CORRESPONDENCE:

Recent observed and simulated warming

To the Editor — Fyfe *et al.*[1] showed that global warming over the past 20 years is significantly less than that calculated from 117 simulations of the climate by 37 models participating in Phase 5 of the Coupled Model Intercomparison Project (CMIP5). This might be due to some combination of errors in external forcing, model response and simulated internal variability[1]. Meanwhile, Kosaka and Xie[2] used an earlier-generation climate model to show that such a difference is substantially reduced if eastern tropical Pacific sea surface temperatures are prescribed to follow the observed rather than the simulated evolution. Kosaka and Xie[2] concluded, therefore, that "accounting for recent cooling in the eastern tropical Pacific reconciles climate simulations and observations". It is in this light that we revisit the findings of Fyfe and colleagues[1].

Figure 1 shows observed[3] (red) and simulated (black) trends over the past 20 years (1993–2012) in global mean surface temperature plotted against corresponding trends in eastern tropical Pacific sea surface temperature. As pointed out by Fyfe and colleagues[1], the observed rate of global warming over this period is less than that simulated in all but two of 117 CMIP5 simulations. Figure 1 shows an even more pronounced discrepancy over the eastern tropical Pacific, with the observed cooling trend being substantially more negative than that in any of the 117 CMIP5 simulations. The observations in Fig. 1 lie on the straight line that best fits the simulated global and eastern tropical Pacific temperature trends over the period from 1993 to 2012 — indicating that the observed global mean trend could be inferred from the observed tropical Pacific trend and the relationship between these two variables in the models.

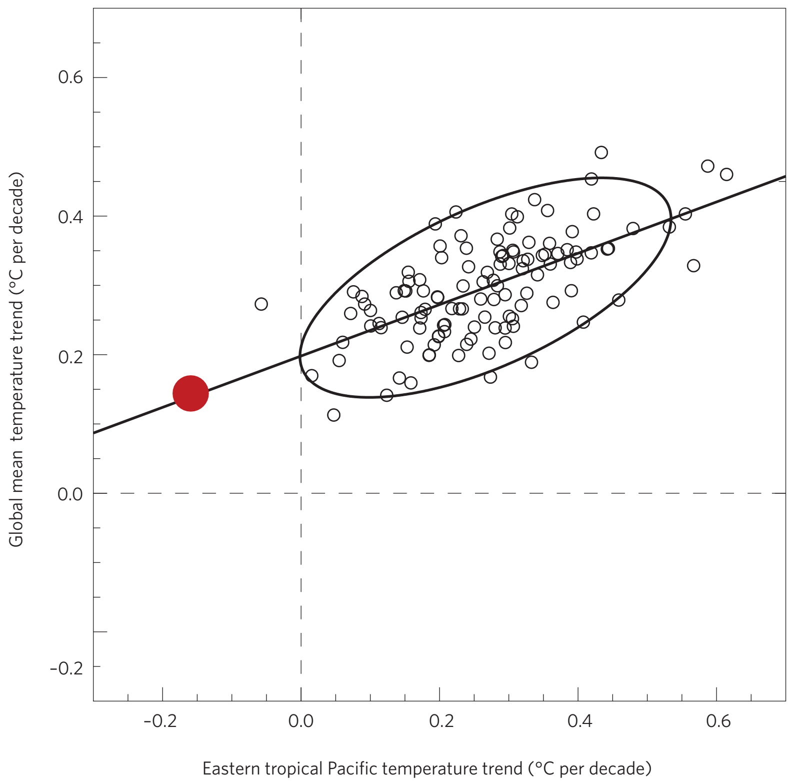

Figure 1 | Trends in global mean surface temperature and eastern tropical Pacific sea surface temperature for 1993–2012. Observed trends (red) are averages over 100 reconstructions of the HadCRUT4 dataset[3]. Simulated trends (black) are from 117 realizations of the climate from 37 CMIP5 models and their 5–95% ranges are shown with the black ellipse. The straight line is the best fit to the simulated global mean and eastern tropical Pacific trends, with a correlation of 0.63. As in Kosaka and Xie[2] the eastern tropical Pacific is defined as the region east of the dateline and between 20° S and 20° N, and as in Fyfe *et al.*[1] the simulations are sampled only where corresponding observations exist.

Because observations are sparse in polar regions, the calculated global mean trends could be less than actual trends given indications of rapid warming in the Arctic over the satellite record[4]. In our analysis, trends in both models and observations are computed only where adequate observations are available *in situ*, making this a robust like-for-like comparison of models and observations. Figure 2 shows observed (a) and model-average (b) trend maps over the past 20 years (1993–2012) computed for locations where adequate observations are available *in situ*. Over this period most of the observed regions exhibited warming, but much of Siberia, the eastern Pacific Ocean and the Southern Ocean cooled[5]. The regions of cooling over Siberia and the eastern Pacific Ocean are not seen in the simulated trends, although some Southern Ocean cooling is suggested on average. Figure 2b shows that for about 21% of grid cells with sufficient observational coverage the observed trends over this period lie outside the 5–95% range of simulated trends, or in other words, they are inconsistent with the simulated combination of internal variability and response to natural and anthropogenic forcings.

Kosaka and Xie[2] concluded that the current hiatus is part of internal climate variability tied to La Niña-like decadal cooling, but we point out that internal climate variability alone does not readily explain the difference between simulated and observed trends over this period, given that none of the 117 CMIP5 simulations captured the current eastern tropical Pacific cooling trend. Although on average the models show realistic 20-year trend variance in this region based on the limited observational record (Supplementary Fig. 1), and do not generally underestimate interannual variability associated with the El Niño Southern Oscillation[5] (Supplementary Fig. 2), CMIP5 simulations of internal variability in the tropical Pacific do exhibit pronounced systematic errors[5] and it remains possible that the

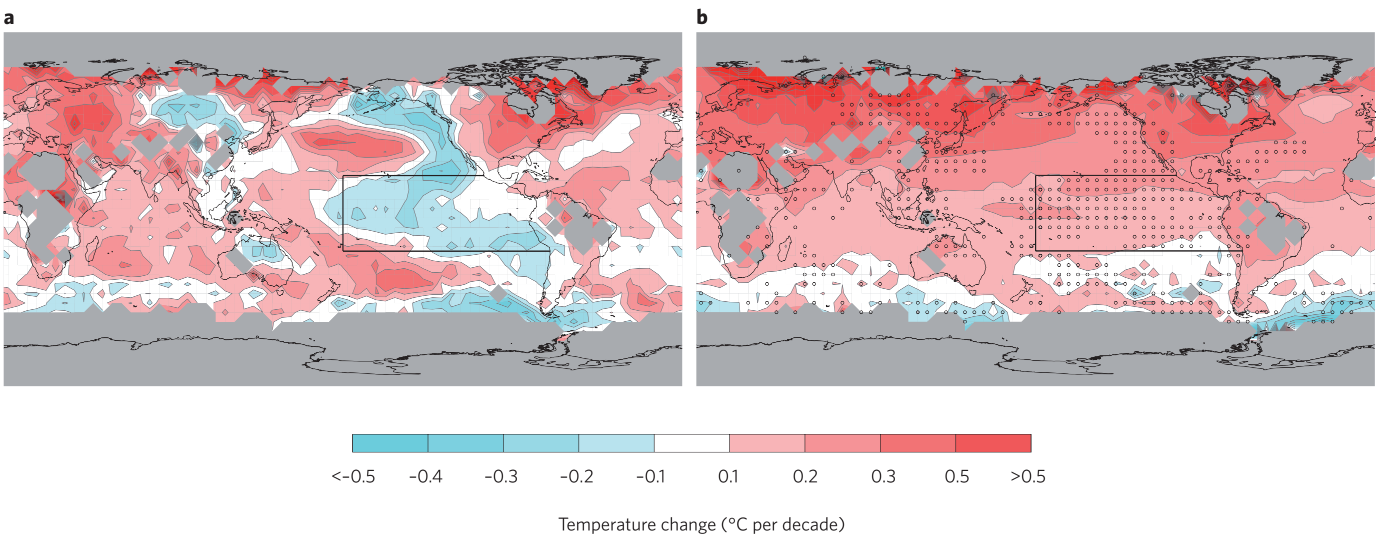

Figure 2 | Trends in global surface temperature for 1993–2012. **a**, Observed trends. **b**, Average simulated trends from 117 simulations of the climate by 37 CMIP5 models. As in Fyfe *et al.*[1] the simulations are sampled only where corresponding observations exist. Trends are computed only at grid points with at least 50% temporal coverage. The rectangles encompass the eastern tropical Pacific region[2]. In **b** the stippling indicates where the observed trends are outside the 5–95% range of the simulated trends.

models underestimate the probability of large internally generated cooling trends in this region. We further note that the models simulate externally forced warming in this region since about 1970 (Supplementary Fig. 1), which is likely to be associated in part with simulated weakening of the Walker circulation[5–7], whereas observed sea surface temperatures cooled and the Walker circulation strengthened over the past 20 years[2,5].

In conclusion, we agree with Kosaka and Xie[2] that accounting for cooling in the eastern tropical Pacific could, in principle, reconcile recent observed and simulated global warming. However, based on the CMIP5 ensemble of climate simulations, the probability of simulating the recently observed eastern tropical Pacific cooling with a freely running climate model under the CMIP5 radiative forcing protocol is very low, and hence so too is the probability of simulating the observed global temperature change over the past 20 years. ❐

References

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Author contributions
J.C.F. carried out most of the analysis and wrote the initial draft. N.P.G. helped with the analysis and edited the paper.

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

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CORRESPONDENCE:

Palm oil wastewater methane emissions and bioenergy potential

To the Editor — Palm oil production is driving economic growth, rural development and poverty alleviation in many equatorial economies, yet often with loss of tropical forests[1]. Here we show that the climate threats do not end following forest clearing: methane (CH_4) emissions from palm oil wastewater effluent, known as POME[2], represent a significant and rising source of atmospheric warming.

A typical wastewater facility emits around 3,288 tCH_4 yr^{-1}, equating to 111,804 tCO_2e yr^{-1} because of the greater global warming potential of CH_4 (Supplementary Tables 1–3 and Excel database) — comparable to the annual emissions of ~22,000 passenger vehicles in the United States[3]. This year, emissions