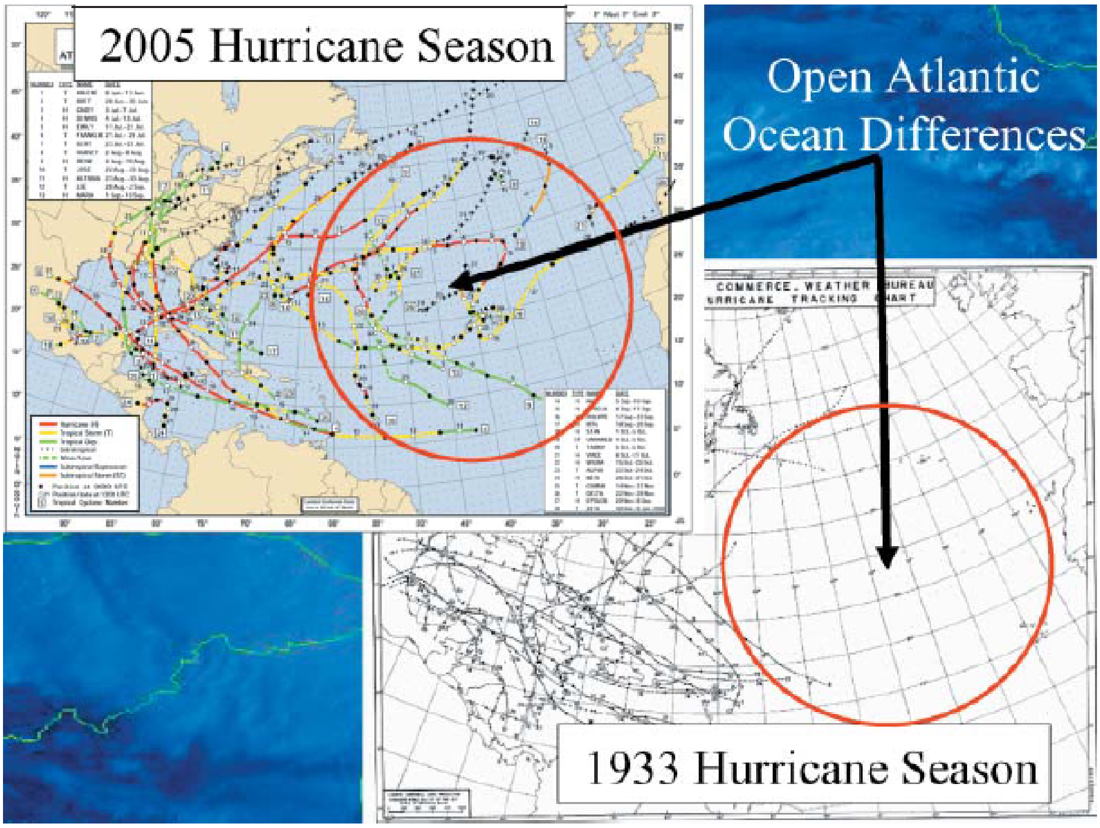

Figure 20 Comparison of 1933 and 2005 hurricane season in the open Atlantic.

67. It may seem surprising that the factual basis for climate-induced changes in the rate of extreme events is so weak. There are repeated assertions that the rate is changing, but these assertions are not born out. In 2012, the IPCC produced a Special Report on Extreme Events[29]. It said:
    - "It is *very likely* that there has been an overall decrease in the number of cold days and nights, and an overall increase in the number of warm days and nights" (Ref 29 p.111). This finding is not surprising; it would be expected in a warmer world. *Very likely* in IPCC use means >90% confidence (See Ref 29, p21).
    - "There is *medium confidence* that the length or number of warm spells or heat waves has increased since the middle of the 20th century" (Ref 29 p.111). *Medium confidence* implies about as likely as not, 33-66% confidence.
    - "There is *low confidence* that any observed long-term increases in tropical cyclone activity are robust" (Ref 29 p. 111). This has a <33% probability
    - "There is *low confidence* in observed trends in small-scale phenomena such as tornadoes and hail" (Ref 29 p.112)
    - "There is *medium confidence* that since the 1950s some regions of the world have experienced a trend to more intense and longer droughts, but in some regions droughts have become less frequent, less intense, or shorter" (Ref 29 p. 112)
    - "There is limited to medium evidence available to assess climate-driven observed changes in the magnitude and frequency of floods. Furthermore, there is low agreement in this evidence, and thus *overall low confidence* at the global scale **regarding even the sign of these changes**." (Emphasis added)(Ref 29 p.112). This implies <10% probability.

- "It is *likely* that there has been an increase in extreme coastal high water related to increases in mean sea level" (Ref 29 p. 112). It is surprising that the IPCC finds this to have only a >66% probability in the light of the discussion at paras 46-55 above.
- "There is generally *low confidence* in projections of changes in extreme winds because of the relatively few studies of projected extreme winds, and shortcomings in the simulation of these events. An exception is mean tropical cyclone maximum wind speed, which is *likely* to increase, although increases may not occur in all ocean basins."(Ref 29 p113). It should be noted that it is only since the 1980's that it has been possible to determine cyclone maximum wind speeds. There is clear evidence that estimates before then were very uncertain.
- "It is *likely* that the frequency of heavy precipitation or the proportion of total rainfall from heavy rainfalls will increase in the 21st century over many areas of the globe." (Ref 29 p113). It should be noted that this is largely the result of modelling; there are no past data to support the hypothesis. It is also worth noting that heavy precipitation is often the cause of flooding, and the IPCC has noted that it cannot say whether flooding is increasing or decreasing.
- "There is *medium confidence* that droughts will intensify in the 21st century in some seasons and areas, due to reduced precipitation and/or increased evapotranspiration." (Ref 29 p113). Again, this is a prediction from modelling; there are no past data to support the hypothesis, which is surprising given that the world has been warming for at least 150 years.
- "**Uncertainty in projections of changes in large-scale patterns of natural climate variability remains large**. There is *low confidence* in projections of changes in monsoons (rainfall, circulation), because there is little consensus in climate models regarding the sign of future change in the monsoons. Model projections of changes in El Niño-Southern Oscillation variability and the frequency of El Niño episodes as a consequence of increased greenhouse gas concentrations are not consistent." (Emphasis added) (Ref 29 p 113). While this speaks to monsoons and El Niño, it in fact applies to the whole of the climate system. The models of future climate have a large uncertainty.
- "There is *high confidence* that changes in heat waves, glacial retreat, and/or permafrost degradation will affect high-mountain phenomena such as slope instabilities, mass movements, and glacial lake outburst floods. There is also *high confidence* that changes in heavy precipitation will affect landslides in some regions." (Ref 29 p114). There is little to support this statement in spite of its *high confidence*. The IPCC stated that there was large uncertainty in future climate projections, so there cannot be much confidence in increasing heat waves. Glacial retreat and loss of permafrost are clearly the result of a warmer world which, as we have seen, may well be natural. There is no historical evidence for changes in heavy precipitation, so it is perhaps being overconfident to claim *high confidence* in increasing precipitation causing more landslides.

68. Taken as a whole, the IPCC assessment of extreme events supports the conclusion that claims of increased frequency of severe weather due to climate change cannot be substantiated.
69. Thus far, we have been considering the possibility of an increase in the frequency of extreme events. Another possibility is that the intensity of a particular aspect of climate may change. However, the challenges faced when trying to quantify any change in intensity are at least as great as the challenges faced when trying to quantify frequency. Indeed, the IPCC considers them together – "Extreme events are rare, which means there are few data available to make assessments regarding changes in their frequency or intensity. The more rare the event, the more difficult it is to identify long-term changes."(Ref 29, p8)

70. For instance, change in the method of measurement affects intensity classification just as such changes affected frequency. Traditionally the strength of hurricanes was determined by the central pressure. A category 3 hurricane was associated with a pressure of ~950millibars [mb]. A category 5 had a central pressure of <920mb. Since the late 1980's, a totally different measure has been used – the wind speed at an altitude of 10 000feet. Aeroplanes can now be made strong enough to fly into the eye of hurricanes, and the wind speed at 10 000feet turns out to be a far better measure of the hurricane intensity than the central pressure. The two are quite strongly related, but the change means that the historical data has a wide error band, which makes it impossible to determine changes in intensity with any degree of certainty.
71. Similar challenges face the determination of the intensity of rainfall. For example, the 2017 hurricane Harvey that made landfall in Texas produced over 60inches of rain over 3 days. In 1979, the Texan hurricane Claudette deposited 42inches in 24h. Which was the more intense? Did either signal climate change? Probably not. Harvey ended a ten-year period when no hurricanes made landfall on the continental US. Claudette followed a year after hurricane Amelia deposited 45inches over two days in central Texas.
72. Rather unhelpfully, the IPCC says "There have been statistically significant trends in the number of heavy precipitation events in some regions. It is *likely* that more of these regions have experienced increases than decreases, although there are strong regional and subregional variations in these trends."(Ref 29, p8)
73. In a similar vein, it reports "There is *medium confidence* that some regions of the world have experienced more intense and longer droughts, in particular in southern Europe and West Africa, but in some regions droughts have become less frequent, less intense, or shorter, for example, in central North America and northwestern Australia." (Ref 29, p8)
74. It can only be concluded that claims of increased intensity of severe weather due to climate change cannot be reliably substantiated.

Impacts of Climate Change

75. As noted in para 57, impact is the result of two prime factors, namely the probability of the event occurring and the consequences of its occurrence. In the previous section, we considered the probability of an increase in the frequency or intensity of extreme weather events, and concluded that claims of increases could not be substantiated. Accordingly, the impacts of climate-change-induced severe weather must be assessed as low. Severe weather carries its own risks, and most infrastructure is purposely designed to withstand that risk. Should it fail, it is an indication of under-design, not a signal of weather severity.
76. The increase in the costs associated with severe storms is often used to support the hypothesis that storm severity is increasing. However, it has been shown[30, 31] that, when allowance is made for an increasing number of structures in the storms' path and an increasing value for each structure, there is no evidence for increasing severity.
77. Indeed, one of the problems with the assessment of supposed impacts is that there is no consistency in the assessment. For instance, the latest IPCC Report [32] suggests "Most reported impacts of climate change are attributed to warming and/or to shifts in precipitation patterns. There is also emerging evidence of impacts of ocean acidification. Relatively few robust attribution studies and metaanalyses have linked impacts in physical and biological systems to anthropogenic climate change." However, we have already seen (Para 67) that there is only *medium confidence*

in shifts in precipitation patterns. There cannot, therefore, be much confidence in impacts from such purported shifts.

78. The list of putative impacts due to climate change is long, and it would not be useful to attempt to address them all. However, there are several which illustrate the general problem of assessing impacts. If the impacts cannot be reliably assessed, then any costs associated with them must be indeterminate.
79. For instance, there is an hypothesis that global warming will increase the spread of malaria. The effect of temperature on the spread of the disease is, however, minimal. As an example, " - - the number of malaria cases still rose after the war, reaching a peak in 1922-1924. Malaria had re-emerged in areas where it had ceased to be endemic, and appeared with greater frequency and severity everywhere else, including in Italy, where the death toll climbed from 1 per 10,000 inhabitants in 1910 to 3.2 at the end of WWI (Celli, 1933). This trend was also associated with attacks of malignant (pernicious) malaria in areas where it had rarely been seen before. In Eastern Europe, the 1922-1923 'epidemics' in Soviet Russia and the Ukraine are often seen as examples of the dramatic changes in the distribution and features of malaria. Gustavo Pittaluga (1876-1956) estimated that in 1923, 18 million people suffered from malaria in Russia, and that sixty thousand deaths occurred out of a total population of about 110 million."[33] It is quite clear that malaria is not a tropical disease. Yet both the second and third[34] Assessment Reports of the IPCC devoted large sections to the impacts of warming on the spread of malaria and other "tropical" diseases.
80. A typical quote indicates a belief in the hypothesis that global warming will spread malaria:-"From results of most predictive model studies, there is *medium* to *high confidence* that, under climate change scenarios, there would be a net increase in the geographic range of potential transmission of malaria and dengue–two vector-borne infections each of which currently impinge on 40-50% of the world population." (Ref 34, p12)
81. One has to question 'predictive model studies', let alone have medium to high confidence in them, when there is such strong evidence that malaria can spread under quite cold conditions. Yes, it is true that a large percentage of the world's population remains at risk, but it does not follow that the risk will increase if there is climate change.
82. These and similar statements became part of the IPCC report [32] after one of the world's foremost malaria specialists resigned in protest. He made his findings known in a memorandum to the House of Lords[35]. Some quotes from that memorandum speak volumes to the falsity of the IPCC claims:
    - "the most catastrophic epidemic on record anywhere in the world occurred in the Soviet Union in the 1920s, with a peak incidence of 13 million cases per year, and 600,000 deaths. Transmission was high in many parts of Siberia, and there were 30,000 cases and 10,000 deaths due to falciparum infection (the most deadly malaria parasite) in Archangel, close to the Arctic circle."
    - "I hope I have convinced you that malaria is not an exclusively tropical disease, and is not limited by cold winters! Moreover, although temperature is a factor in its transmission (the parasite cannot develop in the mosquito unless temperatures are above about 15ºC), there are many other factors—most of them not associated with weather or climate—that have a much more significant role. The interaction of these factors is complex, and defies simple analysis."
    - "The same goes for all mosquito-borne diseases—that is what makes them so fascinating—and even the climatic factors defy simple analysis. Thus, in some parts of the world,

transmission is mainly associated with rainy periods, whereas in others, epidemics occur during drought. In some highland areas, the transmission is highest in the warmest months, whereas in others, it is restricted to the cold season. In Holland, malaria was transmitted in winter because the vector-mosquito did not hibernate, fed both on cattle and on people, and overwintered in houses and barns, taking an occasional blood meal without laying any eggs (most female mosquitoes bite in order to obtain nutrition to develop an egg batch). In the Sudan, low-level transmission occurs during the 10-11 month dry season, when day-temperatures are in the mid-40s."

- "The scientific literature on mosquito-borne diseases is voluminous, yet the text references in the chapter [Chapter 18, Working Group II, Second Assessment Report, IPCC] were restricted to a handful of articles, many of them relatively obscure, and nearly all suggesting an increase in prevalence of disease in a warmer climate. The paucity of information was hardly surprising: not one of the lead authors had ever written a research paper on the subject! Moreover, two of the authors, both physicians, had spent their entire career as environmental activists."
- "Glaring indicators of the ignorance of the authors included the statement that "although anopheline mosquito species that transmit malaria do not usually survive where the mean winter temperature drops below 16-18ºC, some higher latitude species are able to hibernate in sheltered sites". In truth, many tropical species must survive in temperature below this limit, and many temperate species can survive temperatures of -25ºC, even in "relatively exposed" places."
- "In summary, the treatment of this issue by the IPCC was ill-informed, biased, and scientifically unacceptable."

83. This episode illustrates graphically that there can be "fake news" regarding climate change. South Africa was the victim of similar "fake news" when it banned the use of DDT for malaria control on the advice of the World Health Organisation [WHO]. By 2000, there were over 65 000 cases and nearly 500 deaths[36]. DDT control was reintroduced, and by 2005 there were less than 9000 cases and less than 50 deaths. By 2006, WHO had reversed its earlier recommendations in the light of South Africa's experience[37].
84. The falsified hypothesis about climate change increasing the risks of malaria illustrates the absolute need to check putative impacts very carefully. It is often surprising to find how resilient our environment is. Yet there is a groundswell of public opinion that is convinced that our environment is anything but resilient, and at all costs in need of protection from what we do. Certainly there is a modicum of truth in the opinion, but it is not necessarily as great a threat to existence as some would have us believe.
85. There is also the real danger that false impacts may cause faulty policies that can lead to real disasters – the case of DDT and malaria illustrates this. Equally, because of the false link between malaria and climate change, there are some who would rather try to address climate change than to address the real and present problem of malaria. According to the World Health Organisation, [WHO] in 2016 there were an estimated 216 million cases of malaria in 91 countries, an increase of 5 million cases over 2015. Malaria deaths reached 445 000[38]. The WHO predicted that climate change would affect the social and environmental determinants of health – clean air, safe drinking water, sufficient food and secure shelter – and that between 2030 and 2050, climate change was expected to cause approximately 250 000 additional deaths per year, from malnutrition, malaria, diarrhoea and heat stress[39]. We have already shown that there is unlikely to be an increase in malaria deaths, so this estimated 250 000 future annual deaths must be an over-estimate. Climate

change predictions should not be used to avoid addressing the challenge of malaria, which is here and now.

86. At the other end of the scale, there is the saga of the polar bear. An early paper gave the rationale for focussing on the polar bear: "If climate change occurs, the polar bear is the ideal species through which to monitor the cumulative effects on arctic marine ecosystems."[40] The reduction in Arctic sea ice was held to be the likely cause of the disappearance of the species. Monitoring soon showed that the polar bear species was indeed in a decline, but this was traced to an excessive quota of hunting licenses[41]. In 2008, the US Fish and Wildlife Service listed polar bears as threatened in terms of the Endangered Species Act, based on computer models of future polar bear survival in the face of summer sea-ice loss. These models expected the global polar bear population too decline 67% by 2050, with 10 subpopulations out of 19 worldwide predicted to go extinct due to loss of summer ice. However, even though summer sea-ice levels have remained low, the polar bear numbers have not declined as predicted, and in general the bears have shown a marked improvement in body condition, cub production and cub survival[42]. In 2015, a census showed there to be over 28 500 bears in the Arctic.
87. Another putative impact is the bleaching of coral reefs. For example, there was a fairly massive bleaching of the northern part of Australia's Great Barrier Reef in 2016. An official Government report [43] noted "Bleaching-related coral mortality was highest on inshore and mid-shelf reefs in the far north around Cape Grenville and Princess Charlotte Bay, with 80 per cent loss of shallow-water coral cover recorded on average." It attributed the bleaching to climate change and excessive sea surface temperatures, but unfortunately used satellite estimates of the temperature, and, as we have seen (Para 18), satellites detect the temperature of only the topmost millimeter. There were many measurements of sea water temperature in the bleaching area [44], and these failed to show any abnormalities during 2014-16 compared to the prior 10 years at depths between 1m and 10m. What had changed, however, was the sea level[45]. The rise of El Nïno had caused a drop of approximately 0.5m in the average depth of the sea, and had exposed the corals for too long a time to the atmosphere [46]. A similar effect due to El Nïno causing a drop in sea level and bleaching coral was observed at the same time in Indonesia[47]. Climate change was not the cause of coral bleaching.
88. There is an extensive literature on the impacts of climate change on the loss of biodiversity. There is, however, a gap between what is claimed and what is observed. For instance, a recent paper from Harvard [48] stated "Climate change alone is expected to threaten with extinction approximately one quarter or more of all species on land by the year 2050, surpassing even habitat loss as the biggest threat to life on land. Species in the oceans and in fresh water are also at great risk from climate change, especially those that live in ecosystems like coral reefs that are highly sensitive to warming temperatures, but the full extent of that risk has not yet been calculated." Even making allowance for the fact that this is a prediction, the suggested loss of one quarter or more of all species is surprising.
89. Consider, for instance, that South Africa and Australia broke apart about 66-100 million years ago. The *Proteaceae* have persisted on each side of that break – they have evolved, it is true, but remain closely related. The climate changed dramatically several times during that period, but the species remained. It can only be concluded that the biosphere is unlikely to be as dramatically affected as Harvard's models suggest. As Figures 2 and 3 illustrate, diurnal and seasonal changes in temperature are far larger than the measured changes in global average temperature. The biosphere is adapted to change.

90. There is confirmation of the view that climate change is unlikely to be the disaster predicted by many activists in the latest IPCC conclusions: "While recent climate change contributed to the extinction of some species of Central American amphibians (*medium confidence*), most recent observed terrestrial species extinctions have not been attributed to climate change (*high confidence*)." (Ref. 32, p 46)
91. A further possible impact is called "ocean acidification". Chemically, it is a misnomer – the sea has always been slightly alkaline, and the additional carbon dioxide in the atmosphere has increased the quantity of dissolved carbon dioxide in the oceans, which has made them slightly less alkaline – it has not acidified them! The average pH has dropped from about pH8.2 to pH8.1. The chemical equilibria involved suggest that the response to increasing carbon dioxide in the atmosphere is not a linear one, and that the pH is unlikely to drop below pH8 at ten times the present atmospheric concentration of over 400ppm carbon dioxide.
92. Again, the IPCC gives quite a reasoned view: "The fundamental chemistry of ocean acidification is well understood (*robust evidence, high agreement*). It has been more difficult to understand and project changes within the more complex coastal systems."(Ref 32 p74) "Few field observations to date demonstrate biological responses attributable to anthropogenic ocean acidification, as in many places these responses are not yet outside their natural variability and may be influenced by confounding local or regional factors." (Ref 32, p47)
93. Figure 21 illustrates the results of one experiment in which cocolithopores were grown under carbon dioxide concentrations equivalent to today's levels and at nearly four times those levels. Clearly the higher levels of carbon dioxide in the sea water facilitated the growth of the shells.

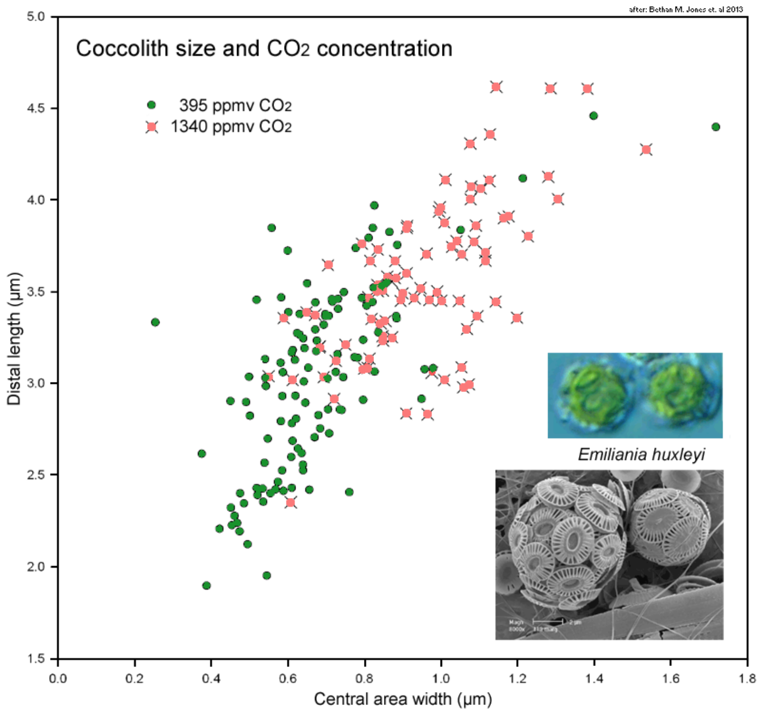

Figure 21. Effect of high levels of carbon dioxide on the growth of a calcium carbonate shell

94. In this case it may be concluded that the impact of growing carbon dioxide in the atmosphere is real and measurable, but the consequences may well be an improvement in aquatic life, rather than harmful as has been claimed. This is not a general finding, however. Many studies have found excess carbon dioxide to be deleterious to juvenile fish and shellfish, but others have found no

effects, and yet others have reported beneficial effects. Alkalinity and carbon dioxide concentrations are linked, and some studies have found the effect of pH to be negative but the effect of enhanced carbon dioxide to be positive. It appears as if shells with the aragonite form of calcium carbonate are more sensitive than those with the calcite form. A confounding factor in all experiments in the ocean has been the facilitated growth of algae in the presence of higher-than-normal carbon dioxide, which has increased the food supply to many species of fish and shellfish, and offset any negative effects of carbon dioxide on the fish themselves.

95. Another real, measurable impact is the effect of increasing carbon dioxide levels on plant growth. The phenomenon has long been recognized. For example, many European greenhouses for vegetables and flowers have used off-gases from furnaces to raise carbon dioxide levels to over 2000ppm. This has enabled them to harvest at least one additional crop each year. A blog[49] summarizes the findings of the effect of an additional 300ppm of carbon dioxide on the growth of a few thousand species. It is positive in every case. For instance, there have been 63 separate studies of the effect on the Scots Pine (*Pinus sylvestris*) the dry mass of which increases by 35%±4% when grown with 300ppm more carbon dioxide than when grown in normal air.

96. The Food and Agricultural Organization statistics[50] show a rapid growth in cereal production globally during the period 2005-2014:

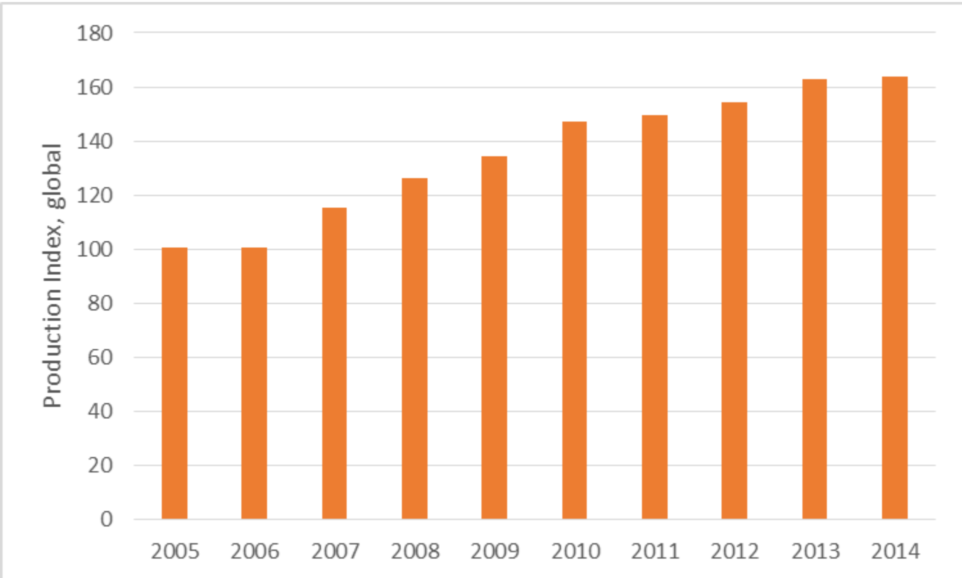

Figure 22. Global cereal production index

Over this period, there was about a 16% increase in the land under cultivation; improved farming practice and wider spread use of fertilizers and irrigation accounted for about a further 20% of the improvement. The balance of some 32% of the growth appears to be largely the beneficial effect of added carbon dioxide in the atmosphere.

97. There is something of a downside to the improved yield – it comes at the cost of more water, although the quantity of water per unit of yield is unchanged. Nevertheless, almost the whole of the biosphere has become greener over recent years[51]:

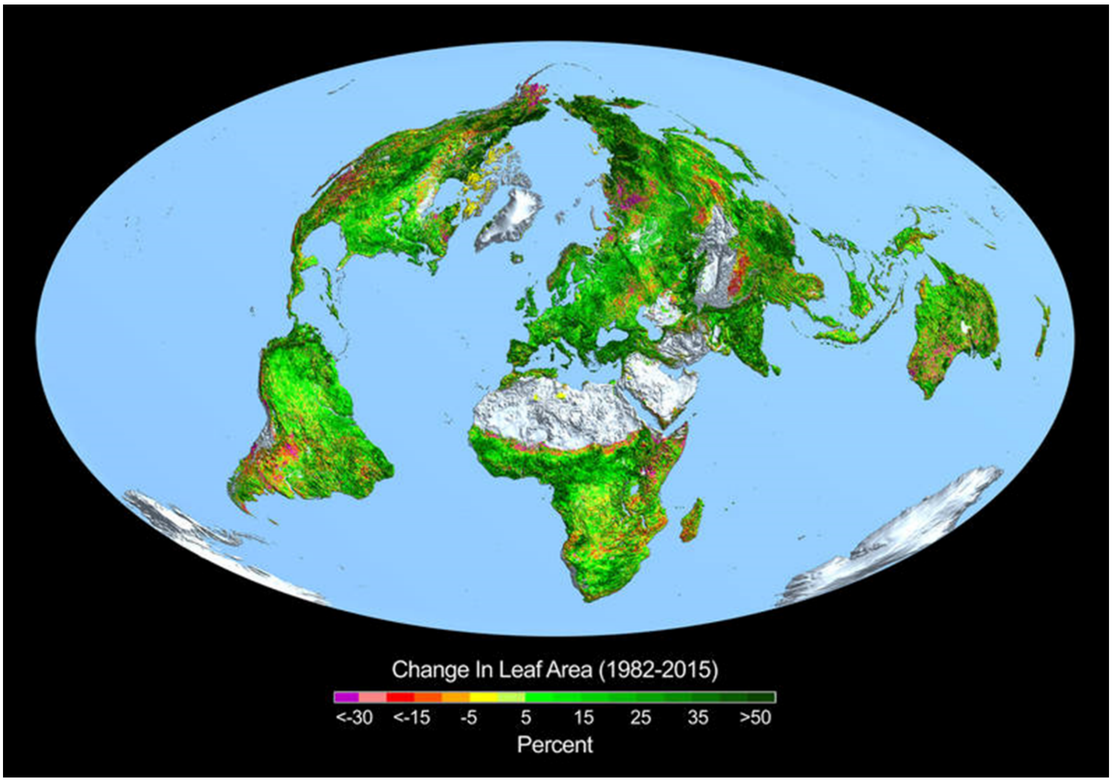

Figure 23. Change in the leaf cover of the world

Thus it is argued that, in the face of a constant supply of rain, natural vegetation will take a larger share of the available water and there will be less for agriculture. However, this is a second-order effect; far more important is the fact that the Millennium Development Goal to "Halve, between 1990 and 2015, the proportion of people who suffer from hunger" has been comfortably exceeded.

98. A final impact which should be considered is that of carbon dioxide emissions on temperature. There have been many attempts to attribute changes in global temperatures to human activities. A typical example is shown in Figure 24[52].

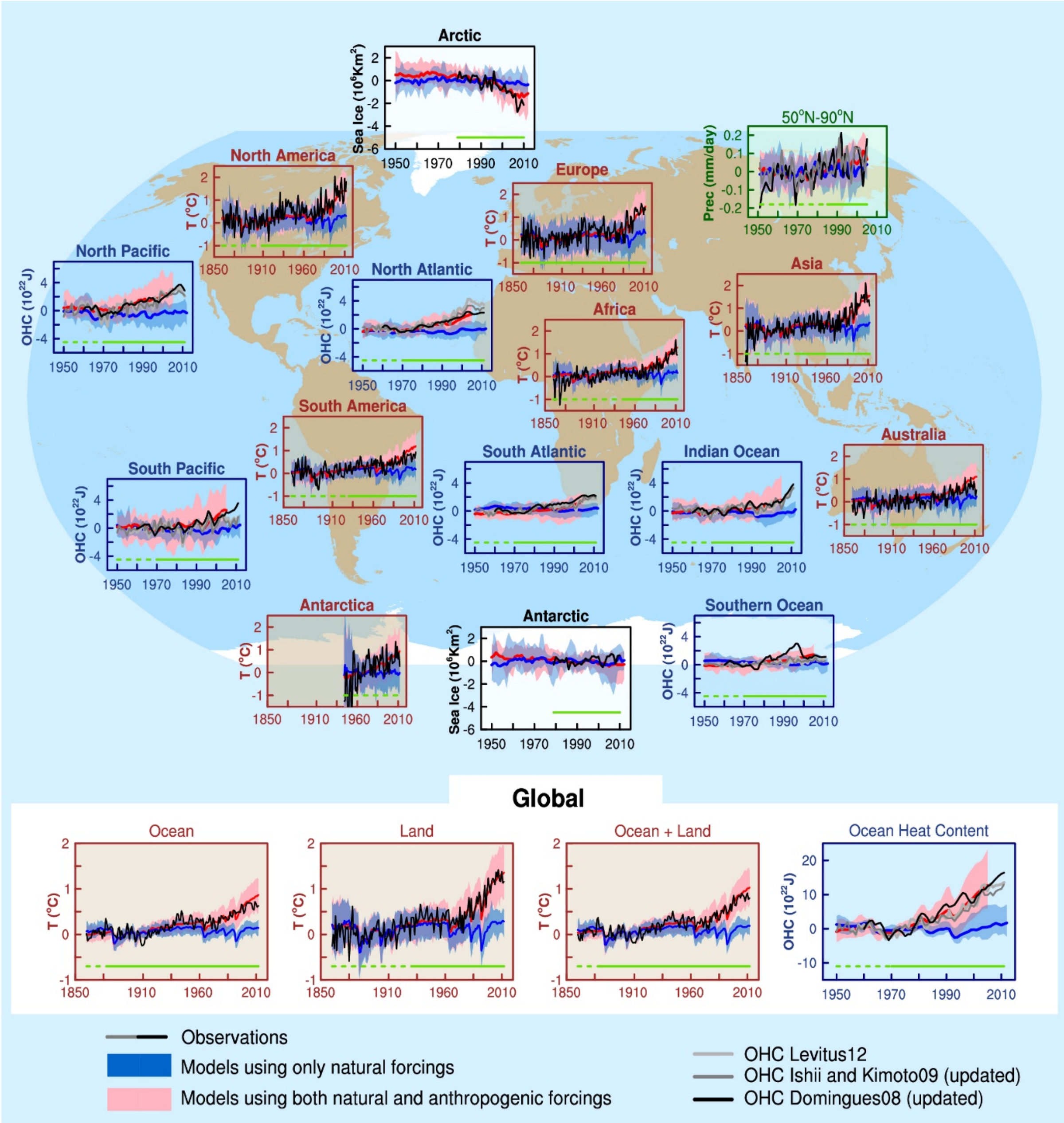

Figure 24. Comparison of models with and without anthropogenic forcings to observations.

99. The problem with this type of analysis is that it relies on models. As we have seen (Para 38), these models require "tuning", i.e. they have to be provided with a set of parameters in order to match the observations. The set of parameters is not constrained in any way – they are merely sets of numbers that allow the model to agree with the observations. One set could well be the annual concentration of carbon dioxide in the atmosphere. So each of the pink bands in Figure 24 is the result of different tunings of the model, so that it can match the observed black lines. Having tuned the model to agree with the observations, it can then be run without the carbon dioxide numbers. The result will differ from the model runs with the carbon dioxide numbers, but this is a mathematical inevitability – because the model is now no longer tuned. It does **not** mean that the model now represents a world without carbon dioxide, with temperature determined only by "natural forcings," although that is the claim. We know this, because such a world does not exist.

100. Moreover, we know that carbon dioxide in the atmosphere really started to increase after WW2 (Figure 10), so it is noteworthy that the supposed impact of carbon dioxide did not appear until at least 20 years later in most of the indicators in Figure 24. This is a further sign that climate modelling is still a developing science, with results that may only be accepted with great caution.

101. Furthermore, it will be observed that there is no sign of warming or cooling in the blue "natural forcings" of Figure 24. Yet as Figure 1 indicates, there was natural warming between 1910 and 1950, and cooling between 1950 and 1980. The absence of such temperature swings in the fictitious "natural forcings" of Figure 24 further demonstrates their failure to reflect reality.

South Africa's emissions in context

102. In 2016, South Africa emitted 426 million tonnes of carbon dioxide[53]. It emitted 1.3% of global emissions, and was the fifteenth largest emitter. In this century, its contribution to global emissions has been essentially constant; China's emissions have gone up three-fold and India's have doubled, while the US has curtailed its emissions by about 10%:

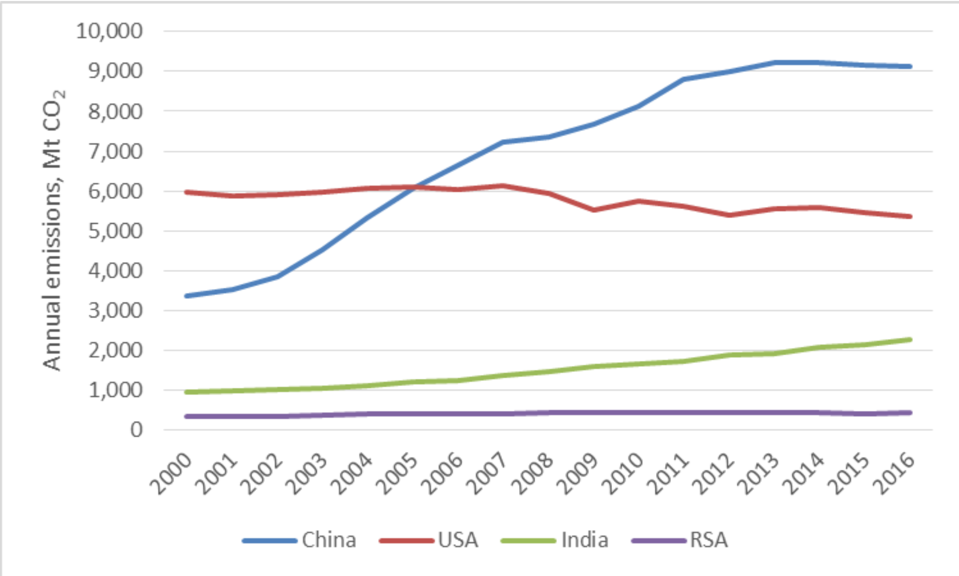

Figure 25 Change in emissions in this century

103. If anything, South Africa is an example to the developing world. The OECD nations have managed to reduce their emissions in recent years. In contrast, the emissions of the non-OECD nations have effectively doubled over this century:

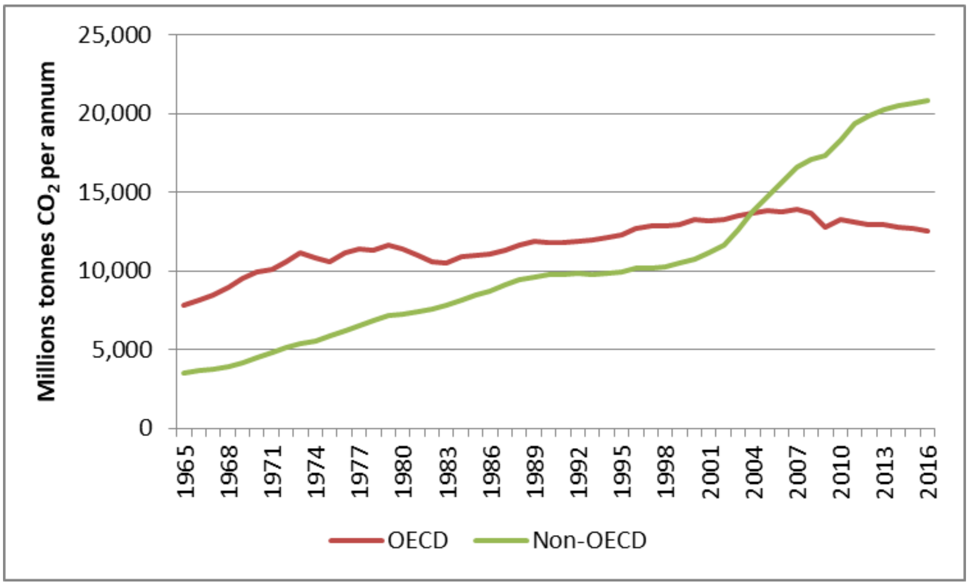

Figure 26 Growth in emissions in OECD and Non-OECD nations since 1965

104. These increases have occurred in spite of international agreements to restrain emissions. The Kyoto Protocol came into effect in 2005, but it only applied to Annex 1 nations – effectively OECD nations. Its targets were modest. It was estimated that the Kyoto protocol would have postponed the effects of global warming by seven days by the end of the century[54]. In 2012, the Protocol was extended by the Doha Amendment, but this has not been ratified. The Protocol has since been succeeded by the Paris Agreement, in terms of which signatories will voluntarily prepare emission reduction targets that will be reviewed and reduced regularly. It will come into force in 2020. Most nations have signed the Agreement, but the US withdrew in 2017, citing excessive costs, and a number of nations have already revised their initial targets upwards. China's contribution is based on "emissions intensity", i.e. emissions per unit of GDP, and it hopes to cut intensity to 60% of the 2005 levels by 2030. If the Chinese economy grows by more than 5% per annum, it will be able to achieve this target with a growth of about 2% annually in its emissions, which would mean 2030 emissions some 25% higher than today.

105. One of the challenges facing the Paris Agreement is its aim to control global temperature rise to less than 2^{o}C above those in 1880. The underlying assumption is that all temperature change is due to greenhouse gas emissions. But this is known to be false. There is a natural variation in global temperatures that is completely unrelated to greenhouse gases. This is implicitly recognized in the Agreement, which has no legal force. Indeed, the thought that mankind could control global temperature is probably a supreme example of wishful thinking. There may be an anthropogenic effect; but control is not possible.

106. In 2011, the South African Department of Environment Affairs produced a white paper on a National Climate Change Response[55]. It is instructive to quote from its opening statement:

"Climate change is already a measurable reality and along with other developing countries, South Africa is especially vulnerable to its impacts. This White Paper presents the South African Government's vision for an effective climate change response and the long-term, just transition to a climate-resilient and lower-carbon economy and society. South Africa's response to climate change has two objectives:

• Effectively manage inevitable climate change impacts through interventions that build and sustain South Africa's social, economic and environmental resilience and emergency response capacity.

• Make a fair contribution to the global effort to stabilise greenhouse gas (GHG) concentrations in the atmosphere at a level that avoids dangerous anthropogenic interference with the climate system within a timeframe that enables economic, social and environmental development to proceed in a sustainable manner."

107. It has to be asked whether "Climate change is already a measurable reality". In previous paragraphs, the measurements of climate change have been reviewed. The review found that, while the world was indeed warming, the measurable effects were primarily on the cryosphere. Glaciers were demonstrably retreating, for instance. But other effects have proved difficult to quantify. There is a general lack of reliable information about the effects on the frequency or amplitude of storms, floods, droughts or any other climate-related phenomenon.

108. Similarly, the evidence for South Africa being "especially vulnerable to its impacts." Is challenging to find. When the putative impacts of climate change were examined, it proved almost impossible to substantiate many of the claims that were made. The spread of insect-borne diseases is, for instance, often cited as a possible impact in a warmer world, but evidence to the contrary was strong.

109. The aim, to "Effectively manage inevitable climate change impacts," is laudable, but in the absence of the supposedly "inevitable" impacts it is difficult to know what actions can possibly flow from this policy.

110. The aim of making "a fair contribution to the global effort to stabilise greenhouse gas (GHG) concentrations" is not unreasonable. However, it has to be asked whether any efforts are "fair" when South Africa has essentially stabilized its emissions for the whole of this century (Figure 25), and its economy has been static, while many other developing nations have increased their economies and their emissions.

111. The extent to which any South African reduction is less than fair becomes clear when the global picture is considered. As shown in Figure 26, emissions have grown annually by about 300 million tonnes of carbon dioxide. South Africa's TOTAL emission are about 425 million tonnes. Even if we were to cut our emissions by half – which in a coal-based economy such as ours is not an easy thing to do – our contribution would be swamped by next year's growth in global emissions.

112. It can only be concluded that while our ambitions to reduce our carbon dioxide emissions are laudable, they are probably misguided at our present state of development. We need economic growth. We have some nine million unemployed, over 30% of those of an employable age. The impacts of climate change are, to all intents and purposes, invisible. The impacts of unemployment are real, present, and truly unavoidable.

<u>Conclusion</u>

The IPCC defines climate change as any change in climate over time, whether due to natural variability or as a result of human activity. What this review has indicated is that any change is difficult to detect; many supposed changes cannot be detected; and that **it is not possible, at present, to ascribe conclusively any detectable changes to human activity.**

If this is accepted, then the obverse is patently true – **it is not possible to show conclusively that human activity will lead to climate change.** Equally, it is certain that ceasing a human activity which is suspected of causing climate change **cannot** have the anticipated effect of stopping climate change – natural variability must still be present, and the climate will continue to change.

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