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Global Warming—Some Perspectives

Anatoly D. Erlykin[1], Arnold W. Wolfendale[2] and Edward Hanna[3]

1. P.N. Lebedev Physical Institute, Moscow 119991, Russia

2. Department of Physics, University of Durham, Durham DH1 3LE, UK

3. Department of Geography, University of Sheffield, Sheffield S10 2TN, UK

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Abstract: Here the authors critically review the IPCC's claim that global warming is "very likely" caused by human activity: such a description underestimates the likelihood of the warming being due to this mechanism. Next examined are known alternative "natural" mechanisms which could give rise to the warming if, despite many claims, the man-made explanation was false because of compensation effects (greenhouse gases versus aerosol effects). Also, a number of difficulties, as yet unresolved, in the human-induced warming explanation are considered.

Key words: Global warming, climate, clouds, aerosols, cosmic rays, meteorites, volcanoes.

1. Introduction

The various processes responsible for human-induced climate-change are well recognised: greenhouse gases (CO_2, methane, halocarbons, ozone, etc.) and aerosols (microscopic particles suspended in the atmosphere). What is not completely clear, however, is their variation in time and space and any resulting amplification or dampening (feedback) effects: most notably, those involving water vapour (and aerosols, which can largely cancel out the warming effect from greenhouse gases). The result is that there is a significant uncertainty in the expected human-induced temperature increase. In what follows, this uncertainty is examined and some specific features of the temperature series for 20^o latitude bands, which the authors view as difficult to explain at the present time, are studied; latitude bands are chosen because of the greater dependence of climate change on latitude than longitude, which is due mainly to the gradient of solar energy receipt between the tropics and poles, and the relative locations of land and ocean.

The various natural effects which are contenders to anthropogenic global warming are also examined, together with some climate problems that defy simple explanation so far.

2. The Uncertainties in Global Warming Attribution

2.1 The "Overall" IPCC Conclusion

As is well known, it is claimed that it is "very likely" (> 90% probability) that global warming is caused by human activity [1]. Their labelling structure means that, statistically, the probability of natural causes could be as high as 10%. Many factors must have been combined to give what is generally regarded by climatologists as an extreme limit with this 10%, i.e. the actual probability of global warming being natural is much lower than this [2].

Our view is that it is important to be more precise than "10%", not least because if it were in fact as high as this then the chance of 50% of global warming being "natural" would probably be approaching 50%, with profound effects for government policies.

Here published data on radiative forcing (the effect of climate change mechanisms, called forcing agents, on Earth's radiation budget) are used as one way of estimating the probability of "natural causes" as being

Corresponding author: Edward Hanna, Ph.D., main research fields: climatology and ice-sheet mass balance. E-mail: ehanna@sheffield.ac.uk.

responsible for global warming.

2.2 The Evidence from Radiative Forcing

The IPCC (2007) and others [3] have listed the various radiative forcings, in watts per square metre ($W \cdot m^{-2}$), both positive and negative. Concerning the important CO_2 and CH_4 contributions, their combined effect is 2.1 ± 0.2 $W \cdot m^{-2}$. There is no criticism of this estimate, assuming that the basic input data are correct [4]. Including all known significant greenhouse gases and the negative forcing due to surface albedo and aerosols (the latter tending to cool Earth's surface through reflection of sunlight), the total net anthropogenic forcing is $+1.55^{+0.75}_{-1.0}$ $W \cdot m^{-2}$.

The "response" comprises water-vapour and ice-albedo feedbacks of magnitude 2.05 ± 1.0 $W \cdot m^{-2}$. Essentially what happens is that, as the world warms, more water vapour can and tends to be held in the atmosphere and also more evaporation occurs from the surface: both factors amplify the warming (water vapour being a potent greenhouse gas). Also, as more ice melts, this darkens the surface, increasing absorption of solar radiation, which also amplifies the warming.

Returning to the former net forcing, the difference from zero is 1.55 error units. Based on the IPCC's premise that the errors quoted represent 90% confidence limits [1], this is equivalent to a probability of 99% of being greater than zero based on a normal statistical distribution modified to take account of meteorological parameters. An approximate check on the validity of this estimated error comes from an analysis of estimates by different workers of the magnitude of the radiative forcing from the Maunder Minimum to the present [5]. With one sigma errors (equivalent to one standard deviation of the various estimates), the radiative forcing is 1.4 ± 0.7 $W \cdot m^{-2}$. The implication is that the one sigma error on the net anthropogenic forcing is nearer 0.7 and thus "1.55 $W \cdot m^{-2}$" is at ~ 2.2 sigma, for which the probability of the 1700-2100 global warming being "natural" is of the order 1%.

2.3 The Evidence from the Difference between the Temperature Observations and the Model Predictions

Formally, inspection of Fig. 1 leads to the conclusion that the uncertainty in both the measured temperature and that estimated by computer models of global climate change is about 0.15 ^{o}C at the one sigma level. However, including the error in the datum temperature, the one sigma error increases to 0.2 ^{o}C. A study of the range of climate-model predictions for the Pinatubo volcano temperature dip (Fig. 1) is consistent with this estimate.

There will be uncertainties common to the predictions and two are identified here: stratospheric water vapour and clouds, the latter being well known as a major problem for climate modellers. Inspection of the water-vapour results [6] yields a one sigma error for the temperature rise of ~ 0.1 ^{o}C. The error for clouds can be estimated from the quoted uncertainty in the radiative forcing for the currently taken reflectivity or albedo for cloud [1]: it is ~ 0.2 ^{o}C at the one sigma level A similar uncertainty is inferred from a comparison of the temperature series with that of total cloud cover (and its constituents [7]). The result is that the temperature rise of 0.7 ^{o}C has an error compounded of one sigma values of 0.2 ^{o}C for observation and 0.3 ^{o}C for prediction, i.e. the rise is 0.7 ± 0.36 ^{o}C: a 1.9 sigma effect. The corresponding chance probability of the temperature rise not being real and due to human-induced greenhouse warming is 3%.

2.4 The Overall Probability of a "Natural" Temperature Increase and the Way Ahead

This study has so far presented two disparate estimates of the probability of the observed temperature increase from about 1960 to the year 2000 being natural: 1% and 3%, both of which are much less than the IPCC's "10%".

It would be natural to conclude that there is little doubt that the temperature increase is caused by humans but such a conclusion would be premature.

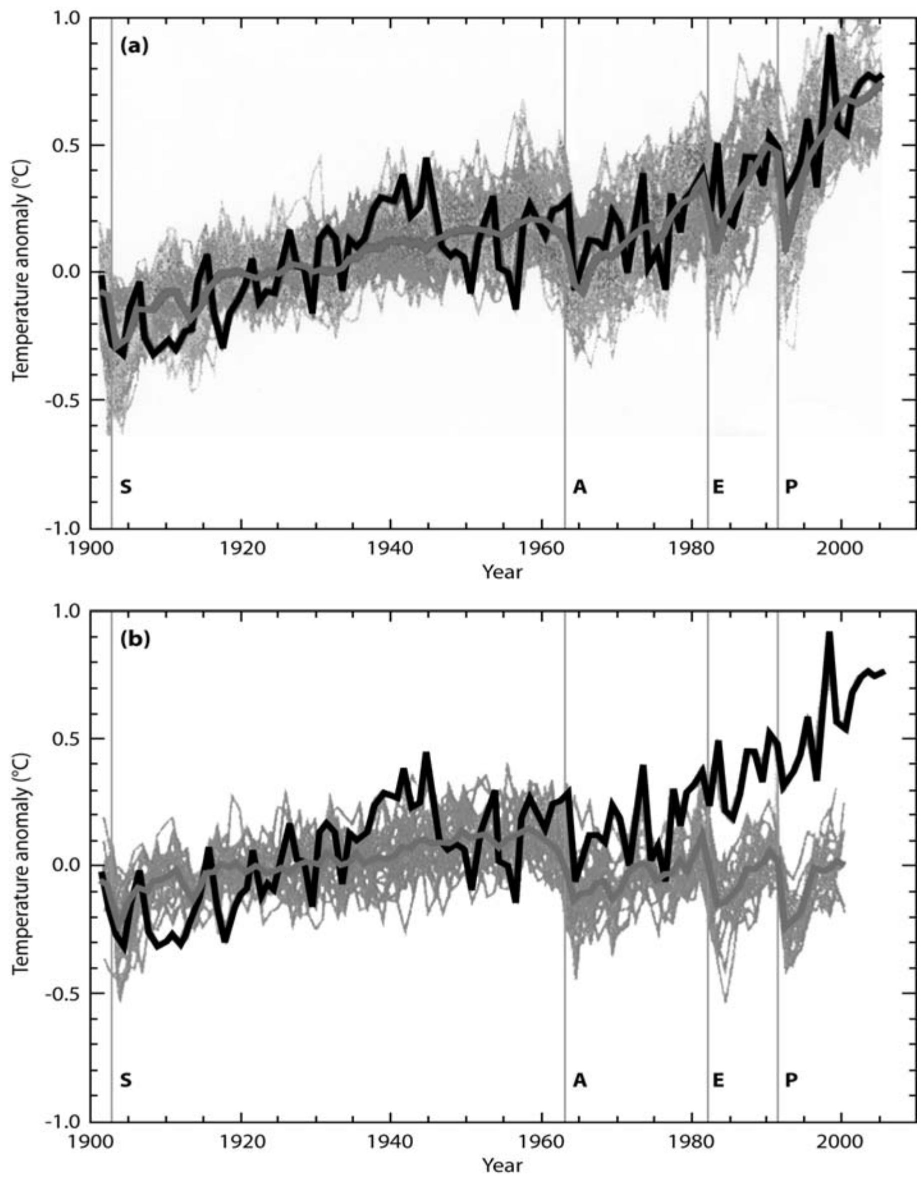

Fig. 1 (a) Global mean surface temperatures over the 20th century from observations (thick line) and as obtained from 58 simulations produced by 14 different models driven by both natural and human-caused factors that influence climate (shaded area with thin grey line as the mean); (b) Atmosphere climate models forced with natural solar and volcanic forcings only i.e. natural forcings (shaded area with thin grey line as the mean) with the observed global mean surface temperature (heavier line reproduced from (a)). Here shaded area and thin grey line show 19 simulations from five models with natural forcings only. Temperature anomalies in both panels are shown relative to the 1901 to 1950 mean. Vertical grey lines indicate the timing of major volcanic eruptions: S—Santa Maria, A—Agung, E—El Chichon, P—Pinatubo. The associated temperature dips are clearly visible (Adapted from Figure 9.5 from the IPCC Fourth Assessment Report WG1 report (2007). Source: Ref. [1]).

There is always the possibility of new observations showing that a particular effect had not been included: an example is the stratospheric water vapour [6], which has changed since 1980 such as to accelerate the decadal rate of temperature change by about 30% in the 1990s and reduce the rate of change over the period 2000-2009 by about 25%. Such changes are not negligible, as indicated in Section 2.3. Another problem is the very recent conclusion that since 2005 there has been significant "missing energy" in the global net energy budget [8]. The magnitude of the current "missing energy", ~1W·m^{-2} is clearly not negligible, being 50% of that associated with CO_2 and CH_4 (see Section 2.2), further remarks about the topic are given later.

Nevertheless, the argument here is that the best estimate of global warming being natural is 1%-3%. If, however, despite the foregoing, the global warming was "natural" in fact then, clearly, there would have to be a reason and in the following section potential "natural causes" are examined to see whether one, or more, of them is a contender.

3. Potential "Natural" Causes of Global Warming

- Cosmic rays: A strong claim has been made that cosmic rays affect surface temperatures [9, 10]. The undoubted correlation of low cloud cover and the cosmic ray intensity over the 11-year solar cycle [11] (at least for Cycle No. 22) led to the claim of a causal connection: the mechanism being that the cosmic ray ionization caused the generation of charged condensation nuclei. The increased cloud cover in turn affected surface temperatures. Although cosmic rays carry an energy of only some 10^{-8} of the solar radiation the cosmic ray hypothesis cannot be ruled out because of the possibility of its effects being amplified and the notorious problems of cloud-induced climate changes. However, in a number of papers, two of us (ADE & AWW) have shown that this mechanism is untenable, not least because the mean cosmic ray intensity has not changed over the past 55 years sufficiently to affect the surface temperature at all [12-14]. Most recently the authors have summarised the effects of cosmic rays and other sources of ionisation, such as radon "hot spots", the Chernobyl accident and nuclear bomb tests, and concluded that cosmic rays contribute less than 1% to the variations of cloud cover, at least averaged over the globe [15]. It is true, however, that regionally (e.g. in the polar regions) the contribution could be substantially higher.
- Solar effects: An adequate increase in solar luminosity could cause the observed increase in global temperature. Indeed, it is very likely that the 0.1% peak-to-peak change in solar irradiance (SI), over the 11-year Solar Cycle, causes a 0.1 ^{o}C change in mean global surface temperature [14]. However, although there was a modest increase in SI from 1880 to 1950 (as evinced by the increase in the mean sunspot number), there has been little change since [14]; indeed the last five years has shown an extended period of low sunspot number and consequently low SI. Although it is highly unlikely that solar changes contributed much to global warming since 1950, it is true that there are doubts about the exact relationship between SI and temperature change [14] and so this is regarded here as one of the outstanding questions to be added to our list (see Section 6).
- Milankovich effects: It is well known that many past changes in global temperatures were associated with changes in the obliquity of the Earth's axis (precession), the eccentricity of the elliptical orbit of the Earth and the time of year when the Sun-Earth distance is smallest (perihelion). The shortest period is the first mentioned (~ 26,000 years) and, although amplification (climate-feedback) effects can (and do) speed up temperature changes, the present increase appears to be too rapid to be explained in this fashion. The fact that the origin of the major Ice Ages is not understood (sudden reduction in CO_2, continental movements, fluctuations in ocean currents?) is a worry but if one of these were happening now, in reverse, it would surely be noticed; the increase in CO_2 is, indeed, happening-from known sources.
- "Statistical" variations over the past 11,000 years: It is often stated that temperature excursions of the magnitude found recently, viz. increases of 0.7 ^{o}C over the past 50 y, 0.9 ^{o}C over the past 100 y and 1.3 ^{o}C over the last 250 y are "not uncommon". Thus, the past temperature record [1] has been examined here for various time intervals, specifically, 1,100 years and 11,000 years. Starting at arbitrary times, the temperature increases/decreases have been determined by the authors over the periods mentioned: 50-year and

100-year intervals over 1100 years and 250-year intervals over 11,000 y. In each case the integral frequency has been determined as a function of temperature change and extrapolation made to the actual recent temperature change. The ensuing probabilities are, for a 1100-year period, about 1% based on 50-year intervals and about 0.1% for 100 year intervals. For 11,000 y and 250-year intervals the resulting probability is approximately 2%. There is virtually no difference between positive and negative temperature changes.

The "2%" just above is worthy of note. It refers to the period 10,000 y ago, when the Earth was rapidly recovering from the last "Glacial", the final stage of recovery from the last Ice Age. The more recent recovery from the "Little Ice Age" has been a much more modest affair; indeed, the latter was not a global phenomenon and the maximum temperature dip was of much smaller magnitude and much shorter duration.

The conclusion is that previous rapid temperature increases of the magnitude found recently are understood whereas the current one cannot be understood without recourse to some other mechanism.

- Geothermal emission changes: Energy from the Earth's interior is potentially important for the Earth's climate but the magnitude of the changes occurring is small, as will be demonstrated. Although there is doubt about the exact magnitude of the heat flow up through the Earth, and its division between various components, it seems that radioactivity is a major source and its magnitude is about 0.06 $W \cdot m^{-2}$ [16]. To put this in perspective, models give a global warming re-radiated energy decrease of 1.7 $W \cdot m^{-2}$, yielding a "thermal fraction" of only 3.5%. Alternatively, using the likely total radiative feedback of 2.8 $W \cdot m^{-2}$ [1, 17], the fraction is 2.1%. Despite the inevitability of a time variability of the "thermal fraction", its effect on global warming is negligible.

- Volcanoes: Volcanoes are important for climate, the rare powerful ones causing significant temperature effects. Indeed, the supervolcanoes of some 300 My ago are credited with considerable temperature falls and significant evolutionary effects. More recent ones such as Toba (74 ky BP) and Taupo (254 ky BP) have also been important. Turning to more recent times, for example, the Pinatubo event of 1991 caused a global temperature reduction of about 0.25 ^{o}C over three years. Its effect can be seen in Fig. 1, as can be reductions caused by three other volcanoes during the last century. An important fact, often overlooked, is that the "efficiency" of the outbursts is very high, the change in oceanic heat content being a million times the energy released. Specifically, the Pinatubo event liberated about 3×10^{14} J, the total energy being about 10^{16} J; the change in oceanic energy was a million times this value [18]. The mechanism by which volcanoes cause terrestrial temperature falls depends on the nature of the emission. If dust predominates the volcanic dust lifted into the stratosphere causes considerable loss of incident sunlight. For those emitting large quantities of sulphur compounds (and Pinatubo was in this category) combination with water vapour leads to a haze of sulphuric acid droplets which yield an even stronger albedo than for dust particles. Although the location and rough magnitude of recent volcanoes are known for several centuries, their effect on climate is not fully determined, however, because the residence time of dust in the atmosphere is determined by the size distribution of the ash particles, which is poorly known and there are similar uncertainties concerning the sulphuric acid haze. Nevertheless, the important recent eruptions are understood with reasonable precision and they have been allowed for in the climate models (Fig. 1).

- Meteoritic and cometary dust: A factor related to the previous section is the undoubted presence of meteoritic dust, probably at the 10% level of total atmospheric dust [19]. One could postulate periodic changes in the stratospheric dust which, by way of albedo changes, could cause "global warming" (i.e. the dust content falling with time so that the albedo has been falling and the surface temperature rising). However, it appears that the major source of such dust is the Taurid meteor stream, a stream associated with the giant Encke comet (Bailey, 2010, private communication). It seems that the peaks of intensity of the stream are 2-3,000 y apart and the next peak is 1,000 y away, thus, from this cause, at least, there should have only been an insignificant change in dust albedo over the last 100 years. However, the necessary more rapid changes cannot be ruled out and this topic is one needing more attention [20, 21].

- Oceanic heat redistribution: There is a systematic change in ocean heat due to global warming and redistribution, but the latter should not have much effect on the former (although there is a worry about the "missing energy" referred to earlier). Thus, the overall temperature rise is not caused by change in oceanic heat. There are potential problems, however, with the oceanic heat budget [8]. Only now are comprehensive oceanic temperature measurements being made, and being accepted, but these show a disturbing near-flattening of the total heat content since 2005. Research on this topic is ongoing; further reference is made later.

4. Some Climate Problems Defying Simple Explanation

4.1 Scope of the Considerations

It is appropriate to mention some aspects of global warming which are not amenable to simple analysis and these will be considered briefly. Mainly considered is the "time series" for surface temperature as a function of latitude range. The authors attempt to understand the similarities and differences and indicate the problems of identification, if any.

It is well known that different climate models predict somewhat different temperature profiles (Fig. 1). These give "fluctuations" which differ in amplitude and "phase" from one model to another and are typically peak-to-peak, 0.15 ^{o}C, 2 y for the whole Earth and 0.5 ^{o}C, 3-8 y for the N hemisphere; the latter may be related to changes of the Arctic Oscillation or North Atlantic Oscillation modes of atmospheric-circulation variability [22]. Thus, for the individual latitude ranges "our" temperature ranges, ~0.5-1.0 ^{o}C, 60 y for the extreme latitudes, are perhaps not unexpected in temperature amplitude but "our" time variability is outside the model-to-model range.

4.2 Latitude Dependence of the Mean Surface Temperature

4.2.1 The Temperature Data and Their Treatment

Although in some parts of the world, surface temperatures have been measured for over a hundred years, the early measurements were inevitably inaccurate. Furthermore, in remote geographical areas, measurements were sparse, if not non-existent. Thus, even contemporary composite temperature time-series will have significant residual errors. The situation is particularly bad for Antarctica, in the latitude band 64^{o}S-90^{o}S, to be considered shortly. The authors use the NASA (National Aeronautics and Space Administration) Goddard Institute for Space Science [23] compendium which covers most of the Earth from 1880 to the present. The exception is the latitude range 64^{o}S to 90^{o}S where the temperature series started in 1905. Insofar as this region will be shown to be important it is considered further, here. It seems that reliable temperature observations in this region did not start until the 1950s [24]. Previous work appears to show that the data prior to 1957 came from one set of meteorological records, only, from Orcadas in the Antarctic Peninsula [25]. Thus, there is uncertainty here. There is uncertainty pre the 1920s in the Arctic, too. The accuracy, or lack of it, of this standard temperature series is a continuing source of concern.

Turning to the latitude distribution of the mean surface temperature versus time as a function of latitude, Fig. 2 gives the results where the opposite hemispheres can be easily compared. Figs. 3 and 4 show the situation where the time-series of Fig. 2 have been smoothed; in Fig. 3, with a 6-degrees of freedom polynomial fit and in Fig. 4 with a 5-year running mean. Fig. 3 also gives a comparison between the overall fit,

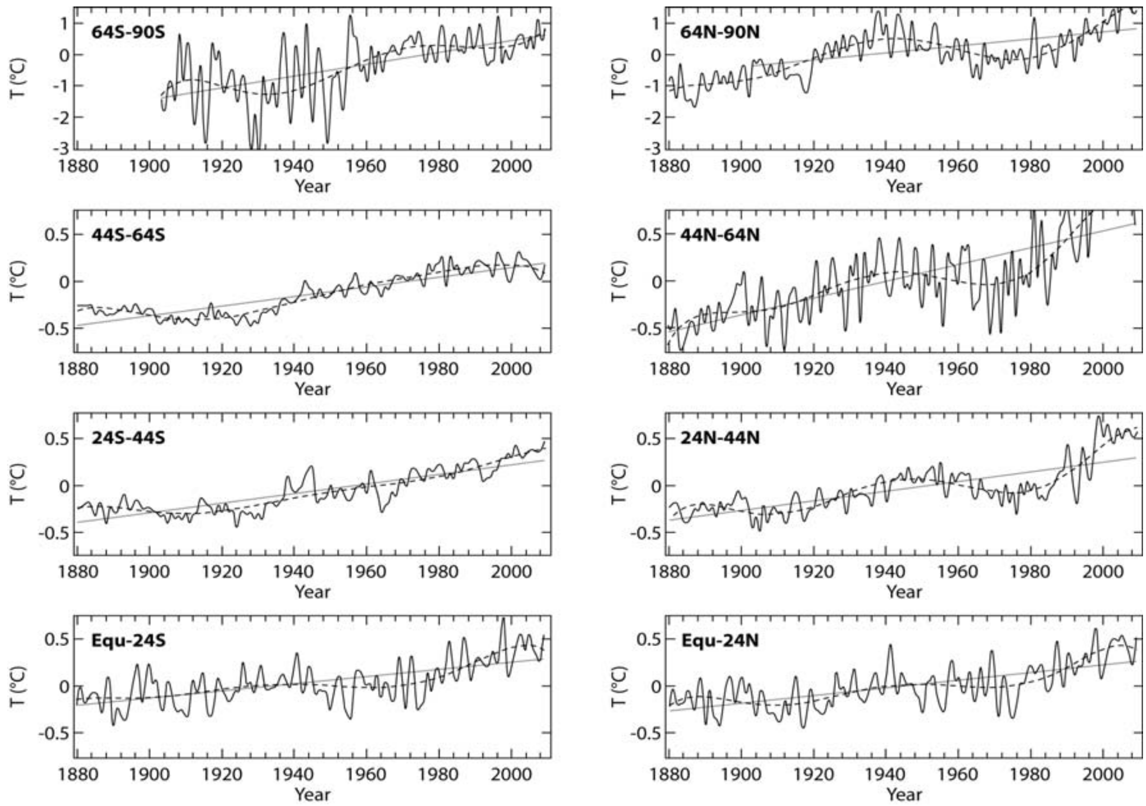

Fig. 2 Monthly mean surface temperature anomaly over the 20th century as a function of the latitude (GISTEMP webpage)—note the comments in the text about the possible inaccuracy in the temperature data before 1950 in the 64°S to 90°S data. Intervals of latitude bands are indicated inside individual panels. Full lines are linear fits, dashed lines—6-degree polynomial fits. Attention is drawn to the change in scale for the two highest latitude ranges.

marked "global mean" and the individual fits. It is apparent that these are differences which need explanation.

It will be noted that the increase in temperature from pre-1920 to 1980 at the highest latitudes is somewhat bigger in the Southern Hemisphere than in the North. Most of the increase in temperature pre-1980 is usually attributed to increases in solar irradiance [5, 26], although there are doubters (Trenberth, private communication). It is not obvious why the latitudinal dependence of the warming should differ so much for solar irradiance changes and for anthropogenic gases such as to give this north-south difference, particularly since the gases are distributed so widely over the globe. It is conceivable that the well-known ozone reduction at high latitudes (the "ozone hole") plays a role. However, although there is evidence for a decrease in ozone with time from 1980 to 1990, such as would be needed to nullify the anthropogenic gas increase, there has been little change in the last two decades at these deep southern latitudes. A more detailed examination will now be given.

4.2.2 Comparison of the Patterns from One Latitude to Another

Starting with Fig. 3 and the large-scale smoothing, it can be remarked that for latitudes between 44ºN and 44ºS there is little difference between the individual and global means. This is a satisfactory result in that it suggests a stability of climate change over much of the Earth (and the likely accuracy of temperature measurements).

For latitudes beyond 44°N and 64°S the situation changes; there are marked differences between north and south and, particularly beyond 64°N and 64°S although there are the problems of accuracy, here, already referred to. For the northern region, the profiles

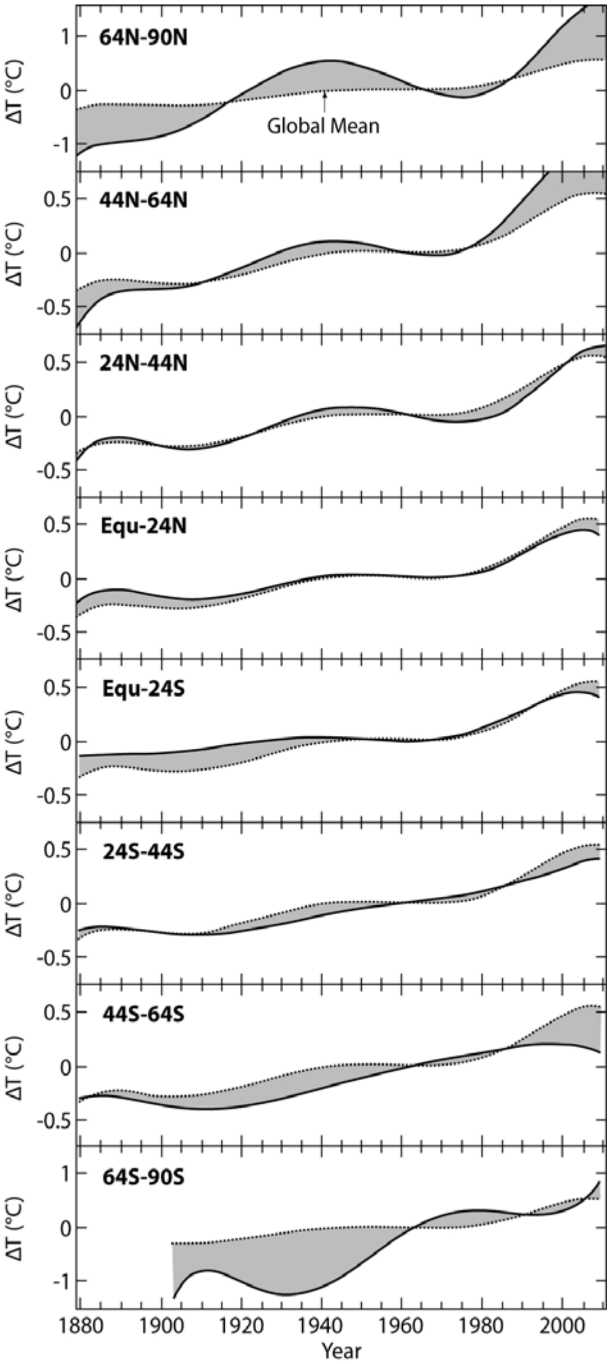

Fig. 3 Comparison of time profiles for temperature anomalies at different latitude bands indicated inside individual panels (full lines) with the global temperature anomaly (dotted line). Shaded areas indicate the marked difference between two profiles at high northern and southern latitudes. The smooth profiles are 6-degree polynomial fits to the 5-year running means of the monthly mean temperatures. Note the comments in the text about the possible inaccuracy of the temperature data before 1950 in the 64°S-90°S data. Attention is drawn to the change in scale for the two highest latitude ranges.

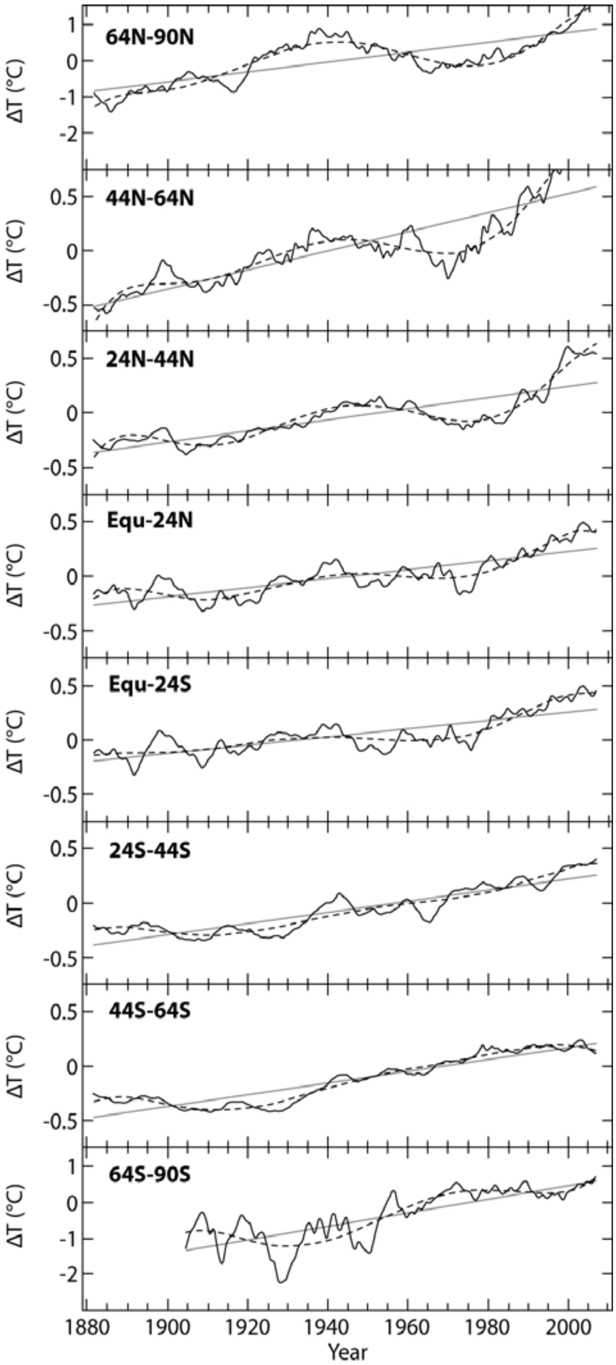

Fig. 4 Fits of the running mean values of the surface temperature anomaly for different latitude bands indicated inside individual panels. Mean temperature anomalies have been averaged over 5-year running time intervals. Full lines—linear fits, dashed lines—6-degree polynomial fit. Note the change in scale of the two extreme latitude ranges.

of the two high latitude regions are very similar, with the excursions for 64°N to 90°N being bigger. Such behaviour is not unexpected in view of the role of polar ice amplifying temperature change at high latitudes.

For the Southern region the shapes are not as closely similar.

The likely reasons for the differences between the profiles and the global mean will be considered later.

4.2.3 Latitudes beyond 44^o

Returning to Fig. 3, it is evident that there are some major features needing explanation. Starting from 1880, there is a large deficit in the Northern Hemisphere (NH) extending to 1900/1910, and this is mirrored in the southern high latitude region, but here extending to 1960. Despite efforts this important feature cannot readily be explained (it is just possible that inaccurate and inadequate temperature data are responsible).

The pronounced bump in 1940, manifest mainly at large northern latitudes, is so strong as to appear in global averages. This peak has already been previously discussed in some detail by the authors [14]. A possibility is that unusually strong burning of biomass was responsible [27]. A feature often responsible for temperature changes is ENSO (El Nino Southern Oscillation) and this is another possibility. Ice cores from the West Antarctic Ice Sheet were examined [28] and attention was drawn to the exceptionally large anomalies occurring in the 1940-1941 period. The anomalies are linked to a strong El Nino event that was unusually persistent—it was the only event in the last century that continued for three years. It seems likely that the 1940s peaks in the SH, such as they are, can be explained in this way.

Evidently the NH 1940s excess cannot be explained in this way however, insofar as inter-hemispheric transfer is not sufficient. Various authors [29-32] have considered the problem. The conclusion appears to be that the excess (an increase in temperature of about 1.7 ^{o}C from pre-1920 at latitudes above 64^{o}N) which contributes to the 1940s peak was purely "natural variability". One mechanism proposed for the variability is that westerly and south-westerly winds north off Norway, lead to enhanced atmospheric and oceanic heat transport from the warm North Atlantic Current. Sea ice feedback completed the temperature rise. However, the likelihood of this explanation needs further study.

An interesting possibility is that the uneven time incidence of volcanoes has contributed to the peak (see also Section 3). Inspection of the parameters of recent volcanoes [29] shows that the decadally smoothed optical depth of the dust (at a wavelength of 0.55 microns) had a pronounced minimum in the period 1920-1940. "Calibrating" using the Pinatubo temperature dips leads to a possible 0.025 ^{o}C increase in temperature over the two decades—a small but non-negligible fraction of the observed bump.

Turning to the situation at later times, there is near-constancy of temperature since 1980 for the two high latitude bands in the Southern Hemisphere: i.e. an increasing loss with respect to the global mean, which is also reflected in relatively stable or even slightly increasing whole Southern Ocean sea-ice coverage over the last 30 years [33] compared with that in the Northern Hemisphere. It is tempting to suggest oceanic changes as being responsible but there are problems. The Southern Ocean heat content [34] down to a depth of about 100 m showed a slow increase from the 1930s to the 1960s, and then a sudden increase by about 0.7 ^{o}C, to the 1970s after which there was constancy. This situation persisted down to a depth of about 200 m, although with a smaller magnitude of increase. At a depth of 500 m, for example, the increase in temperature from the 1940s to the 2000s was about 0.4 ^{o}C. At greater depths, still, (down to 900 m), the increase was smaller even.

The observations of Southern Ocean temperatures at modest depths (down to several hundred m) appear to confirm the surface results, i.e. that there has been little increase in temperature since the 1970s. Interestingly, however, there was a small increase from the 1990s to the 2000s peaking at 0.2 ^{o}C for a depth of 150 m, indicative of a "global warming" of the Southern Ocean from the 1990s to the 2000s. See also Ref. [8] for a summary of later work.

The answer to the temperature flattening is probably to be sought in the atmosphere as distinct from the ocean, by way of the Inter-decadal Pacific Oscillation Cycle, which has a period of 15-30 years. In particular, the SAM (Southern Annual Mode) began a positive phase in the mid 1960s [35] and is continuing.

A contributory cause may be a combination of greenhouse gases and increased ozone loss; a consequence is stated to be an increased cooling [1] (Jones, 2010, private communication). Thus the expected temperature increase could well be nullified. An important suggested consequence of the shift is the remarkable increase in temperature in the Antarctic Peninsula.

Our attitude here is to draw attention to the presence of the 20+ year intrinsic global phenomena (oceanic and atmospheric cycles) which mean that a steady anthropogenic-gas driven temperature rise would not be expected. Thus, the observation of temperature plateaux or even decreases (particularly at a local level) does not negate the overall anthropogenic global warming hypothesis.

5. The Recent Reduction in Overall Temperature Rise

Even more acceptable to the doubters has been the near constancy of the overall mean surface temperature in the 2000s (Figs. 2 and 3). Recent work has highlighted this feature [14] and concluded that statistical variations due mainly to ENSOs could have been responsible. It may be that this explanation can only be confirmed or otherwise by later changes.

6. Conclusions

Despite 97%-99% confidence about the cause of global warming being human-induced greenhouse-gas forcing, which is a significantly greater level of confidence than acknowledged by IPCC AR4 [1], there still remain, however, the following problems:

- Why did the North Polar temperature increase so rapidly from 1880 to 1940? Are the early measurements sufficiently reliable for the rapid rise to be genuine?
- What is the reason for the 1940s “bump” in the northern hemisphere temperature? Recent explanations seem inadequate and at variance with one another.
- Why has there been so little temperature increase since 1980 below 44^{o}S? Again there is uncertainty in the current explanations, although oceanographers consider that they are near to a solution. Perhaps the “missing energy” prominent since 2005 is providing a clue?
- What is the sensitivity of climate to changes in the solar irradiance? This is an old problem that refuses to go away.
- Where has “the missing energy” in the Global Budget gone?

Concerning hypothesised alternative explanation of climate change, one topic appears to need further examination: the possibility of changing meteoritic dust playing a role. The “10%” dust content (in Section 3) may turn out to be an underestimate, particularly in connection with the uncertain size distribution-meteoritic dust could be more efficient than volcanic dust in giving rise to albedo changes.

Despite the problems listed above, the authors consider that, assuming that the above problems are solved, the IPCC conclusion is correct. However, it is incumbent on the IPCC to explain why the 1%-3% probability of the observed temperature change not being man-made surfaces as an unsatisfactory 10% and, furthermore, to be responsive to new observations, some of which have been mentioned here.

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