COMMENTARY:

Robust warming projections despite the recent hiatus

Matthew H. England, Jules B. Kajtar and Nicola Maher

The hiatus in warming has led to questions about the reliability of long-term projections, yet here we show they are statistically unchanged when considering only ensemble members that capture the recent hiatus. This demonstrates the robust nature of twenty-first century warming projections.

The recent slowdown or 'hiatus' in global average surface air temperature (SAT) rise[1–4] has been used in some studies as evidence to argue that current models overestimate the climate response to increasing concentrations of greenhouse gases[5,6]. Other studies suggest instead that the recent hiatus merely reflects interdecadal variability superimposed on a long-term warming trend[2–4,7–9]. However, because climate models seem to underestimate the magnitude of observed interdecadal variability[8], and as this variability may be linked to longer-term sequestration of heat into the deep ocean, the question arises as to what extent future projections need to be re-examined in light of the present hiatus. Here we assess whether twenty-first-century warming projections are altered in any way when considering only simulations that capture a slowdown in global surface warming, as observed since 2000.

We assessed individual global SAT projections in those climate models that participated in the Coupled Model Intercomparison Project Phase 5 (CMIP5), separating the model ensemble members into those that do, and those that do not, capture a slowdown in surface warming during the period 1995–2015. This time window was selected to incorporate the approximate period of the present hiatus (2000–2013), with a slight extension in time to include models whose natural variability is not synchronized precisely with observations. The window did not extend to pre-1995 as the cooling impacts of the Mount Pinatubo eruption dominate the forcing before this time. In principle, the allowable window could have been extended to beyond 2015; however, under high-emissions scenarios, fewer and fewer models capture a hiatus as time progresses through the twenty-first century[10].

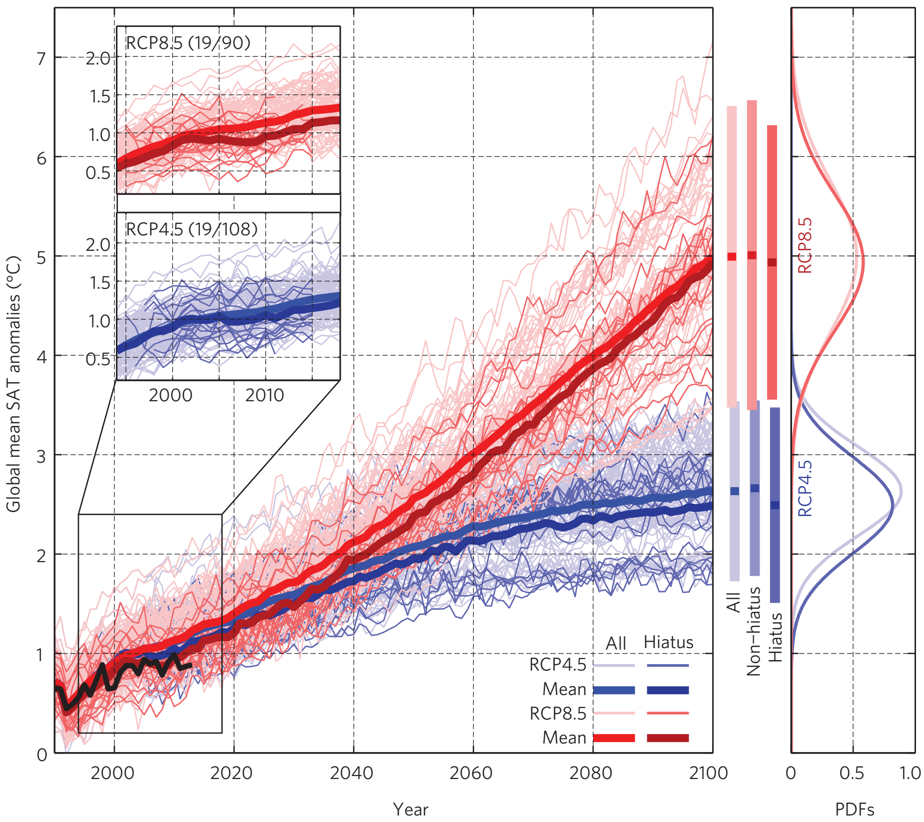

Figure 1 | Global average SAT anomalies relative to 1880–1900 in individual and multi-model mean CMIP5 simulations. Blue curves: RCP4.5 scenario; red curves: RCP8.5 scenario. The future projections have been appended to corresponding historical runs at 2006. Lighter thin lines denote individual ensemble members; darker thin lines denote those that exhibit a multi-decadal hiatus (taken here as a trend of less than 0.096 °C per decade, lasting at least 14 years) at any time during the period 1995–2015. The thicker lines denote the multi-model mean of all experiments and of the subsampled ensemble set displaying an early twenty-first-century hiatus. The observed data (plotted in black) are version 2.0 of the reconstructed HadCRUT4 climatology[11]. The multi-model mean and 2σ bars at 2100 are shown to the right of the panel, along with PDFs of each of the samples. Lighter solid lines denote the PDFs for all ensemble members; darker solid lines are for the hiatus members. The all-ensemble PDF was recalculated excluding all hiatus ensemble members, and the resulting PDF is virtually indistinguishable from the all-ensemble member PDF (refer to mean and 2σ bars). The insets illustrate the early part of the twenty-first century for each scenario, with the individual hiatus periods highlighted. The values in parentheses denote the number of ensemble members exhibiting a hiatus out of the total number of ensemble members.

Although the time window to find model hiatus periods was fixed at 1995–2015, the magnitude of the hiatus SAT trend and the duration of the hiatus, were both varied to test a suite of hiatus criteria in recalculating projections for the end of the twenty-first century. For further details of the methods used and analyses presented, see the Supplementary Information.

Figure 1 shows the results of such an analysis wherein projections are reassessed using only hiatus ensemble members. Although the projected warming distributions are shown for the calendar year 2100 in Fig. 1, these were also recalculated for both the end-of-century decade mean (2091–2100) and multi-decade mean (2081–2100), and robust results were obtained. The hiatus criterion chosen here requires a 14-year period within 1995–2015 when SAT rise is no more than 0.096 °C per decade. This warming rate corresponds to the trend in global average SAT during 2000–2013 in the corrected HadCRUT4 data set[11]. The hiatus subsampling leaves only 19 (of 90) and 19 (of 108) experiment runs under the IPCC Representative Concentration Pathway (RCP) scenarios RCP8.5 and RCP4.5, respectively (see Fig. 1 insets), with most of these ensemble members appearing at the low end of warming at the end of their respective hiatuses. Indeed, at this stage of the simulations (year 2015), the warming of the subsampled hiatus set is weaker than the all-ensemble distribution; significant at >94% and >99.5% confidence levels, respectively, for the RCP4.5 and RCP8.5 scenarios. Yet the resulting warming projections for the end of the twenty-first century show no significant differences compared to the all-ensemble set, with the mean and distribution under each RCP not significantly altered when excluding the non-hiatus experiments. For example, multi-model mean warming at century's end is hardly changed, reaching 2.49 °C and 4.93 °C for RCP4.5 and RCP8.5, respectively (hiatus experiments), compared to 2.63 °C and 4.99 °C in the all-experiment mean. Thus, the difference in projected warming between the two RCP scenarios is much greater than the difference between the hiatus and all-model ensemble means. For example, global mean projected warming is roughly doubled under RCP8.5 compared with RCP4.5, yet reduced by only < 0.1 °C when just considering the hiatus runs in the high-emissions scenario.

Any impact of the hiatus on projections is overwhelmed strongly by global warming in the RCP8.5 high-emissions scenario, with projected warming by century's end virtually identical whether considering all experiments or just the hiatus runs. This is not surprising, as a major driver of the early twenty-first-century hiatus in both models and observations — the negative phase of the Interdecadal Pacific Oscillation (IPO; Fig. 2) — is part of an oscillatory climate mode associated with decadal global mean SAT variability of the order of ±0.1–0.2 °C, compared with end-of-century RCP8.5 warming projections of 3–7 °C (Fig. 1).

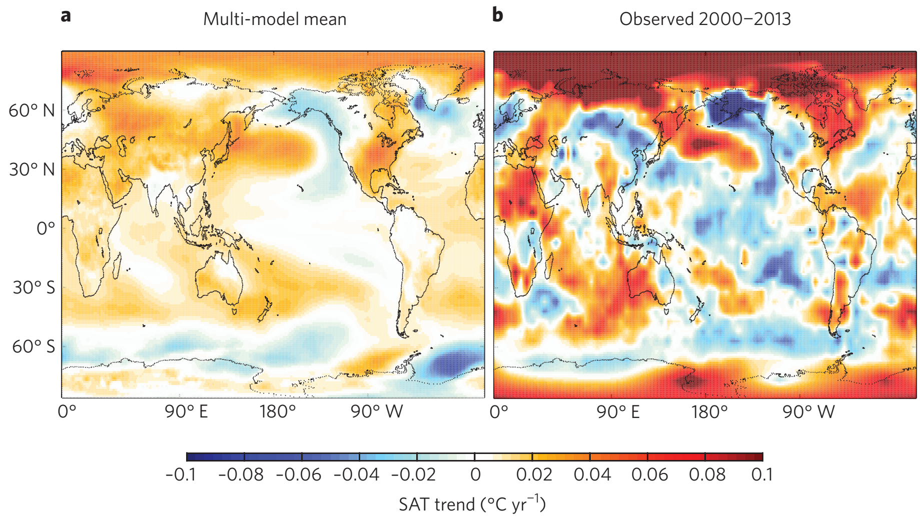

Figure 2 | Trend in SAT during early twenty-first-century hiatuses in models and observations. **a**, The multi-model mean SAT trend during the selected CMIP5 hiatuses, composited over all multi-decadal hiatuses (lasting at least 14 years) when SAT rise is no more than 0.096 °C per decade during 1995–2015 (Supplementary Information). **b**, The actual trend in observed SAT during the period 2000–2013 using the corrected HadCRUT4 data set[11].

The twenty-first-century hiatus warming projections described above are robust to various choices of parameters used to define the hiatus criterion, including changes to the required duration of the hiatus and the magnitude of the slowdown in SAT rise. For example, a stricter subsampling of models requiring a hiatus of <0.062 °C per decade over 14 years (as per the observed Goddard Institute for Space Studies 2000–2013 SAT trend) yields only 7 of 90 (6 of 108) experiments for the RCP8.5 (RCP4.5) scenario, yet there is no significant shift in either the projected mean (RCP8.5 mean = 4.64 °C; RCP4.5 mean = 2.39 °C) or distributions. Other combinations of duration and magnitude also yielded no rejection of the null hypothesis that the twenty-first-century SAT projections are drawn from the same distribution (duration = 10, 12, 13 yr, magnitude < 0.01, 0.04, 0.06 °C per decade and duration = 14 yr, magnitude < 0.04, 0.05, 0.06 °C per decade). The only criteria that result in a significant shift (for example, duration = 14 yr, magnitude < 0.01 °C per decade, which is much stronger than the current hiatus) are when the subsampling becomes so constrained that only one to two model experiments remain; however, in this case the statistical analysis is no longer meaningful. In short, across all observationally derived subsampled hiatus projections, there are no significant changes in the warming probability density functions (PDFs) compared to the all-model PDF.

Testing for distribution changes between the hiatus set and a set comprising all non-hiatus ensemble members also revealed no significant shift. In fact, excluding the hiatus runs from the all-ensemble set yields negligible change in the end of twenty-first-century projections (Fig. 1). We further tested the projections by selecting those ensemble members with the weakest warming by 2014, regardless of hiatus behaviour. Again, the results are robust to this subsampling approach. We thus conclude that twenty-first-century global warming projections derived from the CMIP5 ensemble set are robust, and that the present hiatus requires no recalibration of future warming estimates.

The warming projections were further analysed at various stages during the twenty-first century. Time slices were chosen to examine the hiatus era (2015), snapshots within a few decades of the hiatus (2025–2045) and a period well beyond the multi-decadal duration of the IPO (after 2060). These analyses reveal that the ensemble of RCP8.5 hiatus runs has a significantly different warming distribution from the all-member ensemble to around 2040, but by the latter half of the twenty-first-century there is no significant difference in projected warming. This reflects the fact that the model hiatus events are linked to multi-decadal modes of climate variability (most notably the IPO), whose influence abates in time once global warming overwhelms interdecadal variability.

We have shown here that there is no significant shift in projected end-of-century global warming when considering hiatus-only ensemble sets in lieu of the full ensemble of available projections, or an ensemble sampled from only non-hiatus runs. This suggests that the recent surface warming slowdown is associated with variability not influencing long-term climate change, such as multi-decadal variability in the Pacific[1–4,7–9] and Atlantic[3,7,12] oceans. It also suggests that these climate oscillations largely operate without driving longer-term sequestration of heat into the deep ocean. In short, the drivers of the recent hiatus do not alter the century-scale warming associated with projected greenhouse gas increases. These findings increase confidence in the recent synthesized projections reported in the Intergovernmental Panel on Climate Change Fifth Assessment Report. ❐

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Author contributions

M.H.E. conceived the analyses and wrote the first draft of the paper, J.K. analysed the CMIP5 simulations and undertook the statistical calculations, and N.M. analysed the observations and CMIP5 model trends. All authors contributed to interpreting the results and refinement of the paper.

Additional information

Supplementary information is available in the online version of the paper.

COMMENTARY:

Pricing climate risk mitigation

Joseph E. Aldy

Adaptation and geoengineering responses to climate change should be taken into account when estimating the social cost of carbon.

At the September 2014 United Nations Climate Summit, 73 countries and more than 1,000 companies advocated pricing carbon[1]. Economists have long called for pricing carbon to reflect the social damages associated with the impacts of carbon dioxide emissions on the global climate[2,3]. Such an approach generally reflects the polluter pays principle — as elaborated in the 1992 Rio declaration on environment and development, with its emphasis on the use of economic instruments to internalize environmental costs[4]. Scholars have also called for the organization of international negotiations around agreement on a carbon price to provide the basis for emission commitments[5,6].

The meaning of carbon pricing

For some policymakers, setting a price on carbon that reflects the cost of carbon pollution can inform the 'objective' of climate policy. For example, the US government uses an estimate of the social cost of carbon (SCC) — the present value of monetized damages associated with an incremental ton of carbon dioxide emissions — to evaluate standards for fuel economy, appliance efficiency and carbon emissions[7]. As some laws require regulations to reflect a weighting of benefits and costs, the application of the SCC could determine the ambition of energy and climate policies.

For other policymakers, pricing carbon is an 'instrument' of climate policy — such as carbon dioxide cap-and-trade programmes or a carbon tax. For example, the European Union emissions trading scheme and the British Columbia carbon tax impose a price that carbon dioxide-emitters must bear. Of course, these two interpretations can be mutually reinforcing. In a benefit–cost framework, a policy that maximizes net social benefits would equate the SCC with the price borne by emitters under a tax or cap-and-trade instrument[8].

Whether the SCC determines the objective of policy, informs the design of a pricing instrument, or serves as a focal point in international negotiations, it will play an important role in the future of climate change policy. The social damages of carbon emissions will depend on the impacts of a warming world, such as sea-level rise, extreme weather events and changes in agricultural productivity, as well as potential catastrophic harms, migration, conflict and so on[9]. The SCC will also vary with alternative efforts to mitigate climate change risks, such as adaptation and geoengineering. Thus, it is important to conceptualize the SCC in the context of the full suite of risk management policies for climate change.