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A simple climate change projection for the concerned public

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1 **A simple climate change model for the concerned public**

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3

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7

8 **Abstract**

9 The Intergovernmental Panel on Climate Change (IPCC) addresses policymakers with
10 elaborate models and projections of global warming that are difficult for most people to
11 understand. The simplest model is the trend line in the recent global mean annual
12 near-surface warming data, and the simplest projection is to extrapolate the line into
13 the future. Over the 50 years 1974–2023 the trend has been close to linear with a
14 mean rate of increase of 0.20C per decade. The 20-year time series (2003–2022) gives
15 the very similar rate of 0.21C of warming per decade, but annual updates (2004–2023
16 and 2005–2024) give rates of 0.24C and 0.27C per decade respectively. Amid the high
17 variation from year to year the trend line is a practical index of the mean near-surface
18 warming at any one time, and projected linearly into the future the trend line for the
19 2005–2024 time series predicts +1.5C and +2C in 2029 and 2047, not dissimilar to
20 more complex projections. Such simple exercises are open to almost anyone to
21 understand or to perform for themselves, and could help to lessen the large gap
22 between the public perception of climate change and scientific reality.

23

24 **Keywords:** Intergovernmental Panel on Climate Change, public understanding of
25 science, concerned public, science education, global warming, simplicity.

26

27 1. Introduction

28

29 The desired policy to reduce the consumption of fossil fuels is simple in principle, but in
30 practice it gives rise to much public discourse that is, for various reasons, confusing or
31 misleading. Climate science is also broadly straightforward (if complex in detail), so
32 that an understanding of sophisticated climate models is not needed to have an
33 informed view of climate change [1]. The basic requirement is the ability to interpret
34 graphs that present real-world data [2]. The simplest graph shows the recent trend in
35 the global mean annual near-surface warming, and the simplest projection is the
36 extrapolation of the trend line into the future. Such exercises are open to almost
37 anyone to understand or to perform for themselves, and could help to lessen the large
38 gap between the prevailing perception of climate change and scientific reality [3,4].

39

40 Much climate information effectively dates from 2020 (the last Intergovernmental Panel
41 on Climate Change assessment report) [5]. Forster and colleagues [6] give an annual
42 update that follows IPCC methods and is therefore to be trusted by all associated
43 parties, but this purpose does not lend itself to easy comprehension by the concerned
44 public. Plainer communication is also desired ([7,8]).

45

46 This paper presents the recent trend in global mean annual near-surface warming in
47 four time series, considers extrapolation of the trend lines, and illustrates the utility of
48 such exercises in informing young people and the concerned public. First, the function
49 of the IPCC as an institution, the definition of the global mean near-surface
50 temperature and the uncertainties of extrapolation are briefly reviewed.

51

52

53

54 1.1. Intergovernmental Panel on Climate Change

55

56 The IPCC was established in 1988 by the UN Environment Programme and the World
57 Meteorological Organization to undertake authoritative studies of the climate and
58 climate change, and to be the scientific advisory body to the UN. In serving this
59 purpose it has so many collaborators that its findings have the character of a wide
60 consensus, but the IPCC is also a single institutional entity, and as such its output is
61 open to question on three grounds: the size of its assessments, the elaboration of its
62 projections, and the presentation of its results.

63

64 First, the IPCC's assessments are so large as to be inevitably conservative [9,10].
65 Public disagreement that might be used as an excuse for inaction is avoided to the
66 extent possible so high-end estimates tend to be excluded, and scientists who are
67 outspoken are excluded for similar reasons. Scientists' reputations are less likely to be
68 harmed by underestimates, an anxiety increased in the field of climate change by the
69 threat of attack by hostile commentators, and if the private views of some collaborating
70 scientists differ from their official views, as they do [11], to air such differences would
71 also risk reputational damage [12]. In addition, the IPCC is subject to lobbying by
72 national governments, some of whom are lukewarm or even antagonistic to the idea of
73 climate change action [13].

74

75 Second, for most people, the IPCC's assessments are too elaborate to be easily
76 understood. Even the *Summaries for Policymakers* are so dense that it is doubtful that
77 policymakers, if unschooled in science, really do read and understand them. They
78 create an air of monolithic authority that sometimes approximates to mystique. Global
79 climate models are so complex that leading modellers are gatekeepers to knowledge

80 about the climate [8], and the associated esoteric language raises the bar for popular
81 participation [14].

82

83 Third, the presentation of some of the IPCC's findings is questionable. Its integrated
84 assessment models, which combine science with economics, omit many big risks [15]
85 and are wishful [16], and very long-term projections to 2100 and even 2200 have a
86 comforting remoteness but do not, as they seem to imply, render the distant future
87 knowable or tractable. Some feedback-related warming, such as that due to the
88 increasing emissions of methane from (warming) wetland, is also excluded from the
89 anthropogenic account [6].

90

91 1.2. Global mean near-surface temperature

92

93 Global mean annual near-surface temperature is estimated precisely but integrates
94 many diverse climate phenomena and so varies appreciably from year to year. The
95 Arctic is warming up to four times faster than the rest of the world [17]. The near-
96 surface of the land is warming faster than the surface waters of the ocean (exceeding
97 2C and 1C of warming respectively for the first time in 2023 [18]). Sea surface
98 temperatures contribute to the global mean data rather than the air temperatures near
99 the ocean surface because they are relatively easily measured from buoys and
100 satellites, but the two are warming at slightly different rates [19]. And the temperature
101 of the surface waters is very dependent on the degree to which they mix with deeper
102 (generally colder) waters. Surface warming reduces this mixing [20,21], reducing the
103 amount of heat absorbed by the deep ocean and making marine heatwaves of the
104 surface waters more likely [22]. Numerous climate-related phenomena are
105 unpredictable, cyclical, interrelated or subject to feedback processes, adding to the
106 variation.

107

108 International accords and public discourse are dominated by the global mean near-
109 surface temperature thresholds of +1.5C and +2C above the pre-industrial mean. While
110 no better policy objectives have been proposed, they are arbitrary (for instance
111 depending on the definition of the pre-industrial mean), and have a static quality that
112 diverts attention from the dynamism of the climate including rates of change.

113

114 The IPCC's method for determining the global mean near-surface temperature is the
115 20-year running mean [23], the authoritative method for years of interest that have
116 retreated at least 10 years into the past. In a method involving lesser delay, three
117 consecutive years warmer than +1.5C would give better than 90% confidence that this
118 threshold had been reached [24], while instantaneous (ie. non-retroactive) estimates
119 include the mean of the last 10 years combined with model data for the next 10 [23]
120 and inference from a trend line fitted to a time series of annual means, as in this paper.
121 These latter methods are not future-proof nor consistent with existing IPCC practice
122 [23], but a non-retroactive method is clearly needed [25].

123

124 1.3. Extrapolation

125

126 To extrapolate is to estimate beyond a known range. It is not to be trusted but may
127 have a speculative purpose. The inertia in Earth processes and human society
128 suggests that short-term climate projections are not unreasonable, but longer-term
129 projections, however intricate, are increasingly and inevitably prone to error.

130

131 An extrapolation may be linear, upward or downward. Among the upward influences on
132 the rate of global near-surface warming, the increase of CO₂ in the atmosphere has
133 been accelerating on a timescale of decades [26]. The Earth's ocean heat content [27]

134 and energy imbalance [28] have also been accelerating since the 1960s, and the rate
135 of sea level rise doubled over 20 years from 2.1mm per year (1993–2002) to 4.8mm
136 per year (2014–2023) [29].

137

138 The global mean near-surface temperature itself also appears to be accelerating on a
139 decadal timescale. It increased by 0.14C and 0.21C in the decades 1991–2000 and
140 2001–2010 respectively [30], while the estimated decadal rate 2010–2023 is 0.30C
141 [31]. Recent climate models predict 0.29C per decade (2015–2050) [32] and 0.32C per
142 decade (2011–2050) [33]. Positive climate feedbacks, such as the loss of albedo as the
143 Arctic ice retreats [34], are expected to contribute to the acceleration under business-
144 as-usual. The rapid acceleration in 2023 and 2024 will not be sustained for long if
145 caused mainly by the introduction of cleaner ships' fuels [8].

146

147 Alternatively, warming could slow down as emissions decrease, perhaps owing to
148 policy change such as a carbon tax with border tariff and dividend [35], hoped-for
149 innovation or any measure that constrains growth. However, for 50 years, greenhouse
150 gases in the atmosphere have increased apparently unperturbed by any environmental
151 accord or policy, and this insensitivity suggests that a substantial reduction will only
152 come about through force of circumstance.

153

154 2. Methods

155

156 HADCrut5.2 data, one of several independent datasets of global near-surface
157 temperature [19], were downloaded in January 2025 [36]. The mean global near-
158 surface temperature for 1850–1899 was calculated (the pre-industrial mean), and the
159 difference between that value and each of the last 50 years of global mean annual
160 near-surface data was determined as the temperature anomaly (ie. the amount of

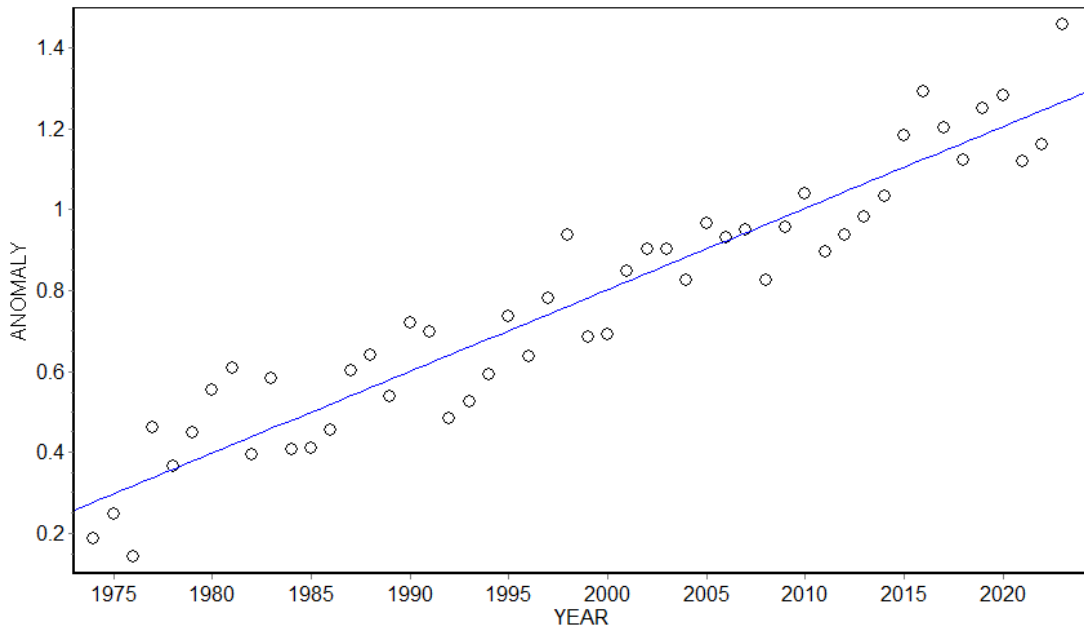
161 warming). Simple linear regression lines were fitted using the statistical software
162 INSTAT, University of Reading.

163

164 The anomaly data were plotted to show the trends in global warming over the last 50
165 years (1974–2023) and in three 20-year time series (2003–22), (2004–23) and (2005–
166 24).

167

168 3. Results



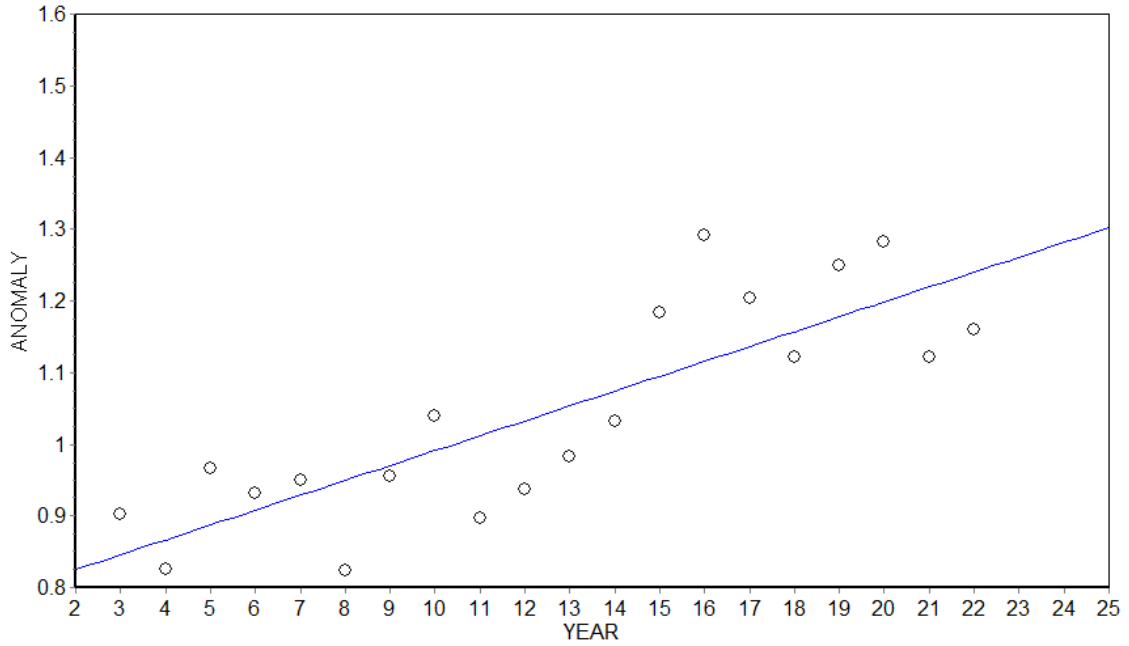
169

170

171 Figure 1. Global warming as the temperature anomaly (global mean annual near-
172 surface temperature minus the pre-industrial mean) over the last 50 years (1974–
173 2023). The Earth has warmed approximately linearly, as the fitted line emphasizes.

174

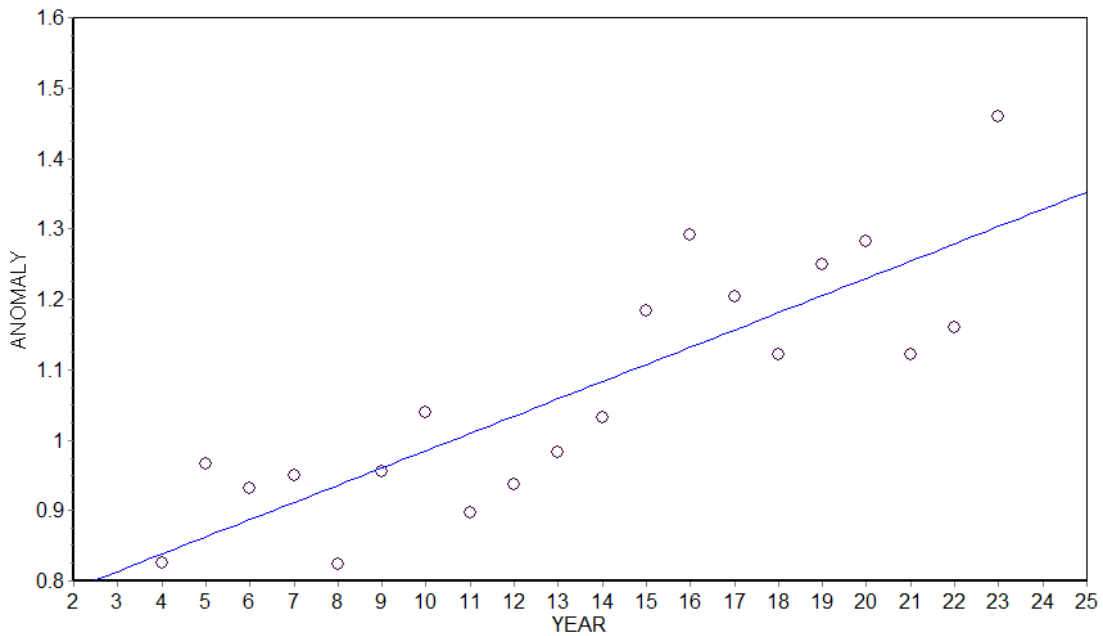
175



176

177 Figure 2. Global warming as the temperature anomaly (global mean annual near-
178 surface temperature minus the pre-industrial mean) over the 20 years 2003–2022. The
179 trend line gives a similar rate of warming to that in Fig 1, about 0.21C of warming per
180 decade compared to 0.20C.

181

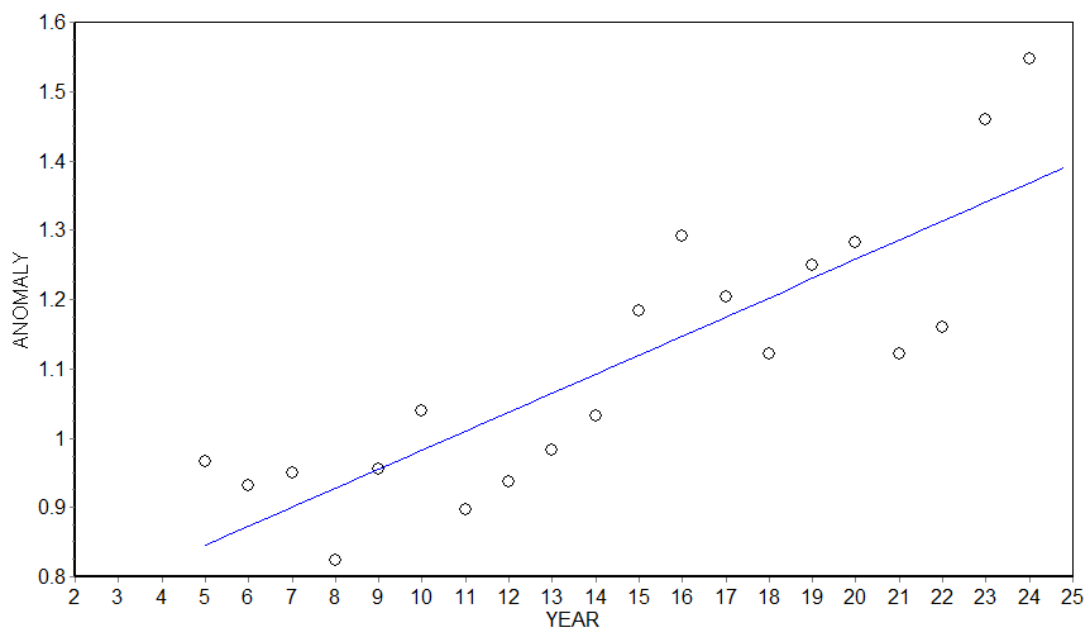


182

183 Figure 3. Global warming as the temperature anomaly (global mean annual near-
184 surface temperature minus the pre-industrial mean) over the 20 years 2004–2023. The
185 trend line, now including the high outlier for 2023, gives a rate of warming of 0.24C per
186 decade.

187

188



189

190 Figure 4. Global warming as the temperature anomaly (global mean annual near-
 191 surface temperature minus the pre-industrial mean) over the 20 years 2005–2024. The
 192 trend line, now including the two high outliers of 2023 and 2024, gives a rate of
 193 warming of 0.27C per decade.

194

195 The trend lines shown in the Figures are the linear:

196 (i) Anomaly = (0.0202 × Year) – 39.59 $r^2 = 0.90$ (Fig 1; 50 years 1974–2023)

197 (ii) Anomaly = (0.0208 × Year) + 0.7835 $r^2 = 0.68$ (Fig 2; 20 years 03–22)

198 (iii) Anomaly = (0.0245 × Year) + 0.7401 $r^2 = 0.72$ (Fig 3; 20 years 04–23)

199 (iv) Anomaly = (0.0274 × Year) + 0.7091 $r^2 = 0.72$ (Fig 4; 20 years 05–24)

200

201 Fig 1 shows that the Earth warmed approximately linearly over the 50 years to 2023 at
 202 the rate of 0.20C per decade. In this time series the datum for 2023 is seen to be a
 203 high outlier but comparable to the earlier high outliers of 2016 and 1998 (all el niño
 204 years), although in more sensitive models the 2023 datum was 0.2C higher than
 205 predicted [37].

206

207 The 20-year time series 2003–2022 (Fig 2) has a very similar rate of warming (0.21C
 208 per decade) to that of Fig 1, but updating the 20-year series by one year (2004–2023)

209 increases the rate to 0.24C per decade (Fig 3), and a further update of one year
210 (2005–2024) gives 0.27C per decade (Fig 4).

211

212 3.1. Linear projections

213

214 In the linear extrapolation of the 50-year data, the world reaches +1.5C and +2C in
215 2034 and 2059. The trend lines of the progressively updated 20-year time series
216 increase in steepness, the linear extrapolation of the most recent (2005–2024) giving
217 +1.5C and +2C in 2029 and 2047. This is not dissimilar to the 2031 and 2043 predicted
218 in a high-emissions scenario [38], or the 2032 and 2052 predicted for an ensemble of
219 models [39].

220

221 The linear extrapolation of the 2005–2024 trend line predicts an annual mean of
222 +1.39C for 2025, not dissimilar to the Met Office's central estimate of +1.41C [40].
223 Referring to Fig 4 and envisaging the 20-year data 2006–2025, this implies a further
224 increase in the rate of warming (to 0.29C per decade; data not shown).

225

226 Annual updates (as in Figs 3 and 4) are very easy to perform but are to be treated with
227 caution. They are helpful in showing rates of change, supplementing the attention
228 generally given to annual means and the static (and somewhat thought-terminating)
229 thresholds of +1.5C and +2C. If near-surface warming were to remain at +0.3C per
230 decade, +3C would be reached in 2078.

231

232 3.2. Non-linear projections

233

234 According to a mainstream view, despite the influence of el niño, the outlying warmth of
235 2023 is still largely unexplained [18]. It has been attributed to a loss of low-level cloud

236 cover and consequent lowered albedo owing to a reduction in aerosol pollution, some
237 other climate feedback or natural variability [38]. Hansen and colleagues [2] also
238 favoured a reduction in sulphur aerosols and associated cloudiness, especially over the
239 ocean owing to cleaner shipping fuels. This effect may have been at least partly
240 negated by an increase in aerosols due to wildfire [6], whose emissions in the 2023–
241 2024 fire season, at least of CO₂, were 16% higher than the 20-year average [41].

242

243 Amid the high variation from year to year it is still early to infer a recent acceleration
244 from Figs 2–4, but in due course, with further annual updates of the 20-year time
245 series, an acceleration could be reasonably inferred without having to rely on a non-
246 linear model.

247

248 4. Discussion

249

250 Caution is required in choosing the variables to correlate in simple linear regression,
251 and in inferring cause and effect. The global mean near-surface temperature is a very
252 imperfect index of the Earth's energy imbalance but is relatively directly associated with
253 the impacts on humanity and is the variable most often referred to in public discourse.
254 Linear trend lines in time series of the global annual near-surface means are shown to
255 be informative, and simple projections of them approximate to the output of more
256 complex models.

257

258 The global mean near-surface temperature (across years) at any one time will attract
259 increasing attention as the +1.5C threshold approaches. A trend line is an index of this
260 mean, is easily understood and is based on real-world data. For most purposes it is
261 more practical than the IPCC's 20-year running mean [23], which is the definitive
262 statistic but is only applicable to data that have retreated at least 10 years into the past.

263 A trend line projected into the future is also a simple way of estimating when a
264 particular global mean will be reached.

265

266 In applying the rudimentary methods employed in this paper, a consensus on the
267 length of the time series to be studied would be desirable. More years add to statistical
268 confidence (cf. Figs 1 and 2), but only if the model is good over the whole range. If a
269 straight-line model is preferred while still accepting the possibility of acceleration a
270 relatively short time series would be indicated, when a 20-year series, as in Figs 2 to 4,
271 would seem to be a reasonable compromise.

272

273 The IPCC as an institution is concerned to avoid disputation that would assist those
274 interests vested in climate delay, and to this extent its conservatism and air of authority
275 are advantageous. Another often-mentioned justification for conservatism is the notion
276 that optimism overcomes fatalism and encourages positive behaviour change [42], but
277 this is disdainful of the public and disfavours intellectual openness [43]. Some authors
278 play down otherwise alarming evidence perhaps to be reassuring. In mid-2024, 6% of
279 IPCC authors responded that warming could still be limited to +1.5C [44], but such
280 hopefulness must sooner or later give way to expressions of surprise, resulting in
281 exactly the public disagreement that is best avoided. Thus, the warming of 2023 has
282 been described in a popular article as 'entirely predicted' [45], or alternatively has
283 'come out of the blue' [46].

284

285 In interpreting such differences of view a clear distinction is to be made between global
286 mean near-surface warming and the many other changes to the Earth system that
287 have been occurring more quickly than expected. For instance, even 20 years ago it
288 was noted that the ice sheets had begun disintegrating more quickly than expected
289 (Richard Alley cited in [47]), and in relation to the weather extremes of 2023 Dr
290 Caroline Holmes of the British Antarctic Survey said: 'We don't really understand the

291 pace of change ... we've fallen off a cliff without knowing what's at the bottom' [48].

292 Global mean near-surface warming is a conservative index of the Earth's heat

293 imbalance.

294

295 The terms of reference of the IPCC are to inform climate policy, but over several

296 decades this policy has had no discernible effect on the increase in greenhouse gas

297 emissions. The policy is widely regarded as faulty [44], and in deferring to it IPCC

298 authors have been admonished for forgoing their academic independence [49] or for

299 quiescence amounting to irresponsibility [16,50]. However, since the IPCC addresses

300 policymakers, support for policy is a *sine qua non* of participation. If former IPCC

301 insiders or respected outsiders dissent it has little influence on mainstream public

302 discourse, and under these circumstances it would be helpful if a large and trusted

303 institution other than the IPCC [11,25] introduced a reporting procedure specifically for

304 the concerned public.

305

306 Young people and the concerned public have long had a poor understanding of the

307 seriousness of climate change [3], but to exert wholesome influence on science-related

308 policy they must be reasonably well informed [51]. Projections so simple that almost

309 anyone can understand or perform them for themselves foster critical thinking, reduce

310 reliance on argument from authority and increase disquiet for a future shaped by

311 climate change.

312

313 5. Conclusion

314

315 The reports of the IPCC are difficult for most people to understand. Simple linear

316 regressions of global mean annual near-surface warming are shown to be reasonable

317 approximations to more complex models and projections. The trend lines give a

318 practical estimate of the global mean (across years) at any one time and are easily
319 updated, increasing awareness of rates of change. The return to simplicity could help
320 young people and the concerned public to observe and interpret the evidence of global
321 warming for themselves, lessening the gap between the prevailing perception of
322 climate change and scientific reality.

323

324 Data accessibility

325

326 The data can be found here [36].

327

328

329 Ethics statement

330

331 The study complies with the ethics guidance of UCL.

332

333

334 Conflict of interest declaration

335

336 The author declares no conflict of interest.

337

338

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350

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