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Interpreting the Paris climate target

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

In Millar et al[4], an observational dataset (HadCRUT4)[5] was used to estimate current levels of anthropogenic warming above 1861-1880 (0.93°C as of 2015) and thereby determine the amount of warming remaining before the 1.5°C target is reached. HadCRUT4, in common with most datasets, calculates global mean surface temperature (GMST) as a blend of surface air temperature (SAT) measurements over land and sea surface temperatures (SSTs) over the 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, are not included. By choosing to use this observational dataset Millar *et al*.[5] have implicitly assumed a definition of GMST that is restricted to observational coverage, measured as a blend of SATs and SSTs. In addition, they assume that 1861-1880 is representative of pre-industrial conditions as used in the UNFCCC ‘Structured Expert Dialogue’ (SED)[6]. However, this approach has potential shortcomings. For example, when model simulations are processed in a similar way to the observations, they show less warming with the SED method, compared to an alternative approach where complete global coverage of SAT is assumed. It therefore seems likely that the SED approach underestimates the warming that has actually occurred in global air temperatures[7]. In addition, changes in GMST could have been calculated from a different baseline. As industrialisation was already under way by the late 19th century, an earlier period could be more appropriate for a pre-industrial baseline.

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 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-industrial, instead of a late 19th century, baseline. The effect of observational coverage is estimated in two ways. First, we compare HadCRUT4 to a dataset that uses identical temperature information but fills in missing data with a kriging statistical technique[8]; alternatively, we calculate a correction factor from CMIP5 model simulations to convert spatially incomplete temperatures to full global coverage. A factor to convert the observed blend of SSTs and SATs to a fully SAT product is also calculated from the range of CMIP5 model simulations[7]. Finally, we estimate additional warming associated with placing the pre-industrial baseline further back in time, using model simulations of the period 1400-1800[3]; an observational-based estimate[9] gives a similar result.

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 budget of carbon emissions consistent with keeping GMST within 1.5°C above preindustrial level, using their observed estimate of current warming. Projections have been tied to more recent observations instead of using model simulations to assess past warming, as in earlier studies[3,10], because it reduces the impact of uncertainty in past radiative forcing for future projections. Negotiators at the time when the Paris Agreement text was finalised[6] were aware of this approach; however, it mixes different definitions of GMST. These inconsistencies may not have been explicitly discussed and have only been fully investigated subsequently[9]. We explore the implications of this approach in Figure 2 using model simulations with strong 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 GMST calculated to mimic observations (blended SATs and SSTs with partial coverage). In addition, if one definition is used for past GMST warming and a different one for projected GMST warming, as in Millar et al[4] and IPCC AR5[10], then the final results will be dependent on the period when the two are joined. For example, the choice of the year 2015 in Millar *et al*. leads to final temperatures close to the blended partial coverage definition, because in this case most of the warming has occurred in the past. Mixing different definitions of GMST could also lead to misleading findings about the carbon budget remaining. In Figure 1 in 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 warming (blended, partial coverage – shown by the black cross) combined with actual emissions is used to re-align the graph to calculate the remaining carbon budget. This is in 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 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 were calculated with a GMST estimate based on SATs with complete coverage[11], contrary to 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.

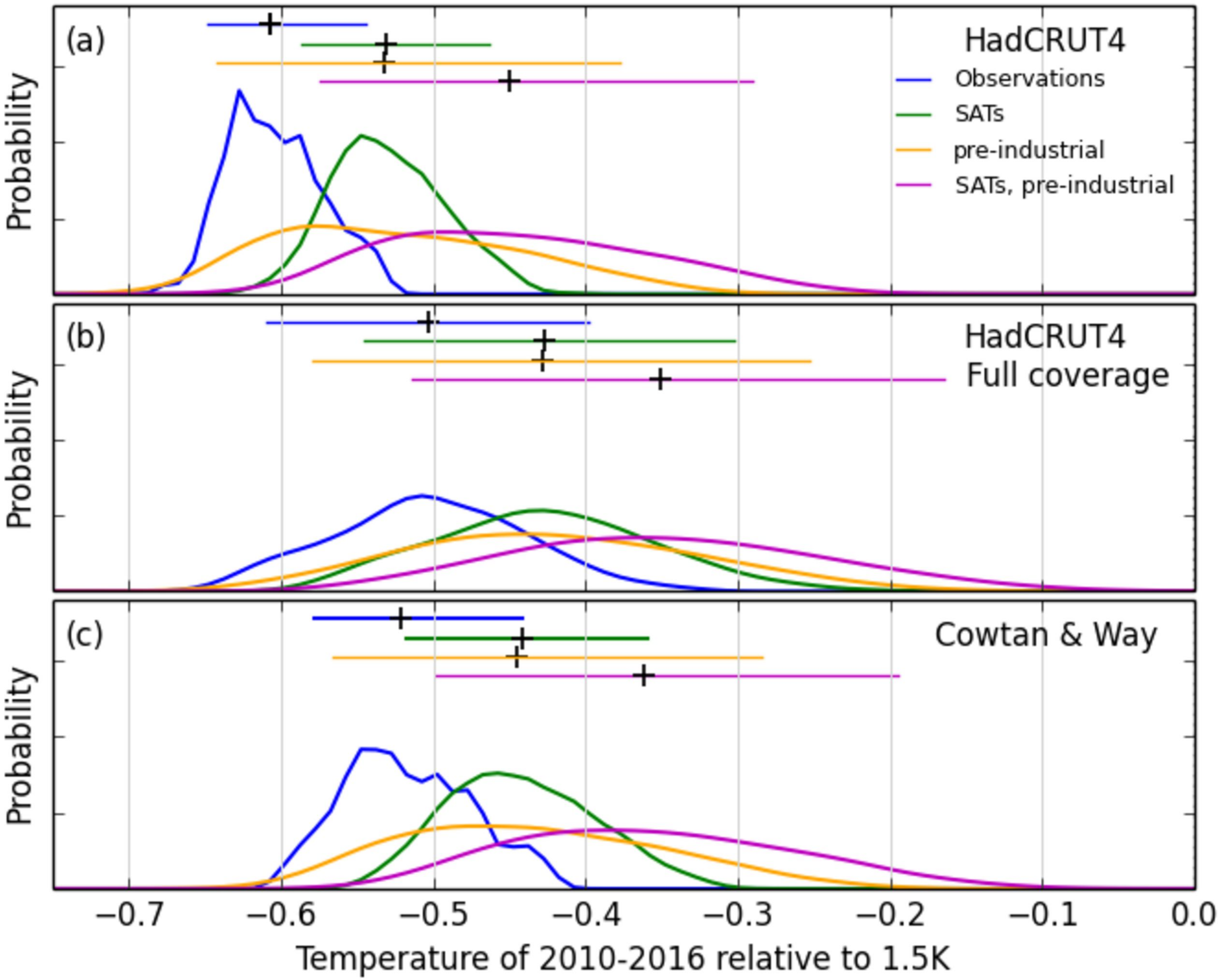
References

1. Adoption of the Paris Agreement FCCC/CP/2015/10/Add.1 (UNFCCC, 2015).
2. 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).
3. 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).
5. 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).
6. 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
7. Cowtan, K. *et al.* Robust comparison of climate models with observations using blended land air and ocean sea surface temperatures. *Geophys. Res. Lett.* **42,** 6526–6534 (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).
9. 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).
11. King, A. D., Karoly, D. J. & Henley, B. J. Australian climate extremes at 1.5 °C and 2 °C of global warming. *Nat. Clim. Chang.* **7,** 412–416 (2017).
12. Gruber, N. *et al.* Rapid progression of ocean acidification in the California Current System. *Science* **337,** 220–3 (2012).

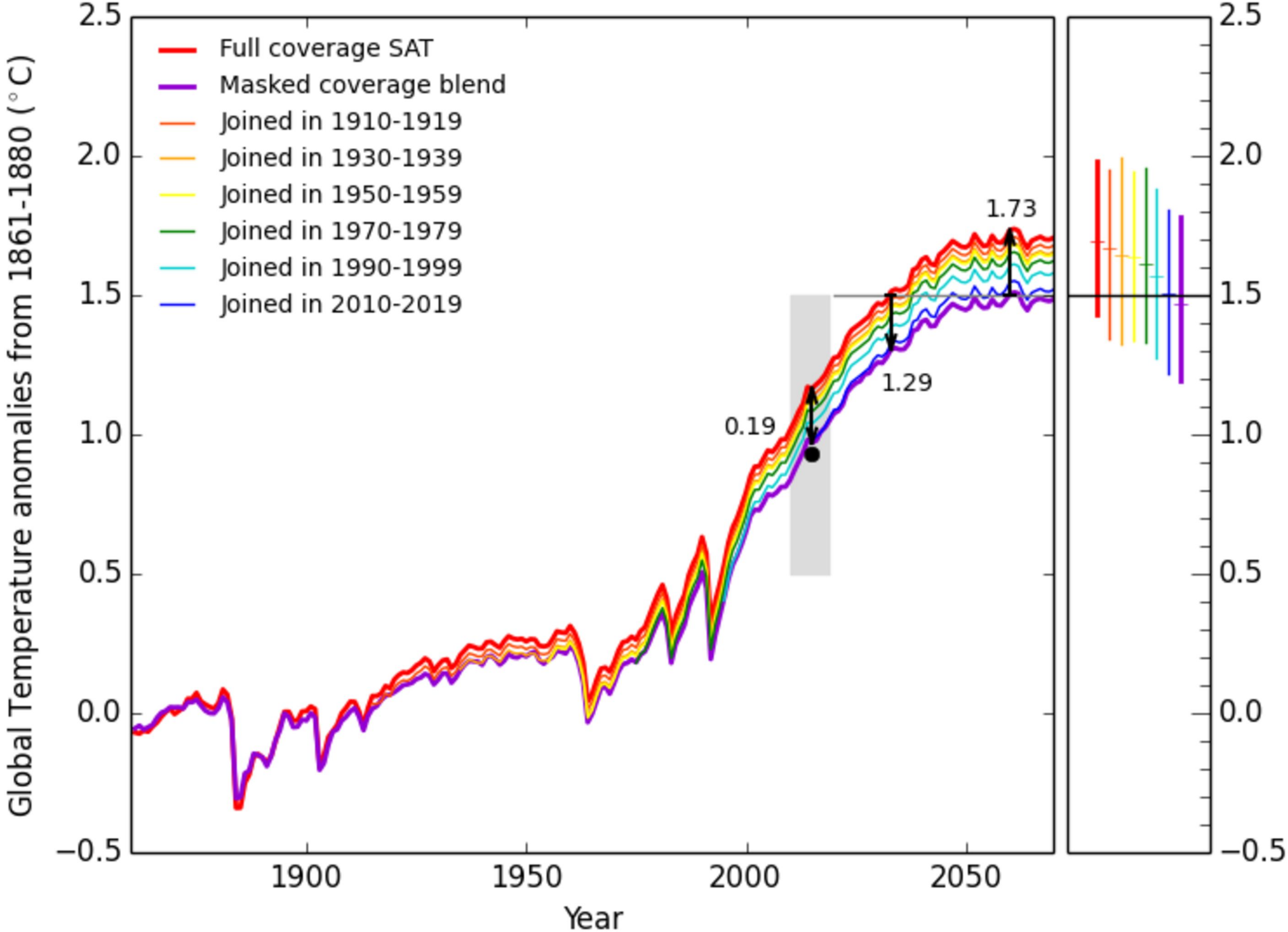
Figures

Figure 1 – Present global temperatures relative to 1.5°C above pre-industrial temperatures. Kernel density estimates and 5-95% range of the observed warming: (a) HadCRUT4[6] (a dataset with partial coverage) (b) HadCRUT4 scaled to full global coverage using a ratio calculated in model simulations, (c) Cowtan and Way[7] (a dataset which has been in-filled using kriging). Panels show observed GMST warming since 1850-1900 with published uncertainty (blue), GMST warming estimated as SATs over whole globe (green), observed GMST with anomalies from for a true pre-industrial baseline (orange), and SATs with pre-industrial baseline (purple). All conversion factors are calculated using model CMIP5 simulations with RCP2.6 projections.

Figure 2 – Global temperature for CMIP5 model simulations with RCP2.6 projections. Multi-model ensemble mean temperature for SATs for complete global coverage (red) and for a blend of SATs and SSTs with masked coverage, mimicking HadCRUT4[6] (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 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°C – Millar et al[4]) 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.



(a)
HadCRUT4
Observations
SATs
pre-industrial
SATs, pre-industrial
(b)
HadCRUT4
Full coverage
(c)
Cowtan & Way
Probability
Probability
Probability
−0.7
−0.6
−0.5
−0.4
−0.3
−0.2
−0.1
0.0
Temperature of 2010-2016 relative to 1.5K



Full coverage SAT
Masked coverage blend
Joined in 1910-1919
Joined in 1930-1939
Joined in 1950-1959
Joined in 1970-1979
Joined in 1990-1999
Joined in 2010-2019
1.73
1.29
0.19
Global Temperature anomalies from 1861-1880 (°C)
Year
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
1900
1950
2000
2050