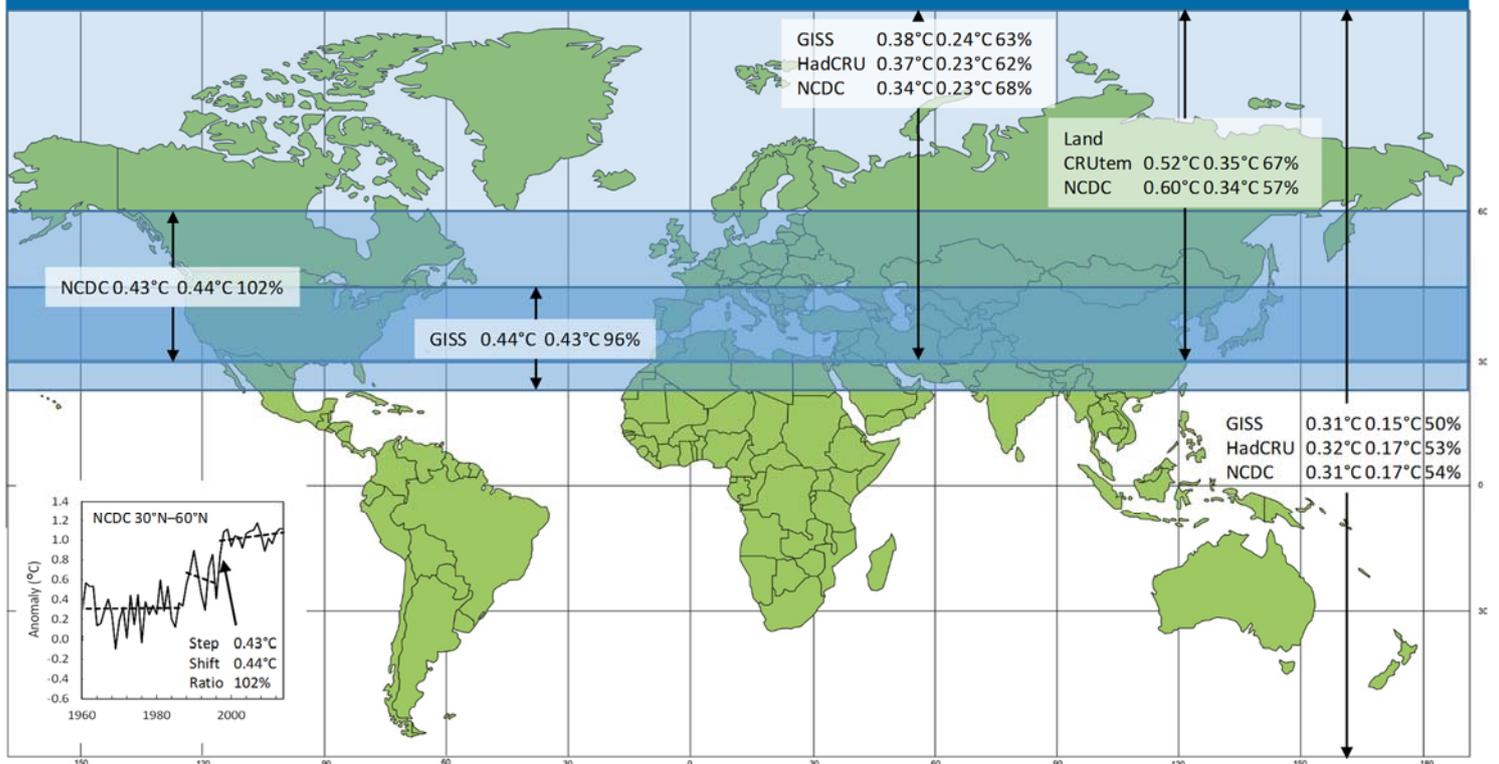


Atmospheric warming 1997–2014: hiatus, pause or regime?

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Key words: air temperature, global warming, decadal variability, hiatus, pause, regime change, step change

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Abstract

For the past decade, climate research has responded to challenges that atmospheric warming either slowed or stopped in 1998. Of the responses, the hypothesis least examined is whether climate change and variability are interacting to produce step-like regime changes. Step-change analysis identifies a step of $0.32 \pm 0.01^\circ\text{C}$ in five records of global mean surface temperature (GMST) in 1997, followed by a trend to 2014 ranging between $0.06^\circ\text{C decade}^{-1}$ and $0.11^\circ\text{C decade}^{-1}$. Thirty-nine of 45 zonal, hemispheric and global records register a step change over the period 1996–98. The difference between one trend and the next across a step change provides a minimum estimate of the shift. The average global shift in 1997 is $0.16 \pm 0.01^\circ\text{C}$, around 50% of the average step. For the northern hemisphere mid-latitudes, steps/shifts measure $0.43^\circ\text{C}/0.44^\circ\text{C}$, indicating no trend. Of the 107 members of a multi-model ensemble (MME) from the CMIP5 RCP4.5 archive, 58 register a step change in 1996–98, averaging 0.41°C (0.22°C to 0.73°C). The following step averaging 0.31°C (0.16°C to 0.52°C) occurs after a period of 7 to 26 years. The 1996–98 step is uncorrelated with model equilibrium climate sensitivity (ECS) but the following step change is highly correlated (0.58). Step-change analysis in both observations and models suggests that rapid changes punctuate more stable regimes forming a step-ladder like progression. If the current spike in temperature from the 2014–16 El Niño event represents the early stages of a step change similar to 1997–98, the world may be entering a regime of new and heightened climate risk.

Introduction

Understanding how the climate warms over decadal timescales is key for characterising changing climate risk. The dominant paradigm used to communicate this understanding is that mean surface temperature follows a long-term trend mediated by random climate variability, where the two are considered to be independent of each other.

The most common method used to analyse this is a signal-to-noise model using ordinary least-squares trend analysis (e.g., North et al., 1995; Hegerl and Zwiers, 2011; Santer et al., 2011). This method dominates climate practice, leading to a narrative of gradual change, which describes adaptation as an incremental series of adjustments over time that represents the signal and overlooks the noise (Jones et al., 2013). However, another hypothesis suggests climate change and variability interact (Corti et al., 1999; Branstator and Selten, 2009), potentially by the imprinting of radiative forcing on modes of climate variability as proposed by Corti et al. (1999), such as the mid-1970s shift in the Pacific Ocean (Meehl et al., 2009) or through two-way interactions (Branstator and Selten, 2009). In a series of related papers we test the proposition that warming proceeds as a series of regime changes producing step-like shifts in temperature interspersed with more stable periods of reduced trend (Jones, 2012; Jones et al., 2013; Jones, 2015; Jones and Ricketts, 2016a, b). When steps and trends from observed and modelled surface warming are compared, steps explain factors such as equilibrium climate sensitivity better than trends (Jones and Ricketts, 2015, 2016b).

Here, we investigate the recent period since 1997/98 in observations and models, variously known as a hiatus, pause or regime (Trenberth and Fasullo, 2013; Trenberth et al., 2014), to see whether it is consistent with the hypothesis that climate does follow step and trend process. Given the recent spike in warming is similar to that in 1997/98, we ask whether the next shift in this sequence may be underway.

Method

A multi-step and rule-based application of the Maronna-Yohai bivariate test (MYBT, Maronna and Yohai, 1978) has been developed to expand the original test beyond the detection of single steps (Ricketts and Jones, 2016, see Supplementary Information for details). Previously, the bivariate test has been used to detect inhomogeneities in climate variables (Potter, 1981; Bücher and Dessens, 1991; Kirono and Jones, 2007; Sahin and Cigizoglu, 2010), decadal regime shifts in climate-related data and step changes in a wide range of climatic timeseries (Buishand, 1984; Gan, 1995; Vivès and Jones, 2005; Boucharel et al., 2011; Jones, 2012; Jones et al.,

2013). The main purpose of automating the test is to improve its objectivity and robustness by using a predefined set of rules.

The test adapts the formulation of Bücher and Dessens (1991) and tests a single serially-independent variate (x_i) against a reference variate (y_i) using a random timeseries following Vivès and Jones (2005). The important outputs of the test in a timeseries of length N are, (1) The T_i statistic which is defined for times $i < N$, (2) the T_{i_0} value which is the maximum T_i value, (3) i_0 , the time associated with T_{i_0} , (4) shift at that time, and (5) p , the probability of zero shift. Note that i_0 is the last year prior to the change. In this paper, we routinely give the year of change.

A single timeseries analysis consists of a *screening pass*, followed by a *convergent pass*. In both passes, we apply a *resampling test* to each segment being examined, where the test is repeated 100 times, resampling the random number reference series. The screening pass starts from the most significant shift in a timeseries, determined using the resampling test and, if $p < 0.01$, the series is divided into shorter timeseries either side of the step and these are tested until all steps have been detected. As such, it is a recursive procedure whereby the first steps detected may be influenced by as-yet-unlocated steps. The convergent pass then serially refines these segments to provide a causal sequence. The convergent process is repeated until a stable set of step changes is produced.

The above procedure is run 100 times. A stable set of results will produce 100 identical solutions and less stable results will produce two or more alternatives. The most stable solution is selected for further analysis. Each time series analysed in this way will provide a set of steps if any are present. The intervals between steps can be analysed for trends and the distance between trends analysed as shifts. This has been used by Jones and Ricketts (2016) to distinguish steps from trends for the purpose of separating gradual from abrupt changes in temperature.

Observations

Observed temperature anomalies tested were mean annual global air temperature anomalies from five groups (GISS, HadCRU, NCDC, C&W and BEST), hemispheric temperatures from three groups (HadCRU, NCDC and GISS) and zonal temperatures from two groups (NCDC and GISS) for a total of 45 records (Peterson and Vose, 1997; Hansen et al., 2010; Morice et al., 2012; Rohde et al., 2012; Cowtan and Way, 2014). All five records of GMST registered a step change in 1997 averaging $0.32 \pm 0.01^\circ\text{C}$. The previous step change in 1979/80 measured $0.22 \pm 0.03^\circ\text{C}$. A step change registered in 1987 at $p < 0.05$ in two global records, and $p < 0.01$ in the three northern hemisphere records tested. This contributes to most of the trend between 1979/80 and 1997, as we show later.

Of all 45 regional to global records tested, 39 register a shift in the interval 1996–98 and 31 in 1997. For the next largest step, 18 occur in 1979 and 6 in 1980. During 1987/88, 8 regional records register a step in 1987 and 6 in 1988. The period between globally-registered steps $p < 0.01$ from 1979/80 to 1996 is 16 to 17 years in length. As of 2014, the subsequent period was also 17 years, extending to 18 in 2015. The trend preceding the 1997 step was consistent at $0.11^\circ\text{C decade}^{-1}$, while the post 1997 trend is more variable. This is part is due to different analytic methods and coverage from the various groups involved. For example, the expanded coverage by Cowtan and Way (2014) of HadCRUT4 data results in a higher post-1997 trend of $0.11^\circ\text{C decade}^{-1}$ compared to $0.07^\circ\text{C decade}^{-1}$. The recalculation by Karl et al. (2015) of NCDC temperatures taking in improved coverage and bias corrections increase the trend from $0.06^\circ\text{C decade}^{-1}$ in Table 1 to $0.11^\circ\text{C decade}^{-1}$, similar to the Cowtan & Way temperatures.

Globally, the shift between the end of the preceding trend and start of the next in 1997 is 52% of the total step registered (Table 1). Because of the northern hemisphere step that occurred in 1987, this is a minimum estimate of the non-linear component. In some regions the shift component predominates. For example, the most step-like region tested is the northern hemisphere mid-latitudes where GISS 24°N – 44°N registers a step change of 0.44°C and shift of 0.43°C ; and NCDC 30°N – 60°N registers a step change of 0.43°C and shift of

0.44°C, close to a 1:1 shift/step ratio (Figure 1). For northern hemisphere land, the NCDC record registers a step change of 0.60°C and a shift of 0.34°C, while for CRUtem, the step is 0.52°C and the shift 0.35°C, producing a lower shift/step ratio around 63%. Some regions show little evidence of a step change at this time (e.g., southern high latitudes).

Table 1. Pre-step period, trends, steps, shifts and post-step trends for five records of global mean surface temperature. Trend significance is defined not significant (NS), $p < 0.05$ (*) and $p < 0.01$ (**).

Model	Pre-step period (y)	Pre-step trend (°C decade ⁻¹)	Significance	Step (°C)	Shift (°C)	Post step trend (°C decade ⁻¹)	Significance
BEST	18	0.10	*	0.31	0.17	0.08	*
Cowan & Way	17	0.11	*	0.32	0.16	0.11	*
GISS	17	0.10	*	0.32	0.15	0.08	*
HadCRUT4.3 Global	18	0.11	**	0.31	0.17	0.07	NS
NCDC	17	0.11	**	0.33	0.17	0.06	NS

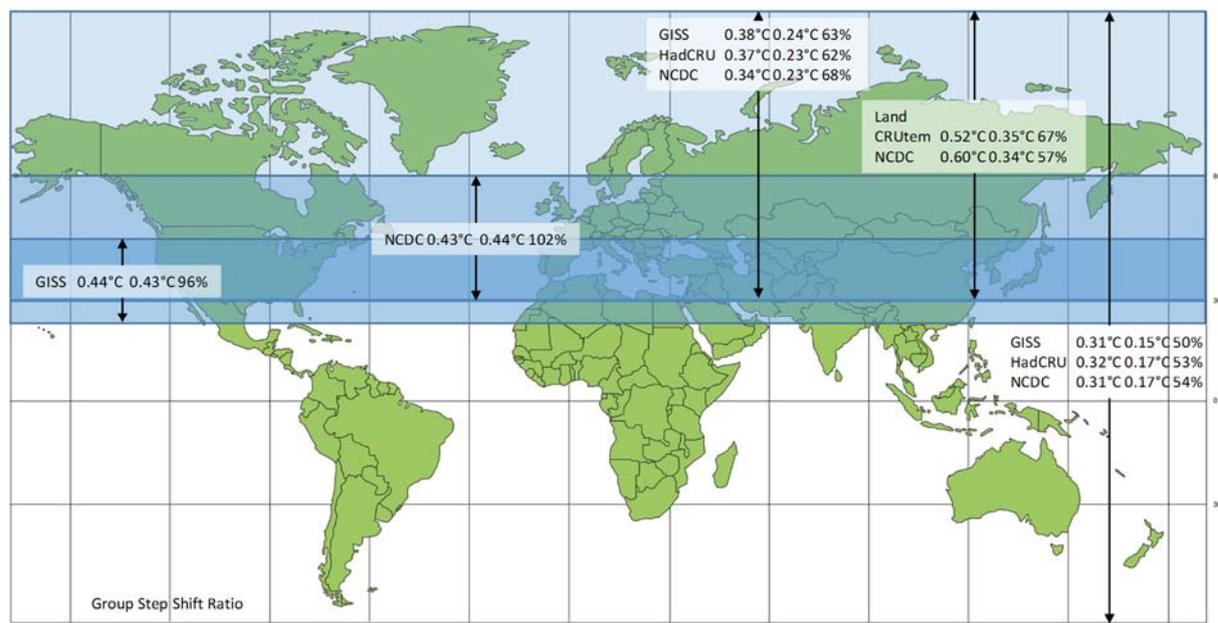


Figure 1. Map showing analysis group, step, shift and shift/step ratio for the measured change in mean surface warming in 1997 for selected parts of the world, specifically 24°N–44°N, 30°N–60°N, the northern hemisphere and global. All changes land and ocean unless indicated.

The global ratio of around 50% shows that trend-like behaviour increases as the area of measurement expands. This is consistent with step-like warming originating in specific ocean regions and rapidly spreading as warming becomes entrained in the nonlinear equator-to-pole transport of heat energy as part of decadal variability (Reid and Beaugrand, 2012; Jones and Ricketts, 2016a). The period 1997/98 is linked to a regime change involving the north Pacific Ocean (Overland et al., 2008) and step-like anomalies in sea surface temperatures in the Pacific, Atlantic and Indian Oceans, with the northern hemisphere components extending into the Arctic (Reid and Beaugrand, 2012).

This supports the proposition that climate change may map onto principal modes of climate variability (Corti et al., 1999) or may interact with variability (Branstator and Selten, 2009). It is also consistent with Wang et al. (2012) who conclude that four modes of climate variability ‘Granger cause’ nonlinear temperature change on decadal scales: the Pacific Decadal Oscillation, the North Atlantic Oscillation, the El Niño/Southern Oscillation, and the North Pacific Index. Regime changes in these combined modes coincide with the shifts where we

detect step changes in temperature. In a similar study, de Viron et al. (2013) study 25 climate indices, integrating their variability into four leading modes of variability using multi-taper and maximum entropy methods; in turn, these modes are correlated with the SST field. These findings are consistent with a physical narrative where warming is the result of a store and release process whereby the added heat trapped by greenhouse gas forcing becomes part of the nonlinear thermodynamic processes of the ocean-atmosphere system associated with climate variability (Jones and Ricketts, 2016a). Step-like responses in warming over decadal timescales form a complex trend over longer periods (Jones and Ricketts, 2016a).

Models

If step-like changes occur in the climate system and are a normal part of climate change, we should be able to detect them in the output of physically-representative climate models.

The RCP4.5 multi-model ensemble (MME) driven by historical forcing 1860–2005 from the CMIP5 model archive has 107 independent members. This provides a large sample of historically-forced simulations for testing. These models do a reasonable job of reproducing the major step changes in the latter part of the 20th century, in the late 1970s, 1987/88 and 1997 (Figure 2). For the period 1950–2005, the correlation between observations and the MME is 0.40. If specific events: 1963/64, 1968–70, 1976/77, 1979/80, 1987/88 and 1996–98 are grouped, and all other years analysed individually, the correlation increases to 0.78 {Jones, 2016 #5234}. Fifty-eight members of the MME or 55% of all the available runs undergo step changes ($p < 0.01$) in 1996–98, so are treated as statistical analogues of the observed step in 1997. One year's error is considered to offer sufficient accuracy for what is widely assumed to be a stochastic event.

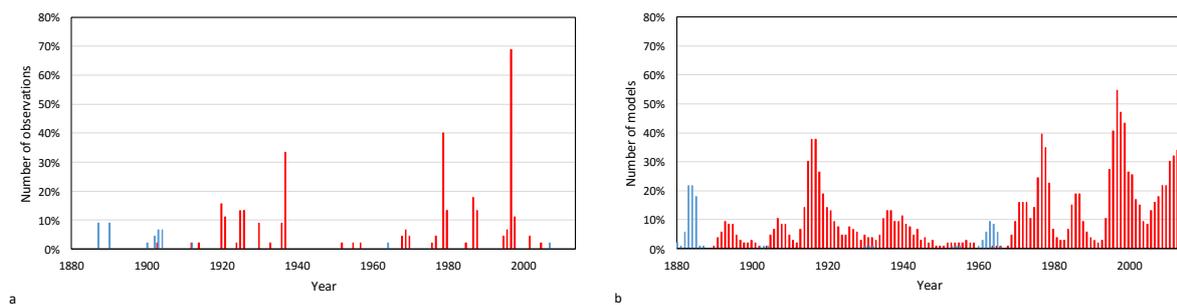


Figure 2. Step changes in observed and simulated surface air temperatures. Frequency in percent of statistically significant step changes from a) Global, hemispheric and zonal averages (45 in total, 1880–2014); b) global mean surface warming 1880–2014 from the CMIP5 archive for historical forcing to 2005 and the RCP4.5 pathway thereafter (107 in total).

These 58 step changes average 0.41°C and range from 0.22 to 0.73°C; the observed step change of 0.32°C is at the 38th percentile of this distribution. The average shift (distance between the preceding and following trend) is 0.24°C compared to the observed shift of 0.16°C. The following steps in these models occur between 2003 and 2023, producing interval lengths varying between 7 and 26 years, compared to the 1997/98–2014 period approaching 17 years (Figure 3a). The year 2015 is at the 81st percentile in this distribution and 2016 is at the 92nd percentile. The post-step trends vary between 0.03°C and 0.35°C decade⁻¹, averaging 0.17°C decade⁻¹. Of these, 13 are non-significant (NS), 11 are $p < 0.05$, 10 $p < 0.01$ and 24 $p < 0.001$.

The size of each step change, the following step change, the period between steps, the internal trend and resulting shift (step minus trend), and equilibrium climate sensitivity (ECS) were all tested for correlation (Table 2). Smaller steps 96–98 and the following step are associated with shorter intervals (0.50 and 0.33, $p < 0.01$). These are shown in Figure 3a with observations to 2015 situated in the lower part of the distribution. The 96–98 step is also positively correlated with the size of the next step (0.43, $p < 0.01$). However, there is no correlation between the 96–98 step with the following trend (0.06, NS). The internal trend carries little information, only being correlated with its length (Table 2).

Table 2. Correlation matrix between variables associated with models that step 1996–98 (n=58) that include the size of the step, its shift (step minus trend), the size of the next step, the period length between steps, the period length prior, the trend following, the likelihood of the null hypothesis for that trend and ECS (n=54). Correlation significance is defined not significant (NS, greyed), $p < 0.05$ (*, standard) and $p < 0.01$ (**, bold). Significance and correlation values are mirrored across the table.

	96–98 step (°C)	96–98 shift (°C)	Next step (°C)	Next period (y)	Last period (y)	Next trend	Trend P(H ₀)	ECS
96–98 step (°C)		**	**	**	*	NS	NS	NS
96–98 shift (°C)	0.82		*	**	*	NS	NS	NS
Next step (°C)	0.43	0.28		*	NS	NS	NS	**
Next period (y)	0.50	0.41	0.33		NS	**	*	NS
Last period (y)	0.33	0.28	0.11	0.15		*	NS	NS
Next trend	0.06	-0.25	0.15	-0.34	0.26		**	NS
Trend P(H ₀)	-0.18	0.04	0.01	-0.29	-0.17	-0.51		NS
ECS	0.14	0.14	0.57	0.13	-0.26	-0.13	0.21	

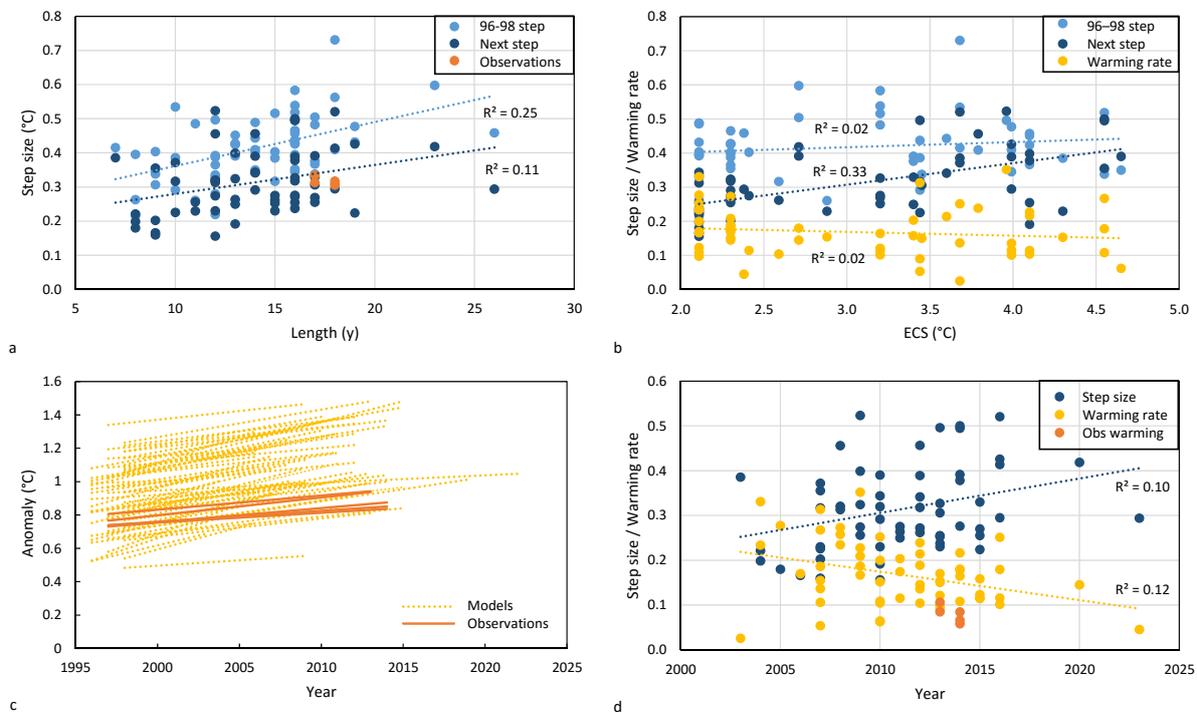


Figure 3. Characteristics of multi-model ensemble of mean global surface warming containing shift dates in 1996–1998 (RCP4.5, 58 members), showing step change and trend relationships with observations; 2a) relationship between the 1996–98 step change, the following step change and period length between changes, b) step changes and internal trend relationship with model equilibrium climate sensitivity (ECS) and c) internal trends for the 58 step changes identified in 1996–98 shown with observations and 2d) following step change and internal trend with year of change shown with observed trends to date (2013, 2014).

The size of the 1996–98 step is uncorrelated with ECS (0.14, NS) and the next step correlation is (0.57, $p < 0.01$), but the intervening trend is not, being slightly negative (-0.13, NS, Figure 3b). Figure 3c shows the anomalies of the 58 post-step trends with observations, all adjusted to the same baseline of 1880–1899. They show the observations in the lower part of the sample, not strongly different although they are at the lower end of the distributions for total warming, interval length and internal trend. Figure 3d shows the step size compared with the warming components from shifts and trends from models and observations.

The step and shift (step minus trends) are highly correlated (0.82, $p < 0.01$) as would be expected. The ratio of shifts to steps is 0.58, close to the value of 0.52 for observations. Figure 3d shows the size of the next step within the ensemble, its timing, the rate of trend and observed trends to 2013/2014. This raises the obvious question, when would we expect the next shift? One may be underway given the current spike in temperatures to new highs.

The statistical analysis of change points requires hindsight. One way around this is to increase the sensitivity of the test by increasing the number of data points, making the Type I/Type II error estimates of the test less meaningful because of the higher sensitivity. However, this can be allowed for by Monte Carlo testing with randomly shuffled data either side of a shift. If a nominated change point receives $< 50\%$ of the hits in 100 trials using this method, it is discarded.

Three records of GMST regularly updated on a monthly basis were analysed for step changes on a monthly basis from January 1970 to June 2016. The results in Table 3 includes the 1986/87 step change, which reduces the size of the 1997 step change by about 0.05°C , but leaves the shift – the distance between the last and next trend – unchanged. A further step change registers in 2014, but because the following record is brief, it manifests as a sharp change in trend that follows the temperature rise to its current peak (Figure 4). Because the period 2014–2016 contains an extended El Niño event, this will mostly be interpreted as a short-term departure from the long term trend. However, if it is analogous to 1997/98, it may be the early part of a shift to a new regime, where temperatures thereafter are sustained at consistently higher levels than previously. A step and trend analysis of monthly anomalies of the record summarised in Table 3 is shown in Figure 4. Only subsequent temperatures (post June 2016) will show how large this latest step is at the global scale.

Table 3. Step changes for monthly anomalies of temperature from January 1970 to June 2016, showing the size of the change ($^\circ\text{C}$) and the month preceding.

GISS		HadCRU		NCDC	
Date	Change ($^\circ\text{C}$)	Date	Change ($^\circ\text{C}$)	Date	Change ($^\circ\text{C}$)
Dec-1976	0.21	Jan-1977	0.16	Jan-1977	0.21
Dec-1986	0.16	Jan-1987	0.16	Dec-1986	0.14
Aug-1997	0.25	May-1997	0.26	May-1997	0.23
Jul-2014	0.31	Nov-2014	0.32	Feb-2014	0.30

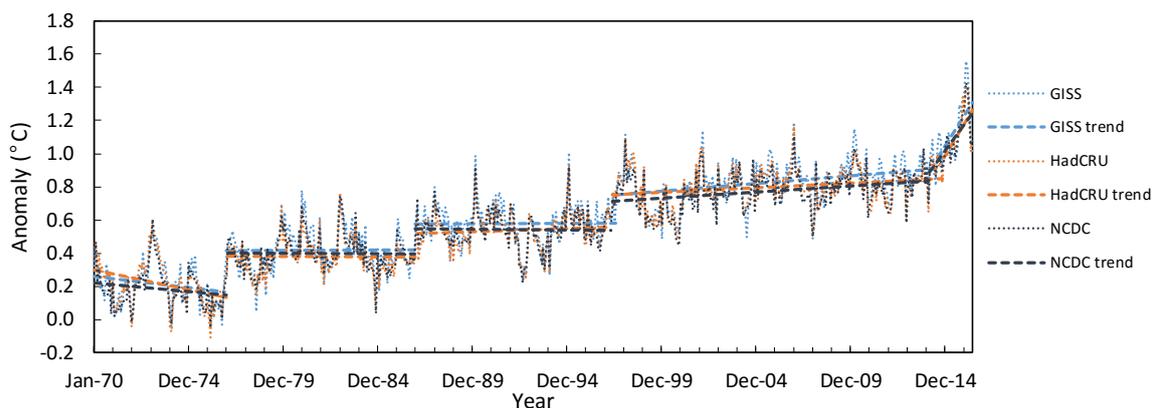


Figure 4. Monthly anomalies from three records of global mean surface temperature plotted with internal trends as identified by step changes ($p < 0.01$) using the bivariate test.

Another way to estimate the size of the next step from the model ensemble is to apply regression analysis using the previous step and period elapsed to estimate its magnitude. This procedure estimates an increase of 0.30°C with a very low r^2 value (0.18) and a sizeable standard error (0.09°C) even though the results have a low

p -value using the F-test ($p=0.003$). Adding the intervening trend slightly increases the r^2 value (0.20) and reduces the standard error (0.08°C) for the same outcome. A range of 0.12–0.47°C is within 95% limits and 0.04–0.56°C is within 99% limits. Similar outcomes are obtained when periods of 17 to 19 years are used (2014 to 2016), so uncertainty about when the step change occurs has little impact on the result.

Although a change of around 0.30°C globally may seem benign, in some regions and on land, following 1997/98 it led to significant shifts in risk which include increased fire danger in regions of Mediterranean climate, large scale coral bleaching, drought in many mid-latitude regions and large increases in high latitude temperature (Jones et al., 2013).

Exploiting the correlation between the size of the next step and ECS, a multiple linear regression of ECS using a projected step change of 0.30°C estimates ECS as 3.2°C, with an r^2 of 0.35 and a standard error of 0.68°C. This result is insensitive to input uncertainties in period length and intervening trend. Because this estimate piles uncertainty on uncertainty, it has little more than curiosity value as a prediction, but suggests that if models are used in this way to constrain observational estimates, the results are not outliers with respect to the models, as has been claimed using short-term historical trends (Otto et al., 2013; Lewis and Curry, 2015). An estimated step change of around 0.31°C, similar to the model average of 0.31°C, results in an ECS of 3.2°C, close to the median estimate from the literature. This suggests a greater degree of consilience between models and observations than is routinely obtained by analysing recent short-term trends.

Discussion

The prevailing paradigm of how the climate is changing over decadal timescales separates the gradual warming produced by increasing radiative forcing from internal climate variability. This is codified in a signal-to-noise model where the gradual trend is interpreted as imparting useful information and noise is interpreted as random and not considered useful (Koutsoyiannis, 2010; Jones, 2015). This has led to method being construed as theory; normalising gradual warming as the theoretical consensus for change, instead of it being accepted as a methodological consensus (Jones, 2015). By contrasting a simple step model with a trend model and subjecting both to severe testing following Mayo and Spanos (2010, 2011) we conclude that steps carry more information about externally-forced warming than long-term trends, and shifts, measured as steps minus internal trends carry more information than internal trends (Jones and Ricketts, 2016a). This paper builds on that theme by assessing the step change centred around 1997.

Model-produced step changes in the 1996–2005 decade are poorly correlated with ECS (0.19, $n=101$) in comparison with decades before and after. Correlations during 1976–1985 and 1986–1995, are 0.41 and 0.47 respectively, and in 2006–2015 correlation rises to 0.68 and for subsequent decades to 2095 ranges between 0.57 and 0.82. The changeover from historical forcing to projection in these models is 2005 from to 2006. In the historical period, decades with high negative forcing characterised by volcanic eruptions and high sulphate aerosols are negatively correlated with ECS, and other decades with positive forcing have positive correlations. These cancel each other out when the entire historical period (1861–2005) is taken into account, where correlation with ECS is -0.01 (Jones and Ricketts, 2016a). These competing forcings may explain the low correlation of simulated step changes in 1996–98: strong negative forcing from the Mt Pinatubo eruption in 1991 (Miller et al., 2014) is followed by a strong positive response on recovery, resulting in widespread, contemporaneous step changes in the model ensemble. In triggering these responses, the strong positive and negative forcing between models of differing climate sensitivity cancel each other out.

This example shows that variations in the rate and direction of forcing can influence the timing of a step change. Timing may also be influenced by how energy is being distributed with the climate system. For example, in explaining the extended period between steps in the observations, where deep-ocean mixing and cooling surface winds (England et al., 2014), may have actually delayed any subsequent step change. This is consistent with the study of Risbey et al. (2014) who show that models in phase with the current ENSO regime have similar trends to observations, and their reproduction of those trends shows a clear inflection around

1997–98. A similar role for natural variability was proposed for the timing of the shift in the Pacific Ocean in the mid-1970s (Meehl et al., 2009).

This explanation turns the explicative component of the conventional paradigm on its head. Rather than the recent period of reduced trend being an ‘exception’, instead it would be the rule in a climate defined by regime-like periods of relative stability punctuated by abrupt regime changes that mark a change in how energy is being distributed by a nonlinear hydrothermal system. As the major heat storage mechanism on the planet, the ocean stores most of the heat trapped by greenhouse gases (Roemmich et al., 2015) and periodically releases some of that heat as atmospheric warming if continuing forcing increases entropy to a critical point (Jones and Ricketts, 2016a). Heat energy is then released as part of the transport of that energy to the upper atmosphere and the poles. In unforced conditions, these mechanisms of climate variability will oscillate through warming and cooling steps largely under the influence of internal variability. Under external forcing, upward steps in warming increase in frequency as the system is forced to transport more energy from the ocean surface to the atmosphere and poles, first producing a step-ladder, evolving into an escalator as forcing increases (Jones and Ricketts, 2016a, b).

A specific question relating to this issue is whether the recent period of reduced trend from 1998 (compared to the previous three decades) is a short-term deviation from a long-term trend or a specific phenomenon in its own right (Boykoff, 2014; Lewandowsky et al., 2015a; Lewandowsky et al., 2015b; Trenberth, 2015). Because this period is being used to claim that global warming is not happening or poses less of a risk than projected by the IPCC (Boykoff, 2014), efforts are being made to either defend the trend and show that a hiatus does not exist (Cahill et al., 2015; Karl et al., 2015; Rajaratnam et al., 2015), or to explain the processes causing it (Kosaka and Xie, 2013; Meehl et al., 2013; England et al., 2014; Watanabe et al., 2014; Yao et al., 2015). Here, we are suggesting that although this model of temperature change is superficially similar to the contrarian one (Jones and Ricketts, 2016a); i.e., that warming is not gradual – it means the opposite of what the critics claim.

Conclusion

Investigation of the so-called ‘hiatus’ period detects a step change during 1997 in 31 of 45 global and regional records of observed surface temperature and in 58 out of 107 independent model runs in 1996–98. The observed interval is potentially around 17 years in length, if the current spike in temperatures is thought to signal the next step change. In the model sample, the longest simulated period following this date is 26 years. Eight of 58 models have intervals of 18-years or longer, so the observed period is unexceptional. The observed mean global 1997 step change in warming was 0.32°C as measured by the bivariate test, reducing to 0.25°C if step-like warming in the northern hemisphere in 1987/88 is incorporated as another step. The current spike in temperatures registers as a step of 0.31°C and appears to be evolving in a similar fashion to that in 1997–98. If this level of warming were to continue, in some land-based regions it would manifest as warming of 0.6 to 1.0°C, leading to an escalation of impact-related risks. In polar regions, warming could be even greater. Under this model, continued forcing would produce further step-like changes in future decades. This suggests that we are not emerging from a hiatus or a pause to experience further trend-like warming, but entering a new and warmer regime that is likely to give way to subsequent step changes as forcing continues.

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