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Key Points:
- Many models overestimate the Pacific influence on global mean temperature
- The recent hiatus is only partly due to the internal Pacific variability
- The TCR of CNRM-CM5 might be overestimated

Supporting Information:
- Figures S1–S7

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The recent global warming hiatus: What is the role of Pacific variability?

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Abstract The observed global mean surface air temperature (GMST) has not risen over the last 15 years, spurring outbreaks of skepticism regarding the nature of global warming and challenging the upper range transient response of the current-generation global climate models. Recent numerical studies have, however, tempered the relevance of the observed pause in global warming by highlighting the key role of tropical Pacific internal variability. Here we first show that many climate models overestimate the influence of the El Niño–Southern Oscillation on GMST, thereby shedding doubt on their ability to capture the tropical Pacific contribution to the hiatus. Moreover, we highlight that model results can be quite sensitive to the experimental design. We argue that overriding the surface wind stress is more suitable than nudging the sea surface temperature for controlling the tropical Pacific ocean heat uptake and, thereby, the multidecadal variability of GMST. Using the former technique, our model captures several aspects of the recent climate evolution, including the weaker slowdown of global warming over land and the transition toward a negative phase of the Pacific Decadal Oscillation. Yet the observed global warming is still overestimated not only over the recent 1998–2012 hiatus period but also over former decades, thereby suggesting that the model might be too sensitive to the prescribed radiative forcings.

1. Introduction

According to the technical summary of the latest Intergovernmental Panel on Climate Change Fifth Assessment Report (AR5), the observed recent warming hiatus, defined as the reduction in global mean surface temperature (GMST) trend during 1998–2012 as compared to the trend during 1951–2012, is attributable in roughly equal measure to a cooling contribution from internal variability and a reduced trend in external radiative forcing. This medium confidence expert judgment was, however, based on a small number of studies and has been recently contradicted by several numerical experiments, suggesting that the hiatus can be fully explained by the internal multidecadal variability of the tropical Pacific Ocean [e.g., *Kosaka and Xie*, 2013; *England et al.*, 2014; *Watanabe et al.*, 2014] (hereafter KX13, E14, and W14, respectively). Such a conclusion has the twin advantages of challenging neither the forcings nor the feedback of the Coupled Model Intercomparison Project Phase 5 (CMIP5) models and seems to have overshadowed the results of parallel studies, suggesting that the dimming effect of both natural and anthropogenic aerosols could be underestimated [e.g., *Santer et al.*, 2014; *Schmidt et al.*, 2014] or that the model sensitivity could be overestimated [e.g., *Stott et al.*, 2013; *Otto et al.*, 2013].

The key role of internal climate variability was first emphasized by statistical studies. For instance, *Foster and Rahmstorf* [2011] obtained a steady warming trend over the 1979–2010 period after removing the influence of the El Niño–Southern Oscillation (ENSO), as well as of volcanic aerosols and solar variability, from observed GMST time series. Nevertheless, *Fyfe et al.* [2013] suggested that the ENSO variability was not enough to reconcile CMIP5 models with observations. Moreover, such statistical studies do not provide a physical explanation for the recent GMST evolution and often rely on simple regression schemes that have been shown inadequate to remove ENSO-related climate variations [*Compo and Sardeshmukh*, 2010]. This might explain why the first numerical study by KX13 has received a stronger attention from the global climate modeling community. The experiment design is relatively simple and consists in nudging the central to eastern tropical Pacific sea surface temperature (SST) anomalies toward observations in the Geophysical Fluid Dynamics Laboratory coupled climate model version 2.1 (GFDL-CM2.1) coupled ocean-atmosphere general circulation model (OAGCM) driven by natural and anthropogenic radiative forcings. Unlike the free historical simulations, the nudged experiments were shown to capture the interannual to multidecadal variability of GMST, including the recent pause in global warming. It was therefore concluded that "accounting for recent cooling in the eastern tropical Pacific reconciles climate simulations and observations." Using a different experiment design and different models, E14 and W14 obtained similar results and confirmed the major contribution of tropical Pacific variability to the global warming hiatus. Moreover, E14 analyzed the zonally averaged 0–1000 m potential temperature profiles in the Pacific and found consistent linear trends between their model and the average of five ocean reanalysis products, thereby supporting the hypothesis that the pause in sea surface warming could be due to an enhanced ocean heat uptake in the tropical Pacific [e.g., *Balmaseda et al.*, 2013]. W14 also performed AGCM experiments driven by prescribed observed SST, in which the anthropogenic influence was removed to confirm that the recent global warming hiatus was mainly triggered by internal climate variability, in line with the observed strengthening of tropical Pacific trade winds that contradicts the weakening of the Walker circulation simulated by most CMIP5 models in response to enhanced greenhouse gas concentrations [e.g., *Di Nezio et al.*, 2013].

Does it mean that we now have a comprehensive understanding of the recent global warming hiatus? Here we claim that the debate is not closed, and we address two subsidiary but basic questions that have been eluded by former numerical studies. Can we trust the coupled OAGCMs in their modulation of GMST by internal climate variability? How sensitive are the model results to the experiment design? For this purpose, we use both a multimodel ensemble of historical and representative concentration pathway 8.5 (RCP8.5) simulations from the CMIP5 archive and two dedicated ensembles of 1979–2012 simulations with the Centre National de Recherches Météorologiques coupled global climate model version 5 (CNRM-CM5). We show that most OAGCMs overestimate the ENSO influence on GMST and, at the same time, underestimate the potential role of the North Atlantic Ocean [e.g., *Chen and Tung*, 2014]. We also show that the tropical Pacific influence on GMST in a given model depends on the details of the experiment design. These results highlight the difficulty to draw robust quantitative conclusions from numerical sensitivity experiments without a thorough model evaluation and a careful experiment design.

2. Data and Methods

As a first step, a subset of 15 independent CMIP5 models (i.e., based on different AGCMs), including Model for Interdisciplinary Research on Climate version 5 (MIROC5) used by W14 and CNRM-CM5 further used in the present study, has been analyzed over the 1850–2100 period after concatenating the historical simulations and the RCP8.5 scenarios and detrending the resulting time series using a fourth-order polynomial fitting (similar results are obtained with spline functions). The former-generation GFDL-CM2.1 coupled model used by KX13 was also included in this intercomparison, using both the historical simulation and Special Report on Emissions Scenarios' A2 scenario provided in CMIP3. We did not include the model used by E14, which apparently did not contribute to CMIP.

As a second step, three five-member ensembles of 1979–2012 experiments have been conducted with the CNRM-CM5 model [*Voldoire et al.*, 2013], which ranks among the top CMIP5 models in many respects, both at the global scale [e.g., *Watterson et al.*, 2013] and over the tropical Pacific [e.g., *Bellenger et al.*, 2014]. This reasonable behavior is confirmed by Figures 1a and 1b (as well as Figure S1 in the supporting information), which suggests that CNRM-CM5 is more suitable than many other models to assess the role of ENSO variability on GMST. All ensembles have been driven by the same natural and anthropogenic radiative forcing history [*Voldoire et al.*, 2013]. The control ensemble (HISCTL) consists of five CMIP5 historical simulations extended until December 2012. Two parallel perturbed ensembles have been performed over the 1979–2012 period using the 1 January 1979 initial conditions from each control integration. The HISSST experiment is based on the KX13 methodology where the SST is nudged toward the observed SST history over the central to eastern tropical Pacific (cf., the solid black rectangle in Figure S3 in the supporting information). In order to avoid an initial shock due to model biases, we prescribe monthly mean SST anomalies (relative to the 1969–1989 climatology of HISCTL) from the Hadley Centre Sea Ice and Sea Surface Temperature data set (http://www.metoffice.gov.uk/hadobs/hadisst/) rather than raw observed monthly mean SST. For this purpose, we use a simple Newtonian relaxation with a 10 day time scale, and we ensure a smooth transition between the nudged central to eastern tropical Pacific and the free global ocean. The HISTAU experiment consists in prescribing the ERA-Interim daily wind stress reanalysis (http://data-portal.ecmwf.int/data/d/interim_daily/) between 20°S and 20°N over the tropical Pacific (cf., the dashed black rectangle in Figure S3 in the supporting information, which also includes a transition zone between the perturbed and the free ocean).

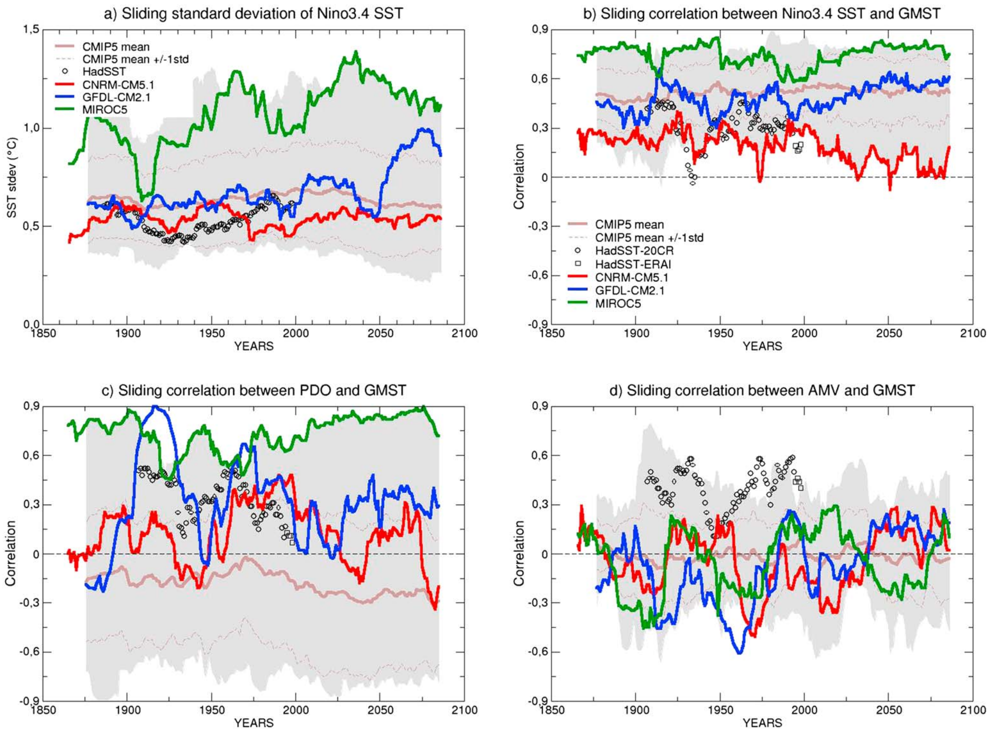

Figure 1. Simulated (historical + RCP8.5) versus observed (a) standard deviations of the Ninõ3.4 SST, (b) correlations between the Niño3.4 SST and GMST, (c) correlations between the PDO index and GMST, and (d) correlations between the AMV index and GMST. The tick marks on the *x* axis correspond to the central year of a 31 year sliding window. Besides CNRM-CM5.1 (in red), GFDL-CM2.1 (in blue), and MIROC5 (in green), the grey shading extends over the range of 15 CMIP5 models (also shown are the ensemble mean ±1 standard deviation in brown). Note that GFDL-CM2.1 is not among the 15 CMIP5 models. All annual mean time series have been first detrended using a polynomial fit. The PDO index is here defined as the leading empirical orthogonal function of the annual mean SST anomalies over North Pacific (110°E–100°W/20°N–70°N) after the global mean SST anomaly has been removed. The AMV index is simply the average of the annual mean North Atlantic (80°W–0°W/0°N–60°N) SST anomalies after the global mean SST anomaly has been removed.

In doing so, we avoid an artificial heat input into the climate system and expect to get a more physical response in the upper Pacific ocean than with the SST nudging technique (which here consists in adjusting once a day the nonsolar heat flux that is provided to the ocean model). Since we prescribe the raw daily mean surface wind stress from ERA-Interim, there is an initial shock (cooling) in the tropical Pacific, which is, however, fast enough to avoid a persistent drift in the HISTAU integrations (as indicated for instance by the evolution of the upper ocean heat content averaged over the whole tropical Pacific). While the details (i.e., the selected domain and time scale) of the wind stress overriding (WSO) technique differ from E14 and W14, our aim is not to replicate these former experiments but to show that the simulated global climate response to the prescribed tropical Pacific variability is different between HISSST and HISTAU and therefore sensitive to the experiment design.

3. Results

Figure 1a shows that the observed ENSO variability is overestimated by many OAGCMs over the course of the 20th century. This is true for the CMIP5 ensemble mean and especially for the MIROC5 model used in W14. In contrast, CNRM-CM5 shows a lower and presumably more realistic ENSO variability, given the range of both observed and simulated sliding standard deviations. It should be, however, recognized that some models, including GFDL-CM2.1 and MIROC5, show a particularly strong interdecadal modulation of ENSO so that the limited observational record and the use of a single realization of the 20th and 21st century climates might not be sufficient for an accurate model assessment. Figures 1b–1d show the sliding correlations between GMST and different regional modes of SST variability. In line with Figure 1a, the correlation with the Niño3.4 SST is overestimated by many models, especially MIROC5. Regressing the detrended Niño3.4 SST onto grid cell near-surface temperature at the global scale (Figure S1 in the supporting information) shows that the high correlation found in MIROC5 is due to a too strong ENSO influence on both the tropics (a feature also found in the GFDL-CM2.1 model) and the northern high latitudes. Most models are also unable to capture the observed influence of the Pacific Decadal Oscillation (PDO) [*Mantua et al.*, 1997] and of the Atlantic multidecadal variability (AMV) [*Trenberth and Shea*, 2006] on GMST (cf., Figure 1 for the details of the PDO and AMV calculation). In particular, none of the CMIP5 models is able to capture the observed persistent positive correlations between AMV and GMST, which might explain why the role of North Atlantic multidecadal variability has been so far much less tested than the role of the tropical Pacific. As far as the PDO is concerned, the CMIP5 models exhibit a wide range of correlations with GMST, which is partly due to their difficulty to simulate this horse-shoe pattern but also to the strong multidecadal variability of the correlations estimated over 31 year sliding windows. Once again, MIROC5 is clearly an outlier among the CMIP5 models with a strong PDO influence on GMST. Note that this model, however, shows a realistic highly positive correlation between ENSO and PDO indices (not shown), which suggests that the spurious PDO-GMST relationship is partly related to the too strong ENSO variability in this model. In contrast, GFDL-CM2.1 and CNRM-CM5.1 show a reasonable range of PDO-GMST correlations but underestimate the PDO-ENSO relationship as many OAGCMs [e.g., *Newman*, 2007]. Regressing the PDO index onto grid cell near-surface temperature at the global scale (Figure S2 in the supporting information) confirms the spurious global PDO signature in MIROC5, while the other two models fail at capturing the observed PDO connection with the tropical Pacific.

Moving to the sensitivity experiments conducted with CNRM-CM5, Figure 2 first shows the 1979–2012 time series of the annual mean Niño3.4 SST anomalies. Per design, HISSST perfectly matches the observations, but HISTAU is also successful in capturing both for the timing and amplitude of ENSO. The spatial distribution of the temporal correlations between the simulated and observed annual mean Pacific SST anomalies (cf., Figure S3 in the supporting information), however, shows significant differences. While both experiments capture the SST and low-level wind variability within the equatorial Pacific, HISTAU apparently fails at controlling the off-equatorial Pacific variability and even shows negative correlations within the perturbed tropical domain. These results highlight a mismatch between the prescribed wind stress and the free CNRM-CM5 tropical Pacific climatology rather than an intrinsic shortcoming of the WSO technique. They could explain why HISTAU is less successful than HISSST in capturing the recent global warming hiatus. Nevertheless, they do not imply that HISTAU is less credible than HISSST. The annual mean GMST does not tell much about the seasonal and spatial distribution of the simulated warming [e.g., *Trenberth et al.*, 2014b]. More importantly, as explained in the Introduction, Pacific variability is just one plausible candidate for the mismatch between models and observations, so that we do not expect to capture the observed GMST evolution in such sensitivity experiments. The fact that HISSST simulates the pause in global warming is, however, a strong result given the weak but realistic ENSO-GMST relationship in the CNRM-CM5.1. It suggests that most CMIP5 models could also replicate the hiatus by following the same experiment design.

The next question is whether the SST nudging is the most suitable technique for constraining tropical Pacific variability in a coupled OAGCM. In other words, should we trust HISSST more than HISTAU? A first way to address this question is to look at the spatial distribution of the near-surface temperature trends, which is quite heterogeneous in both observations and the ensemble simulations (Figure S4 in the supporting information). Globally speaking, the spatial correlations between the simulated and ERA-Interim 1998–2012 trends are the same in both perturbed experiments and, surprisingly, lower than in HISCTL. This result reflects the dominant role of the prescribed radiative forcings on the pattern of the recent global warming but does not tell much about the model ability to capture the ENSO teleconnections since we here compared a single realization of real climate with an ensemble of coupled simulations with free-running SST conditions outside the tropical Pacific Ocean. More noticeably, HISTAU is more consistent with ERA-Interim than HISSST (and than HISCTL if a linear trend is removed) when averaging the recent global warming over land (Figure 2). While GMST is obviously dominated by ocean surfaces, the recent land surface cooling simulated in HISSST suggests that the model ability to capture the pause in global warming might be partly due to a spurious tropical Pacific influence over land. Focusing now on the Pacific Ocean, both HISSST and HISTAU look better than the control experiment at capturing the observed pattern of surface warming (Figure S4 in the supporting information). Yet only HISTAU simulates the transition toward the negative phase of the Pacific Decadal Oscillation (PDO), as revealed by the lowest panels in Figure 2. Given the expected influence of the PDO on the Pacific trade winds (e.g., E14 and W14), our results suggest a positive feedback mechanism

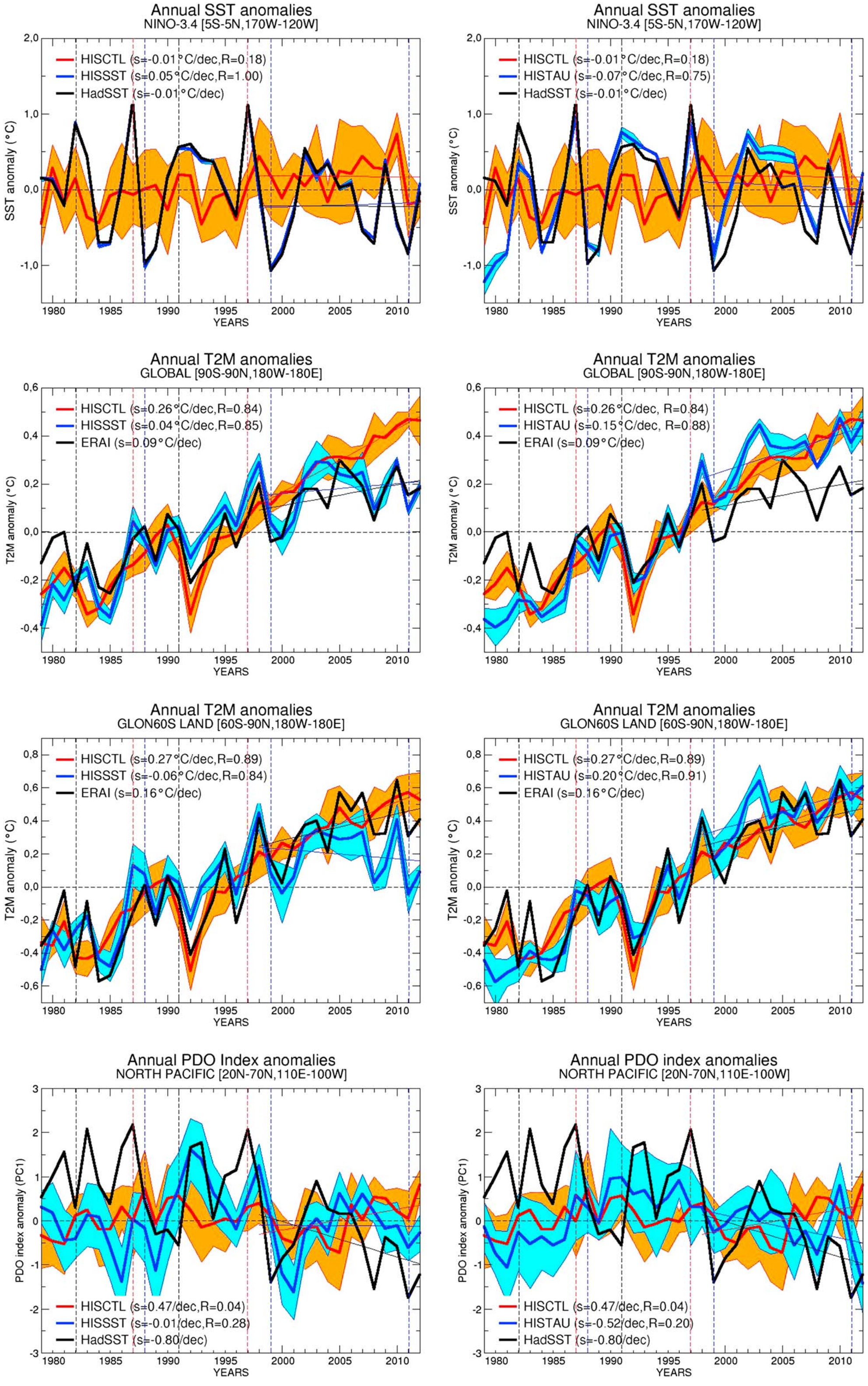

Figure 2. Simulated versus observed (in black) annual anomalies relative to the 1979–2008 climatology for Niño3.4 SST, GMST, GMST over land, and the PDO index from top to bottom, respectively. (left to right) HISSST/HISTAU (in blue) versus HISCTL (in red). For each ensemble, the mean is shown in thick line, while the shading represents the 95% confidence interval of the ensemble response. *R* denotes the interannual correlation (no detrending) with the observed time series, and *s* denotes the slope of the 1998–2012 linear trend. The black, red, and blue vertical dash lines correspond to years with major volcanic eruptions, El Niño events, and La Niña events, respectively. The PDO index is defined as in Figure 1.

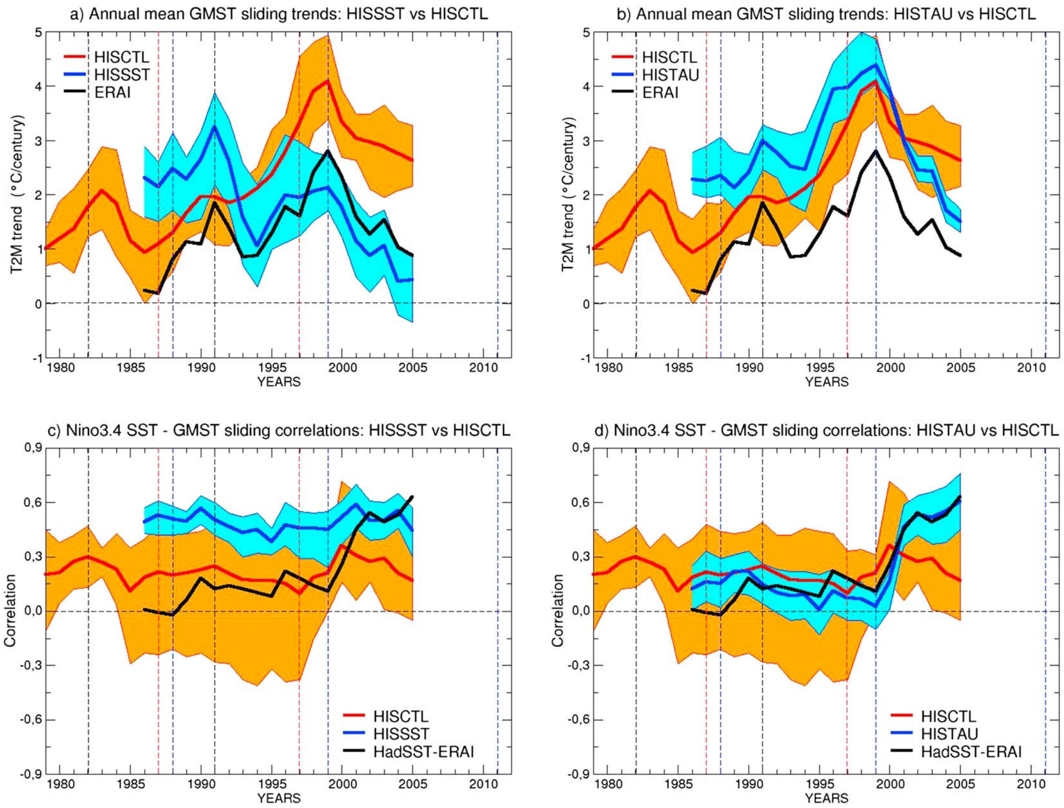

Figure 3. Simulated versus ERA-Interim (in black) sliding linear trends in the annual mean GMST (°C/century) in (a) HISSST (in red) versus HISCTL (in blue) and (b) HISTAU (in red) versus HISCTL (in blue). Simulated versus observed (in black) sliding correlations between the annual mean Niño3.4 SST and the annual mean GMST in (c) HISSST (in red) versus HISCTL (in blue) and (d) HISTAU (in red) versus HISCTL (in blue). For each ensemble, the mean is shown in thick line, while the shading extends over the range of all ensemble members. The tick marks on the *x* axis correspond to the central year of a 15 year sliding window.

whereby the enhanced surface wind stress prescribed in HISTAU triggers a negative PDO response in the North Pacific which further strengthens the trade winds. Such a feedback hypothesis, however, needs further evaluation of the underlying atmospheric and/or oceanic pathways and is beyond the scope of the present study. Moving to the South Pacific and circumpolar Southern Ocean, note that HISTAU is also the only experiment that captures the recent zonally asymmetric expansion of the Antarctic sea ice (F. Codron, personal communication) and the associated near-surface temperature pattern (Figure S4 in the supporting information). In other words, this is not just the PDO but a Pacific-wide manifestation of the PDO known as the Interdecadal Pacific Oscillation [*Power et al.*, 1999], which is better captured in HISTAU than in the other ensemble experiments.

Also interesting is the evaluation of the simulated global warming over the whole 1979–2012 period using 15 year sliding linear trends (Figures 3a and 3b). While HISSST captures the pause in global warming from 1998 to 2012, it strongly overestimates the initial warming despite the steady nudging of tropical Pacific SST. This result cannot be attributed to the observed transition from a negative to a positive phase of the Atlantic Multidecadal Oscillation, which occurs in the 1990s rather than the 1980s [e.g., *Sutton and Dong*, 2012]. It shows that the nudging of tropical Pacific SST anomalies does not lead to a systematic improvement of the simulated global warming. In contrast, HISTAU overestimates the 1998–2012 global warming, but this overestimation is relatively stationary (after the initial tropical Pacific cooling due to the perturbed wind stress climatology). This result suggests that the WSO technique leads to a better control of the GMST internal variability and that the model transient climate response (TCR) is overestimated, in line with its above mean value among the CMIP5 multimodel ensemble (2.1°C for CNRM-CM5 against 1.8°C for the ensemble mean; cf., Table 9.5 in the AR5). Note that the equilibrium climate sensitivity of CNRM-CM5 is very close to the CMIP5 ensemble mean and is therefore not responsible for the above mean TCR, which is rather due to a very low

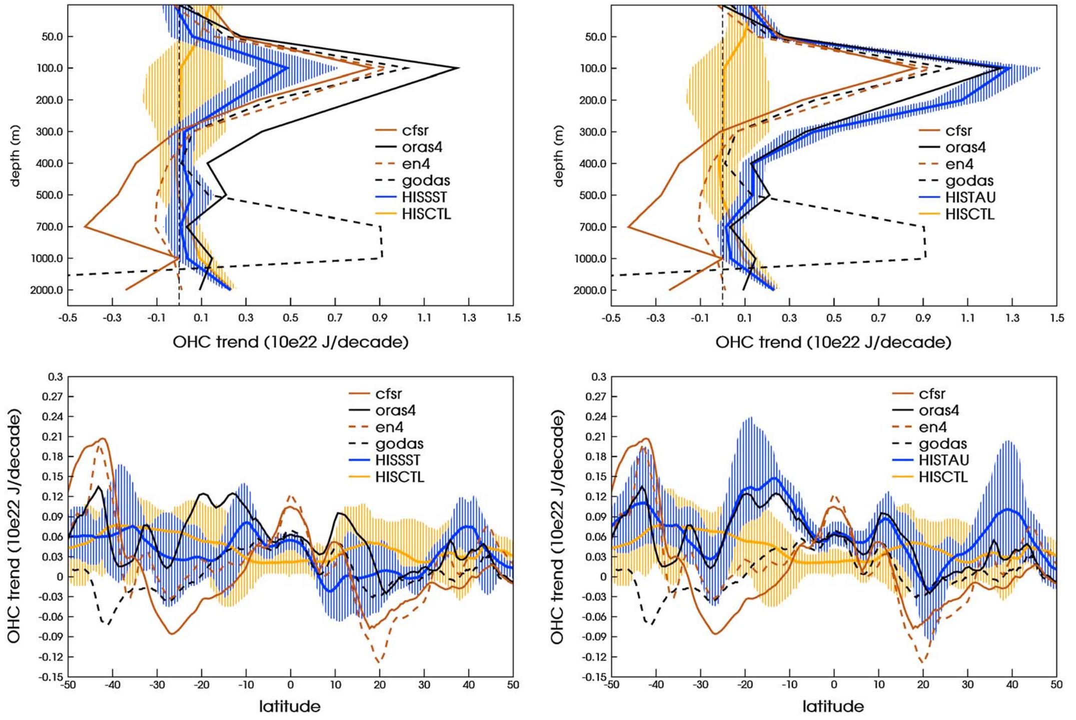

Figure 4. (top) Vertical profiles (as a function of depth in meter on the *y* axis) of the 1998–2012 linear trends in the west tropical Pacific (20°S–20°N, west of 200°E) heat content (in 1022 J/dec) in four global ocean reanalysis data sets and in the ensemble experiments (HISSST versus HISCTL on the left and HISTAU versus HISCTL on the right). The ensemble mean linear trend profiles are shown as thick lines, while the shading extends over the range of all ensemble members. (bottom) Latitudinal profiles of the 1998–2012 linear trends in the zonal mean 0–700 m global ocean heat content (1022 J/dec). The four global ocean reanalysis data sets have contributed to the Ocean Reanalyses Intercomparison Project. EN4 is a simple optimal interpolation of temperature and salinity profiles developed by the Met Office Hadley Centre (version EN4.0.2 downloaded on 3/4/2014); Global Ocean Data Assimilation System (http://www.esrl.noaa.gov/psd/) is a reanalysis assimilating sea level anomalies and temperature profiles; Climate Forecast System Reanalysis is a coupled ocean-atmosphere reanalysis from National Centers for Environmental Prediction only assimilating temperature profiles; and ORAS4 is the ECMWF ocean reanalysis assimilating sea level anomalies, temperature, and salinity profiles as well as SST.

ocean heat uptake efficiency [cf., *Geoffroy et al.*, 2013, Tables 3 and 4]. Interestingly, HISTAU captures the multidecadal modulation of the sliding correlations between the Niño3.4 SST and GMST (Figures 3c and 3d). This modulation, which is also partly found in the control experiment, might arise from the prescribed volcanic forcing. In contrast, HISSST shows more stable correlations which are shifted upward compared to the control experiment. This result suggests that the SST nudging leads to a too strong ENSO influence on GMST (including over land). Therefore, the correct simulation of the recent global warming hiatus by HISSST might arise from the combination of a too strong cooling due to the SST nudging and a too strong warming due to an overestimated TCR.

Looking at the ocean heat content (OHC) provides further evidence of the superiority of the WSO technique compared to the SST nudging. Figure 4 compares the simulated 1998–2012 trends in OHC against four global data sets from the Ocean Reanalyses Intercomparison Project. While it is difficult to rank such products, the Ocean Reanalysis System 4 (ORAS4) from European Centre for Medium-Range Weather Forecasts (ECMWF) is probably the most constrained by the available surface and subsurface observations. Figure 4a focuses on the tropical west Pacific where most ocean reanalyses agree and show a significant increase in OHC over the last 15 years. This behavior is not found in the control experiment and is strongly underestimated in HISSST. In contrast, the WSO technique allows the model to capture the observed trend and thereby partly reconciles the simulations with the observed warming not only at the surface but also in the 0–700 m ocean layer. Globally, the averaged 1998–2012 rate of change of the full-depth OHC simulated by HISTAU is equivalent to 0.95 W/m^2 (against 0.72 W/m^2 and 0.69 W/m^2 in HISCTL and HISSST, respectively) and agrees with the 0.90 W/m^2 estimated from ORAS4 [*Balmaseda et al.*, 2013]. Yet the closure of the observed global energy budget remains elusive given uncertainties in both satellite data and ocean reanalyses [*Trenberth et al.*, 2014a]. In contrast, the observed trends in OHC are relatively consistent in the tropical Pacific and yield high confidence in the assessment of continued ocean energy accumulation in this region. Moreover, the latitudinal profile of the zonal mean trend in the 0–700 m integrated OHC is also fairly consistent between HISTAU and ORAS4 (Figure 4b). This striking similarity is also found in global maps of the 1998–2012 linear trend in OHC (Figure S5 in the supporting information), at least outside North Atlantic, which accounts for the zonal mean difference between HISTAU and ORAS4 between 30 and 50°N. In line with the results obtained by E14, the enhanced tropical Pacific heat uptake is associated with a realistic intensification of both the zonal (Figure S6 in the supporting information) and meridional (Figure S7 in the supporting information) upper ocean circulations compared to ORAS4. This strengthening is much better captured by HISTAU than by HISSST and cools the equatorial SST through an increase in the upper divergent meridional circulation.

4. Discussion

By prescribing the ERA-Interim surface wind stress over the tropical Pacific, HISTAU seems to capture some of the key mechanisms, whereby a multidecadal intensification of the trade winds is likely to induce an enhanced ocean heat uptake and a slowdown in global surface warming. Although the PDO probably plays a key role in the multidecadal variability of GMST [e.g., *Meehl et al.*, 2013; E14; *Maher et al.*, 2014], our results emphasize the role of the tropical Pacific and suggest a possible positive feedback between the trade winds and the extratropical Pacific SST, which can contribute to the persistence of the Pacific-wide multidecadal SST variability. A body of evidence suggests that the WSO technique is more suitable than the nudging to capture the GMST internal variability, even if the constraint on central and east tropical Pacific SSTs is thereby weaker. Additional experiments would be, however, necessary to strengthen this conclusion and thereby demonstrate that prescribing tropical Pacific wind stress is a promising technique to diagnose deficiencies in the global radiative forcings and/or in the model TCR. According to our results, the interannual to multidecadal Pacific variability remains the main reason for the recent pause in the observed global warming but is not necessarily the only reason for the overestimated recent warming found in most CMIP5 historical simulations. The CNRM-CM5.1 model, which shows a slightly above normal TCR among the CMIP5 ensemble, might be indeed too sensitive, thereby tempering the conclusions of other studies constraining model projections toward relatively severe future warming [e.g., *Sherwood et al.*, 2013].

Why do we usually attribute the recent intensification of the Pacific trade winds to internal climate variability? Beyond the recent W14 claim, which relies on the authors' ability to isolate the internal versus externally forced component of the globally observed SST variations and to capture the climate response to the prescribed SST boundary conditions with their model, a strong argument comes from the multimodel study by *Di Nezio et al.* [2013], which shows a dominant 20th century weakening of the Walker circulation in the CMIP5 historical simulations that is qualitatively consistent with the observations. In line with the conclusions of KX13, E14, and W14, this implies that global warming has not stopped and should even accelerate over the next few decades unless mitigated by natural (volcanic eruptions) or anthropogenic (geoengineering) external forcings. Yet *McGregor et al.* [2014] suggest that the recent Walker circulation strengthening has been amplified if not triggered by the observed Atlantic warming, which cannot be accounted for by natural climate variability only [e.g., *Mann et al.*, 2014]. Moreover, *Xiang et al.* [2014] show that the weakening of the equatorial Pacific trade winds projected in the CMIP5 models is robust only over the eastern equatorial Pacific. Therefore, this debate is not closed even if internal variability remains the most plausible explanation for the recent intensification of the Pacific Walker circulation.

Finally, what can be done further for a better understanding of the global warming hiatus and, more generally, of the modulation of anthropogenic global warming by internal climate variability? The assessment of this modulation should not be undermined by a publication bias toward successes (rather than failures) in capturing the observed climate variability using imperfect models. This is the reason why a great attention should be paid to the model evaluation and credibility in any modeling attempt at deciphering the influence of dominant modes of internal variability on GMST. Moreover, a clean multimodel intercomparison study could be useful to assess the robustness of such numerical studies. As revealed by the present study, the experiment design must be specified precisely and could include pacemaker-type experiments not only for the tropical Pacific but also for the North Atlantic Ocean.

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