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1 Interpreting the Paris climate target

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To the editor – In the 2015 UNFCCC Paris Agreement, article 2 targets "Holding the increase 12 in global temperature to well below 2°C above pre-industrial levels and pursuing efforts to 13 limit [...] to 1.5°C [...] recognising that this would significantly reduce the risks and impacts 14 of climate change"¹. Different interpretations of the precise meaning of the phrases "increase 15 in global temperature"² and "pre-industrial"³ could have large effects on mitigation 16 requirements and corresponding social, policy, and political responses. Here we suggest that 17 levels of current global mean surface warming since pre-industrial times higher than those 18 derived by Millar et al.⁵ could have been calculated using alternative, but equally valid 19 20 assumptions as the ones made by those authors.

In Millar et al⁴, an observational dataset (HadCRUT4)⁵ was used to estimate current levels of 21 anthropogenic warming above 1861-1880 (0.93°C as of 2015) and thereby determine the 22 amount of warming remaining before the 1.5°C target is reached. HadCRUT4, in common 23 with most datasets, calculates global mean surface temperature (GMST) as a blend of surface 24 25 air temperature (SAT) measurements over land and sea surface temperatures (SSTs) over the 26 ocean. It only has partial global coverage, limited to where the observations exist. As such, data from the Arctic, which has been found to be warming much faster than the global mean, 27 are not included. By choosing to use this observational dataset Millar *et al.*⁵ have implicitly 28 assumed a definition of GMST that is restricted to observational coverage, measured as a 29 blend of SATs and SSTs. In addition, they assume that 1861-1880 is representative of pre-30 industrial conditions as used in the UNFCCC 'Structured Expert Dialogue' (SED)⁶. However, 31 this approach has potential shortcomings. For example, when model simulations are 32 processed in a similar way to the observations, they show less warming with the SED 33 method, compared to an alternative approach where complete global coverage of SAT is 34 assumed. It therefore seems likely that the SED approach underestimates the warming that 35 has actually occurred in global air temperatures⁷. In addition, changes in GMST could have 36 been calculated from a different baseline. As industrialisation was already under way by the 37 late 19th century, an earlier period could be more appropriate for a pre-industrial baseline. 38

The sensitivity of observed warming in 2010-2016 to these choices is highlighted in figure 1 which estimates the effect of calculating: (1) warming for total global coverage rather than 41 for the coverage for which observations are available; (2) warming using SATs over all the globe instead of the observational blend of SSTs and SATs; (3) warming from a pre-42 industrial, instead of a late 19th century, baseline. The effect of observational coverage is 43 estimated in two ways. First, we compare HadCRUT4 to a dataset that uses identical 44 temperature information but fills in missing data with a kriging statistical technique⁸; 45 alternatively, we calculate a correction factor from CMIP5 model simulations to convert 46 spatially incomplete temperatures to full global coverage. A factor to convert the observed 47 blend of SSTs and SATs to a fully SAT product is also calculated from the range of CMIP5 48 model simulations⁷. Finally, we estimate additional warming associated with placing the pre-49 industrial baseline further back in time, using model simulations of the period 1400-1800³; an 50 observational-based estimate⁹ gives a similar result. 51

We conclude that alternative assumptions that are equally valid as those made in Millar *et al*⁵ lead to estimated higher levels of present-day GMST warming compared to pre-industrial conditions. Each of the factors considered above adds approximately 0.1° C of warming to the estimate in ref. 5 (Figure 1). Millar *et al.*⁵ show (their Tables 1, 2) that an additional 0.3° C warming to date would halve the remaining carbon budget, which highlights the high sensitivity of carbon budgets to definitions of GMST.

Millar et al. then used climate models (using full coverage of SAT) to calculate the remaining 58 budget of carbon emissions consistent with keeping GMST within 1.5°C above preindustrial 59 level, using their observed estimate of current warming. Projections have been tied to more 60 recent observations instead of using model simulations to assess past warming, as in earlier 61 studies^{3,10}, because it reduces the impact of uncertainty in past radiative forcing for future 62 projections. Negotiators at the time when the Paris Agreement text was finalised⁶ were aware 63 of this approach; however, it mixes different definitions of GMST. These inconsistencies may 64 not have been explicitly discussed and have only been fully investigated subsequently⁹. We 65 explore the implications of this approach in Figure 2 using model simulations with strong 66 67 mitigation (RCP2.6). The simulations display a difference of approximately 0.25°C by 2050-2060 between the typically model-derived GMST values (SATs for complete coverage) and a 68 GMST calculated to mimic observations (blended SATs and SSTs with partial coverage). In 69 addition, if one definition is used for past GMST warming and a different one for projected 70 GMST warming, as in Millar et al⁴ and IPCC AR5¹⁰, then the final results will be dependent 71 on the period when the two are joined. For example, the choice of the year 2015 in Millar et 72 73 al. leads to final temperatures close to the blended partial coverage definition, because in this 74 case most of the warming has occurred in the past. Mixing different definitions of GMST 75 could also lead to misleading findings about the carbon budget remaining. In Figure 1 in 76 Millar et al, results from model simulations (SATs, full global coverage) are used to calculate the warming for a given level of cumulative carbon emissions and then the current observed 77 warming (blended, partial coverage – shown by the black cross) combined with actual 78 emissions is used to re-align the graph to calculate the remaining carbon budget. This is in 79 80 effect a correction of the modelled estimate based on the observations. However, approximately 0.2° C of the difference between the two approaches can be explained by the 81 82 different definitions of GMST (Fig 2).

Crucially, in order for the temperature targets in the Paris Agreement to be as meaningful as possible, the amount of mitigation required to cap GMST needs to be linked to the impacts expected at that level of warming. It is here that ambiguity surrounding the definition of GMST is most problematic. For example, the impacts of 1.5°C global warming on Australia

- 87 were calculated with a GMST estimate based on SATs with complete coverage¹¹, contrary to
- 88 Millar *et al*'s assumptions, and other impact studies also used different definitions,¹².

We therefore recommend that a clear definition of GMST change is agreed, so that mitigation
actions required to limit climate change impacts are assessed using self-consistent
information. This would prevent apparently contradictory results due to differing
interpretations.

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94 **References**

- 95 1. Adoption of the Paris Agreement FCCC/CP/2015/10/Add.1 (UNFCCC, 2015).
- Rogelj, J., Schleussner, C.-F. & Hare, W. Getting It Right Matters: Temperature Goal Interpretations in Geoscience Research. *Geophys. Res. Lett.* 44, 10,662-10,665 (2017).
- Schurer, A. P., Mann, M. E., Hawkins, E., Tett, S. F. B. & Hegerl, G. C. Importance of the pre-industrial baseline for likelihood of exceeding Paris goals. *Nat. Clim. Chang.* 7, 563–567 (2017).
- 4. Millar, R. J. *et al.* Emission budgets and pathways consistent with limiting warming to
 1.5 °C. *Nat. Geosci.* 10, 741–747 (2017).
- Morice, C. P., Kennedy, J. J., Rayner, N. A. & Jones, P. D. Quantifying uncertainties
 in global and regional temperature change using an ensemble of observational
 estimates: The HadCRUT4 data set. J. Geophys. Res. Atmos. 117, (2012).
- SED. Report on the structured expert dialogue on the 2013–2015 review. *FCCC*(2015). doi:http://unfccc.int/resource/docs/2015/sb/eng/inf01.pdf
- 108 7. Cowtan, K. *et al.* Robust comparison of climate models with observations using
 109 blended land air and ocean sea surface temperatures. *Geophys. Res. Lett.* 42, 6526–
 110 6534 (2015).
- 8. Cowtan, K. & Way, R. G. Coverage bias in the HadCRUT4 temperature series and its impact on recent temperature trends. *Q. J. R. Meteorol. Soc.* 140, 1935–1944 (2014).
- Hawkins, E. *et al.* Estimating Changes in Global Temperature since the Preindustrial
 Period. *Bull. Am. Meteorol. Soc.* 98, 1841–1856 (2017).
- 10. Kirtman, B. et al. in Climate Change 2013: The Physical Science Basis 953–1028
 (IPCC, Cambridge Univ. Press, 2013).
- 117 11. King, A. D., Karoly, D. J. & Henley, B. J. Australian climate extremes at 1.5 °C and
 118 2 °C of global warming. *Nat. Clim. Chang.* 7, 412–416 (2017).
- 119 12. Gruber, N. *et al.* Rapid progression of ocean acidification in the California Current
 120 System. *Science* 337, 220–3 (2012).

121 Figures

122 Figure 1 – Present global temperatures relative to 1.5°C above pre-industrial

123 temperatures. Kernel density estimates and 5-95% range of the observed warming: (a)

HadCRUT4⁶ (a dataset with partial coverage) (b) HadCRUT4 scaled to full global coverage

using a ratio calculated in model simulations, (c) Cowtan and Way⁷ (a dataset which has been

in-filled using kriging). Panels show observed GMST warming since 1850-1900 with

- 127 published uncertainty (blue), GMST warming estimated as SATs over whole globe (green),
- 128 observed GMST with anomalies from for a true pre-industrial baseline (orange), and SATs

129 with pre-industrial baseline (purple). All conversion factors are calculated using model

130 CMIP5 simulations with RCP2.6 projections.

131 Figure 2 – Global temperature for CMIP5 model simulations with RCP2.6 projections.

132 Multi-model ensemble mean temperature for SATs for complete global coverage (red) and

for a blend of SATs and SSTs with masked coverage, mimicking HadCRUT4⁶ (purple),

where future projections are masked with the mean HadCRUT4 coverage in 2000-2009. To

- mimic the use of observed temperature for the past and projected model temperatures for the
- future, different coloured lines show results when the two are joined together in different

137 periods. Shaded box in main panel shows where Millar et al^4 tied the past observations to

future projections. Double headed arrow and accompanying value indicate difference

- between red and purple lines in 2015 and dot shows the anthropogenic warming $(0.93^{\circ}C$
- 140 Millar et al⁴) in 2015. Additional arrows indicate GMST for the HadCRUT4 approach when
- the models (SAT, full coverage) passes 1.5° C and vice versa. The p>0.66 GMST model
- range in 2050-2060 is shown in the right panel.
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