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A simple climate change projection for the concerned public

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Abstract

The Intergovernmental Panel on Climate Change (IPCC) addresses policymakers with elaborate projections that are difficult for most people to understand. The simplest model is the recent trend in mean annual global warming, and the simplest projection is the extrapolation of the trend line into the future. Amid the annual variation the trend line is an index of the global mean warming at any one time, whereas the IPCC's method of estimation (the 20-year running mean) is retroactive. Until now the trend has been almost linear. Projected linearly into the future (a conservative projection if warming has begun to accelerate), the 50-year data give results similar to the IPCC projections to mid-century, the 20-year data, which have a slightly more rapid rate of change, to less cautious published projections. A mean warming of 1.5C would be reached in 2032 and 2029 respectively. To plot the graphs, and to decide how to project the trend lines into the future, is a simple exercise that avoids much complexity and is open to almost anyone to understand or to perform for themselves. It fosters critical thinking, lessening the gap between the public's perception of climate change and that of climate scientists.

[197 words]

Keywords: Intergovernmental Panel on Climate Change, public understanding of science, climate change, global warming, global mean warming, simplicity.

1. Introduction

Climate science is complex in detail but more broadly straightforward; an understanding of sophisticated climate models is not needed to have an informed view of climate change [1]. The desired policy to reduce the consumption of fossil fuels is also simple in principle, but in practice gives rise to much public discourse that is, for various reasons, confusing or misleading. Consequently, there has long been, and still is, a large gap between the prevailing perception of climate change and scientific reality [2,3].

A return to simplicity is advocated. The basic skill required is the ability to interpret graphs that summarize real-world data [4]. The simplest shows the recent trend in mean annual global warming, and the simplest predictive model is the extrapolation of the trend line into the future. A picture or diagram is said colloquially to be worth a thousand words (empirical studies suggest a range from 84 [5] to 10,000 words [6]), but more importantly the exercise is open to almost anyone to understand or to perform for themselves. The simple projections are consistent with the Open Science principle of disseminating scientific knowledge beyond the traditional scientific community [7].

1.1. Intergovernmental Panel on Climate Change

The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 by the United Nations Environment Programme and the World Meteorological Organization to undertake authoritative studies of the climate and climate change, and to be the scientific advisory body to the UN. In serving this purpose it has so many collaborators that its findings have the character of a wide consensus, but the IPCC is also a single institutional entity, and as such its output is open to question on three

grounds: the size of its assessments, the elaboration of its projections, and the status of some of its findings.

First, the IPCC's assessments are so large as to be inevitably conservative [8,9]. Public disagreement that might be used as an excuse for inaction is avoided to the extent possible, so high-end estimates tend to be excluded, and scientists who are outspoken are excluded for similar reasons. Scientists' reputations are less likely to be harmed by underestimates, an anxiety increased in the field of climate change by the threat of attack by hostile commentators, and if the private views of some collaborating scientists differ from their official views, as they do [10], to air such differences would also risk reputational damage [11]. Making matters potentially worse, the IPCC is subject to lobbying by national governments, some of whom are lukewarm or even antagonistic to the idea of climate change action [12].

Second, for most people among the concerned public and in public life, the IPCC's assessments are too elaborate to be easily understood. Even the *Summaries for Policymakers* are so dense that it is doubtful that policymakers, who are largely unschooled in science, really do read and understand them. They create an air of monolithic authority that is sometimes reinforced with mystique. A 2021 projection that there was a 40% chance of an outlying warm year reaching +1.5C by 2026 was said to incorporate the expertise of internationally acclaimed climate scientists and the best prediction systems in 11 countries [13], even though the projection was unsurprising.

Third, some of the IPCC's findings are questionable. Its integrated assessment models are said to be so wishful that they have been described by former senior insiders as fantasy [14], and the measures they assume for removing carbon dioxide from the air as so hypothetical as to be carbon unicorns [15] or science fiction [16]. Long-term projections to mid-century, 2100 and beyond have a comforting remoteness but do not,

as they seem to imply, render the distant future knowable or tractable. Instead they suggest reliance on starting assumptions that are implausible. For instance, in a low-emissions scenario, GDP growth in the Global South will not be overtaken by persistent climate change impacts until 2200, that is for another 175 years [17]. In addition, some warming is excluded from the anthropogenic account simply by making a category (called ‘indirect’) to exclude the warming due to self-reinforcing (positive) climate feedbacks such as wildfire and the increasing emissions of methane from (warming) wetlands [18]. In such ways physical reality is challenged by an administrative reality of metrics and semantic nicety.

In an example of questionable scientific practice, according to the IPCC’s sixth Assessment Report [19]:

> … low-likelihood outcomes such as ice-sheet collapse, abrupt ocean circulation changes, some compound extreme events and greater warming than expected cannot be ruled out and are part of risk assessment.

In this statement the term ‘risk assessment’ appears to refer to the statistical error of estimation, allowing low confidence in a certain estimate, owing to lack of data or high variability, to be interpreted by an uncritical reader as unlikely. The reasoning is especially faulty because, as more is learnt about complex processes, errors of estimation (hence the width of the confidence limits) may well increase, a process called negative learning [20]. Risk assessment requires an estimate of likelihood and impact (to give the traditional risk matrix common in business) and so does not apply to unknowns [21]. To imagine that policymakers evaluate the IPCC’s findings in a judicious risk assessment exercise [22] is fanciful.

1.2. Global mean near-surface temperature

International accords and public discourse are dominated by the global mean near-surface temperature thresholds of +1.5C and +2C. Many sources of variation affect this mean, which consequently varies from year to year.

The Arctic is warming up to four times faster than the rest of the world [23]. The land is warming faster than the surface waters of the ocean (exceeding 2C and 1C of warming respectively for the first time in 2023 [24]). Sea surface temperatures contribute to the global mean data rather than the air temperatures near the ocean surface because they are relatively easily measured from buoys and satellites, but the two are warming at different rates [25]. And the temperature of the surface waters is very dependent on the degree to which they mix with deeper (generally colder) waters. Surface warming reduces this mixing [26,27], reducing the amount of heat absorbed by the deep ocean [28] and making marine heatwaves of the surface waters more likely [29]. Numerous climate-related phenomena are cyclical, interrelated or subject to feedback processes, adding to the variation.

The IPCC's method for determining the global mean near-surface temperature is the 20-year running mean [30], an appropriate method for years of interest that have retreated at least 10 years into the past. In a method involving lesser delay, three consecutive years warmer than +1.5C would give better than 90% confidence that this threshold had been reached [31]. Instantaneous (ie. non-retroactive) estimates include the mean of the last 10 years combined with model data for the next 10 [30] and inference from a trend line fitted to a time series of annual means. These are not future-proof nor consistent with existing IPCC practice [30], but an instantaneous method is desired to inform the public [32]. A trend line can also be extrapolated to predict a future global mean temperature. A linear extrapolation of a 30-year dataset

gives +1.5C in 2033 [33], extrapolation by a non-parametric method gives +1.5C in 2030 [34].

2. Methods

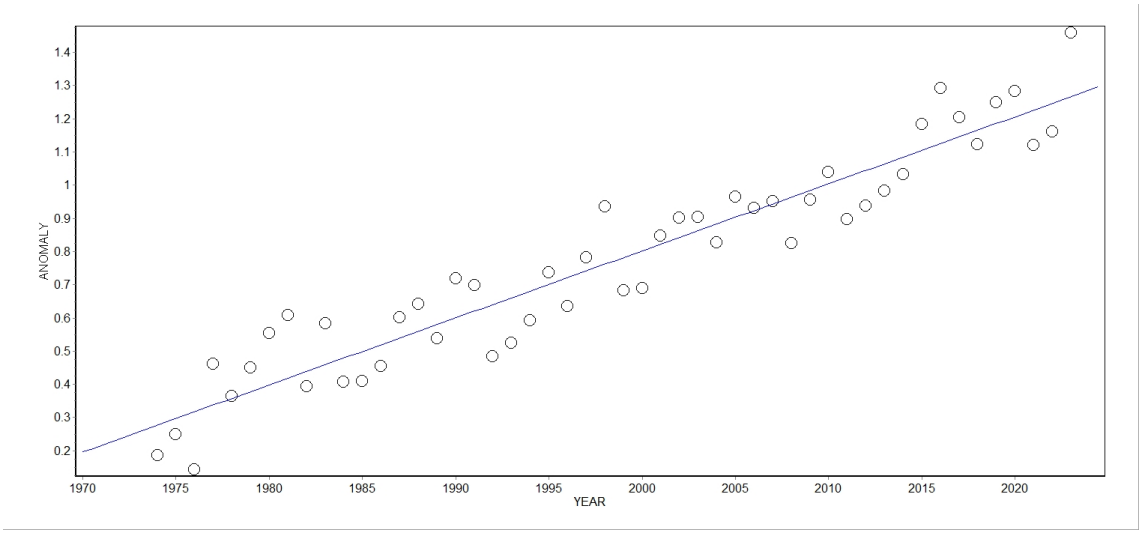
HADCrut5.2 data, one of several independent datasets that estimate global near-surface temperature [35], were downloaded in January 2024. The mean global temperature for 1850–1900 was calculated (the pre-industrial mean), and the difference between that value and each of the last 50 years of mean annual data was determined as the temperature anomaly (ie. the amount of warming). Simple linear regression lines were fitted using the statistical software INSTAT, University of Reading.

The anomaly data were plotted to show the trends in global warming over the last 50 years (1974–2023) and the last 20 years (2004–2023).

3. Results

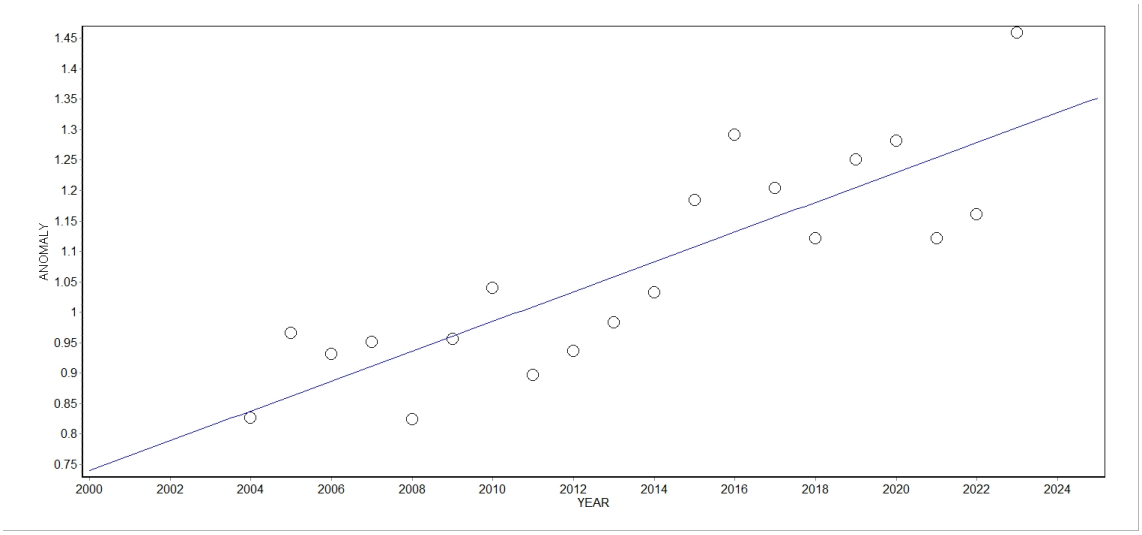
The results are presented in Figs 1 and 2.

Figure 1. **Global warming as the temperature anomaly (mean annual global near-surface temperature minus the pre-industrial mean) over the last 50 years (1974–2023)**.



The Earth has warmed approximately linearly, as the fitted line emphasizes. HADCrut5.2 data accessed January 2024.

Figure 2. **Global warming as the temperature anomaly (mean annual global near-surface temperature minus the pre-industrial mean) over the last 20 years (2004–2023)**.



The trend line is steeper than that in Fig 1, giving about 0.24C of warming per decade compared to 0.20C, but there is less statistical confidence in the line. HADCrut5.2 data accessed January 2024.

3.1. Linear extrapolations

A trend line as in Fig 1 or 2 is an easily understood index of the global mean near-surface temperature any one time and is based on real-world data. It gives means for 2024 of approximately 1.30C and 1.35C. A linear extrapolation of the trend line in Fig 1

gives means of +1.5C and +2C in 2032 and 2054 respectively, similar to the output of an ensemble of IPCC models [36], while Fig 2 gives means of +1.5C and +2C in 2029 and 2040 respectively, close to the less cautious prediction of Hansen and Sato [37]. The linear projection of the 20-year data is less conservative than that of the 50-year data because the trend line is slightly steeper (about 0.24C of warming per decade compared to 0.20C), but with less statistical confidence in the line (r^2=0.72 cf. 0.90). At least at present, simple linear short-term projections are reasonably close to more complex published projections.

3.2. Non-linear extrapolations

It is likely that warming is accelerating [38]. Greenhouse gases in the atmosphere continue to increase while air pollution in the form of (cooling) aerosols decreases [4,39]. According to the mainstream view the outlying high datum for 2023 is largely unexplained, notwithstanding the onset of el niño in mid-2023 [40]; 2024 is likely to be as warm or warmer [41]; and in the next five years an outlying warm year could reach as high as 1.8C above the pre-industrial mean [42].

Positive climate feedbacks, of which there are many, are adding to the acceleration, and under business-as-usual will increase in magnitude. Several tipping points could tip if warming exceeds 1.5C [43], or could have tipped already, to give an entirely new climate system. In a striking example, if the Atlantic Meridional Overturning Circulation were to fail, within decades sea ice in March in the vicinity of western Europe would extend southward as far as Upper Normandy [44]. Positive feedbacks due to humanity are also significant and easily overlooked. Climate-related loss and damage has to be made good, while the use of air conditioners has tripled since 1990 (by 2018 consuming 10% of the world's electricity), and is projected to triple again by 2050 [45].

Alternatively, carbon emissions may decrease. Much reliance is put on the increase in renewable energy but this has done little more than keep pace with the increase in demand, increasing its global contribution from 13% to 15% in the first 20 years of the 21st century [16]. Emissions could decrease owing to policy change such as a carbon tax with border tariff and dividend [46], hoped-for innovation yet to be seen, or any measure that constrains growth such as restricting the exploitation of new oil and natural gas fields [47], banning harmful advertising [48] or increasing the cost of private travel. However, for 50 years, greenhouse gases in the atmosphere have increased largely uninfluenced by any finding of climate science, UN accord, environmental policy, technological innovation, protest, exhortation or physical harm, and this insensitivity suggests that a substantial reduction will only come about through force of circumstance.

The financial crash of 2008 occurred when confidence was lost that mortgage debt could be repaid, and emissions dipped owing to the consequent loss of economic activity. Banks continue to create mortgage debt *de novo* and indefinitely [49], and a more permanent decline in the value of property is also easy to envisage. The assets of carbon extractors and emitters are most at risk [50], but much other property will become ‘stranded’ as insurance premiums increase owing to damage from extreme weather events. In the US the loss due to the largest events now costs about $120 bn per year compared to $21 bn per year during the 1980s [51]. Insurance premiums have increased to the extent that two out of three US dwellings are already underinsured [52] but building continues in high-risk areas [53]. Similarly, property valued at over £200bn in England and Wales is at risk of flooding yet dwellings continue to be built on floodplains [54].

Any projection, however intricate, is at least partly a guess because the future is at least partly unknown. It is clear that non-linear or any but short-term extrapolations are extremely conjectural.

4. Discussion

Young people and the concerned public have long had a poor understanding of the seriousness of climate change [2], but to exert wholesome influence on science-related policy they must be reasonably well informed [55]. The reports and projections of the IPCC are difficult for most people to understand, but simple climate projections are shown to be a reasonable approximation. As an active exercise that almost anyone can understand or perform for themselves, the simple projections foster critical thinking and reduce reliance on argument from authority. The sense of agency could also have a desired visceral impact [56], increasing disquiet for a future shaped by climate change.

The exercise has three further advantages over IPCC reportage. It is guaranteed free of conservative influence; the global mean near-surface temperature at any one time is easily inferred; and young people and the concerned public are helped to come to their own conclusions regarding the merits or otherwise of climate policy.

The IPCC is concerned to avoid disputation that would assist those interests vested in climate delay, and to this extent its conservatism and air of institutional authority are advantageous. Another often-mentioned justification for conservatism is the notion that optimism overcomes fatalism to encourage positive behaviour change [57], but this view is disdainful of the public [58]; in an apt analogy a patient must be given both a (fearful) diagnosis and a (hopeful) course of treatment before having a compelling reason to act [59]. Some individual IPCC authors nevertheless play down otherwise

alarming evidence, but in due course this gives rise to either continued reassurance or expressions of surprise, and results in the very public disagreement that is to be avoided. Thus, the warming of 2023 has been described as ‘entirely predicted’ [60]), or alternatively has ‘come out of the blue‘ [61].

In interpreting such difference a clear distinction is to be made between global mean warming, a relatively conservative and accurately modelled index of the Earth’s heat imbalance (at least until 2022), and the many other changes to the Earth system that have been occurring more quickly than expected. Even 20 years ago, among what were then thought to be slow feedbacks, it was noted that the ice sheets had begun disintegrating ‘a century ahead of schedule’ (Richard Alley cited in [62]), and in relation to the weather extremes of 2023 Dr Caroline Holmes of the British Antarctic Survey said: ‘We don’t really understand the pace of change ... we’ve fallen off a cliff without knowing what’s at the bottom’ [63].

The estimation of the global mean near-surface temperature will attract increasing attention as the +1.5C threshold approaches. The trend lines of Figs 1 and 2 are reasonable indices of this mean at any one time, are easily understood and are based on real-world data. To extrapolate a trend line into the future is a simple way of predicting when a particular mean is to be reached. More years in the time series add to confidence, but only if the model is good over the whole range. If a straight-line model is preferred while still accepting the possibility of acceleration, a relatively short time series might be preferred (as in Fig 2 cf. Fig 1).

The terms of reference of the IPCC are to support policymakers, but over several decades climate policy has had no discernible effect on the increase in greenhouse gas emissions. The policy is widely regarded as faulty [64], and in deferring to it IPCC authors have been admonished for forgoing their academic independence [65] or for

quiescence amounting to irresponsibility; ‘the path to disastrous climate change is paved with feasibility studies and impact assessments’ [14]. However, since the IPCC addresses policymakers, support for policy is presumably a *sine qua non* of participation, and even when former insiders or respected outsiders dissent it seems to have little influence on mainstream public discourse. Under these circumstances it would be helpful if a large and trusted institution other than the IPCC [10], such as the World Meteorological Organization [32], introduced a reporting procedure specifically for the concerned public.

5. Conclusion

The reports and projections of the IPCC are difficult for most people to understand. Simple climate projections, that almost anyone can understand or perform for themselves, are shown to be reasonable approximations to more complex published projections. This return to simplicity would help young people and the concerned public to interpret the evidence of global warming for themselves, to easily see the trend in global mean temperature and to reflect critically on the merits or otherwise of climate policy. It would lessen the gap between the prevailing perception of climate change and scientific reality.

Data accessibility

The data can be found here [35].

Ethics statement

The study complies with the ethics guidance of UCL.

Conflict of interest declaration

The author declares no conflict of interest.

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