Is homogenisation of Australian temperature data any good?

Part 7. Victoria River Downs, Northern Territory, Australia

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Summary

The ACORN-SAT project is deeply flawed, flagrantly unethical and should be abandoned.

Read on …

The First Law of Thermodynamics predicts that maximum temperature (Tmax) depends on rainfall such that the drier it is the warmer it gets. BomWatch protocols based on that Theorem are used to assess the quality of individual weather station datasets, investigate climatic trend and change, and evaluate Australian Climate Observations Reference Network – Surface Air Temperature (ACORN-SAT) datasets used to monitor climate warming. Located in an isolated portion of the Northern Territory, Victoria River Downs (ID 14825) is one of 112 such datasets.

From when observations commenced in 1965 until about 1979 data were plagued by seasonal runs of missing observations, or low data counts per month. Observations were also mostly reported in whole and ½°C from 1975 to 1982 and more frequently in whole degrees than other decimal fractions from when the automatic weather station (AWS) was installed in May 1997 until about 2006. Site-surrounds were also irregularly watered prior to about 2007. Mean maximum temperature data (Tmax) could therefore not be judged as high-quality. As data were unavailable from June to September 1973 (N=210), 1973 was omitted from the analysis.

Tmax depended on rainfall P<0.001), which explained 30.7% of Tmax variation (R^2_{adj} = 0.307), so although data conformed with the First Law Theorem, precision was less than the benchmark of R^2_{adj} = 0.50. Due to a significant step-change in 2013, re-scaled Tmax ~ rainfall residuals were not homogeneous. Categorical multiple linear regression verified that responses to rainfall each side of the change were the same (responses were parallel) and that due to the up-step rainfall adjusted segment means were offset 1.12°C (SE=0.191, P <0.001). Rainfall reduced Tmax 0.197°C/100mm and the step-change and rainfall together explained 56.8% of Tmax variation (R^2_{adj} = 0.568). As the $Shift_{factor}$ explained 61.2% of variation that was not explained by rainfall alone, the shift was predominant. *Post hoc* analysis found that although not significant, the overall trend in Tmax of 0.125°C/decade was spuriously related to two non-trending segments interrupted by the abrupt step-change in 2013 which was not related to the climate. No additional signals remained that could be attributed to CO_2, coalmining, electricity generation or anything else.

BomWatch protocols were also used to explore faults in ACORN-SAT homogenisation. The implications of fabricating trends to agree with *The Science* under the guise of data homogenisation were outlined and discussed. As the point of implausible adjustments is near, the whole edifice must eventually collapse, possibly within a decade, and probably sooner than the net-zero goal of 2050.

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[1] Former NSW Department of Natural Resources research scientist and weather observer.

1. Introduction

> The main question is whether trends and changes in maximum temperature data reflect site and instrument changes, the true climate, carbon dioxide (CO_2), coal mining or anything else.
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Situated 443 km south of Darwin, 410 km NE of Halls Creek and 433 km north of Rabbit Flat, the weather station at Victoria River Downs (BoM ID 14825) was not used to monitor Australia's warming prior to the advent of the Australian Climate Observations Reference Network – Surface Air Temperature dataset (ACORN-SAT) in 2012, and subsequent updates in 2017 and 2022. While daily rainfall is available from the Bureau of Meteorology (BoM) from 1886, temperature records are only available from 1965. Adjustments made by ACORN-SAT v1 (AcV1) are not listed in the most recent (AcV2.3) catalogue but were available in the initial 2012 adjustment summary. Due to its isolation (Figure 1), ACORN-SAT station-weights indicate Tmax data for Victoria River Downs is representative of about 3.3% of Australia's land area.

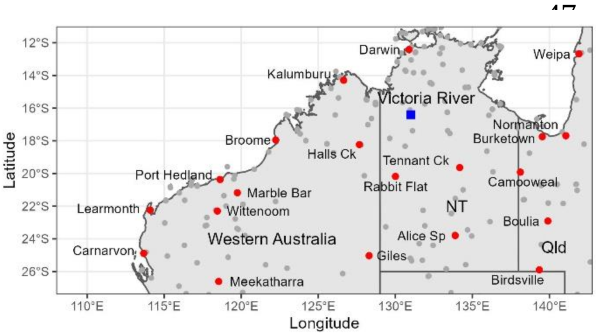

Figure 1. Victoria River Downs and ACORN-SAT sites in the Northern Territory (NT), Western Australia and Queensland (Qld) (red buttons) and other temperature reporting sites (grey circles).

According to the ACORN-SAT Catalogue: *The site is located on the grounds of the Victoria River Downs homestead, over natural grass (which becomes bare ground during dry seasons), about 60m away from the nearest building. The site moved 250m northwest in August 1987. An automatic weather station was installed on 9 May 1997. Station photos indicate that the grass was watered up until around 2007; data indicate a marked increase in maximum temperatures around this time, especially during the dry season.*

As 60-litre Stevenson screens were not specified until 1973[1] thermometers were probably originally housed in a standard 230-litre screen. A station list archived in 2014 placed the site at Latitude -16.4044°, Longitude 131.0131°, about 210m SW of its current position (-16.4030°, 130.0145°). Coordinates of the original site and the move in August 1987 were not reported in site-summary metadata. A Rosemont electronic dry-bulb sensor was installed on 29 June 1997 and replaced on 17 June 2009. Maximum and minimum (Tmax and Tmin) thermometers were removed on 26 July 2012, but were re-installed on 7 January 2014 (Tmax), and 2 March 2016 and 7 January 2019 (Tmin) suggesting problems may have occurred with the automatic weather station (AWS). There is no manual vs. AWS data comparison.

The most recent site diagram and the ACORN-SAT catalogue photograph shows the 60-litre Stevenson screen about 40m west of a large tree, with the amenities block behind (Figure 2). As the proximity of trees and lawn in an otherwise seasonally-arid landscape is likely to affect observations, and as metadata is scant on detail, trend and change in Tmax, and the effect of site changes on temperature extremes is best examined using rigorous BomWatch protocols that use objective statistical methods.

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[1] http://www.bom.gov.au/climate/data/acorn-sat/documents/ACORN-SAT_Observation_practices_WEB.pdf (p. 9).

Figure 2. The monitoring site at Victoria River Downs, photographed from the west showing the 60-litre Stevenson screen (the white louvered box on the left) about 40m from a large tree and about 30m from watered lawns. The raingauge is in the centre and the A-pan evaporimeter (and water-supply tank) is on the right.

ACORN-SAT aims to remove non-climate influences on data so datasets are more homogeneous for extremes as well as for means[1]. Reference series consisting of up to 20 neighbouring stations whose first-differenced data are correlated with those of the target, are used to both detect and adjust inhomogeneities in target-site data. The method uses transfer functions to skew data distributions at identified changepoints allegedly so they align. Adjustments were applied to AcV1 in January 1976 (statistical) and 1 August 1987 (move), and for AcV2.x on 9 June 1968 (screen), 1 January 1974 (statistical) and 1 January 2007 (site vegetation). ACORN-SAT undertakes no routine QA or *post hoc* evaluation to verify that homogenised data reflect the true climate.

In this study BomWatch protocols are used to analyse Tmax data and evaluate adjustments made by ACORN-SAT. **The questions are whether trends and changes in observed Tmax reflect site and instrument changes or the true climate; and whether adjustments made by iterations of ACORN-SAT (AcV1 to December 2011, AcV2.1, December 2017, and AcV2.4, December 2022) are unbiased.**

2. Methods

> Understanding the data is a fundamental tenet of the scientific method. *Assuming* that data are fit-for-purpose leads to poor science and potentially misleading outcomes. BomWatch protocols use objective, replicable statistical methods to assess data fitness and investigate trend and change.
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Daily temperature data for Victoria River Downs (BoM ID 14825) were downloaded from the BoM's climate data online facility and summarised into multi-attribute annual datasets using R (R Core Team, 2021[2]). Monthly rainfall was also downloaded, infilled as necessary using data for the nearest available site and incorporated into the analysis dataset.

Tmax trend and change was analysed using protocols as detailed in the Parafield (SA) case-study[3] and in subsequent reports in the *homogenisation* series. The dataset used in the study is available separately as an Excel workbook (Victoria River.xlsx).

Daily data for the grid-cell encompassing Victoria River Downs (1900 to 2022) were also downloaded from https://www.longpaddock.qld.gov.au/silo/ and likewise summarised. As SILO data are interpolated using data for surrounding sites, they may better reflect the general climate.

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[1] Trewin, Blair (2018). *The Australian Climate Observations Reference Network – Surface Air Temperature (ACORN-SAT) version 2*. Bureau Research Report No. 032. (http://www.bom.gov.au/climate/change/acorn-sat/documents/BRR-032.pdfRR-032 (bom.gov.au))

[2] R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

[3] https://www.bomwatch.com.au/data-quality/part-1-methods-case-study-parafield-south-australia-2/

3. Results

3.1 Preliminary analysis

Four of the 58 years of Victoria River Downs data reported fewer than 250 daily observations, eight reported fewer than 300, and 14 reported fewer than 320. Runs of missing data before 1979 were most common in spring (from September to December). No data was available for January 1968 or June 1991 and data was missing from March to May 1970, December 1970 to March 1971, and from June to September 1973. Most months from 1975 to November 1978 were also incomplete. Precision may also be problematic. Observations from 1975 to 1982 were mostly reported in whole and ½°C. Even after the AWS was installed in May 1997, whole degrees were reported more frequently than other decimal fractions until about 2006.

Missing data and low precision are more likely to impact on daily temperature extremes, trends in extremes, and record hot days than long-term trend and change. However, runs of missing data in winter or spring for example, may result in warmer annual averages than if data were missing in summer. As observations were unavailable from June to September 1973 (N=210), 1973 was omitted from the analysis.

3.2 The general climate

Average rainfall of 605mm/yr is strongly skewed. The eight highest rainfall years (6% of years, in rank-order 1904, 1995, 2003, 2008, 1991, 1974, 2011, and 2010) accounted for 10% of total rainfall since 1900, and 21 of the highest-rainfall years (17%) contributed 25% of the total. With the dry season extending from April to October, rainfall is also highly seasonal (Figure 3). Average monthly maxima and minima are slightly warmer before the onset of the 'wet' in November than in summer or early autumn.

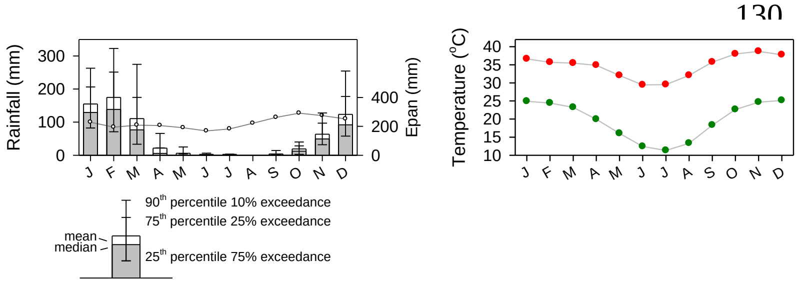

Figure 3. Monthly rainfall distributions, evaporation and average maximum and minimum temperatures for Victoria River Downs. As evaporation (0.7*EPan) exceeds rainfall by a factor of 2 (circles, right axis) there is little likelihood of a sustained positive soil moisture balance.

Unpredictable in timing, length and amount received, rainfall occurs as episodes of wet/dry years (Figure 4). Rainfall was relatively low from 1900 to 1973 (average 610mm/yr), higher from 1974 to 1992 (740mm), and increased from 1993 before tapering-off in 2018 (827mm/yr to 2022).

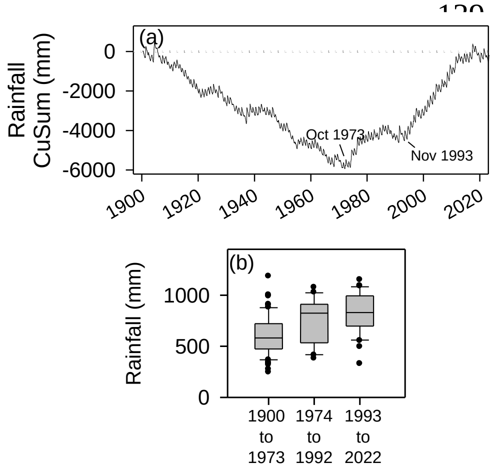

Figure 4. Lower rainfall prevailed from 1900 to 1973 (the CuSum in (a) declined). It increased from 1974, then more rapidly from 1993, reaching a peak in 2018 (the CumSum inclined) before tapering off (2019 was the 4th driest year). Box-plots for each of the three epochs (b) show the upper and lower quartiles bound by the box, the median within, and outliers.

Except for 2019, which was the 4th driest year since 1900, recent years have been generally more favourable than previously, particularly those before 1973.

3.3 Trend and change in Tmax

> Non-climate factors such as lackadaisical observing practices, watering, the state of equipment and station re-locations profoundly affect trend and change. The Bomwatch approach uniquely examines latent signals in data that naïve time-series analysis cannot.
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Consistent with the First Law Theorem, Tmax depends on rainfall and the drier it is the warmer it gets (Figure 5(a), Table 1(i)). However, rainfall only explains 30.7% of Tmax variation overall (R^2_{adj}= 0.307), suggesting the quality of data is exceptionally poor or a 'hidden' factor affects the naïve relationship.

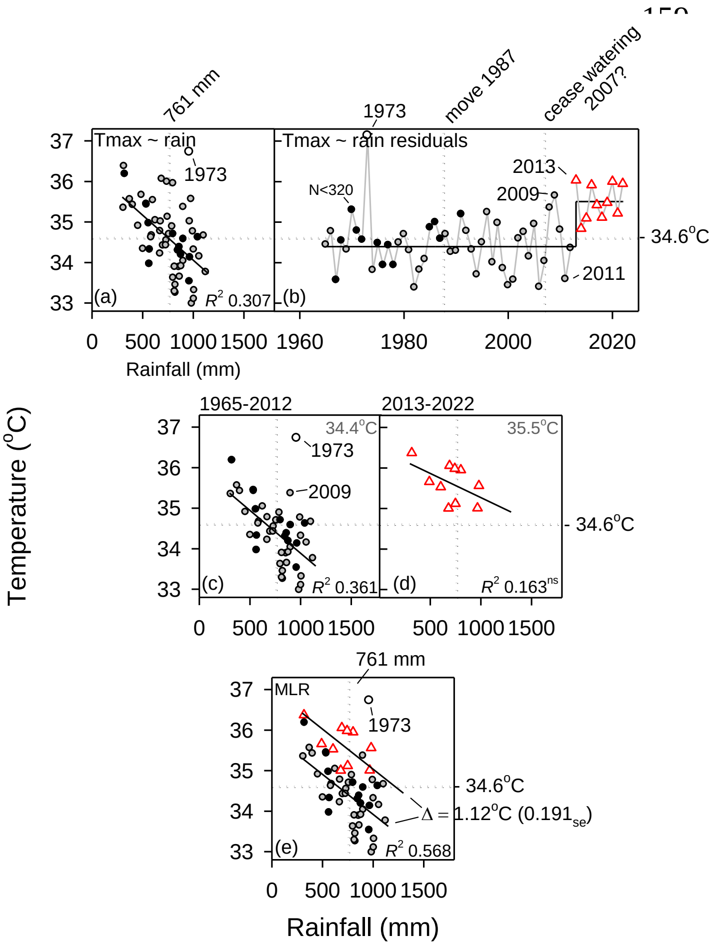

Figure 5. Analysis of trend and change in Tmax data for Victoria River Downs. A statistical summary is provided in Table 1.

A step-change in Tmax ~ rainfall residuals (Figure 5(b)) initially in 2008 (not shown) reversed in 2010/11 and was possibly an artefact related to nearby watering. Despite the AWS continuing to operate, multiple Tmax thermometers were removed and replaced in 2008 suggesting AWS data were supplemented with manually observed data up to the time that thermometers were removed in 2012. The 2013 step-change persisted to the end of the record in 2022 (data for 2023 was incomplete at the time of writing).

Relative to average rainfall and mean Tmax (dotted lines in Figure 5(c) and (d)), segmented means were not likely to be the same. Further, while data for 2009 may be an outlier, slope coefficients were similar (Table 1(ii)).

Multiple linear regression (Figure 5(e), Table 1(iii)) confirmed that the rainfall-adjusted difference (1.12°C) was significant (segmented regressions were offset), and that responses to rainfall were the same (interaction was not significant, thus relationships were parallel). Rainfall reduced Tmax 0.197°C/100 mm and rainfall and the step-change simultaneously explained 56.8% of variation in Tmax. While trend in raw Tmax was possibly significant (P=0.055) (Table 1(iv)), additional analysis confirmed that data consisted of two non-trending segments interrupted in 2013 by the abrupt step-change.

A Q-Q plot showed MLR-residuals were normally distributed; residuals were also independent (Durbin-Watson test P=0.178), with equal variance across categories (Breusch-Pagan P=0.123). Analysed with data for 2009 omitted, as average Tmax (35.36°C) was less than the upper 95% prediction interval of 35.52°C, it was unlikely to be an outlier to the Tmax ~ Sh_{factor} + rainfall case.

Table 1. Statistical summary relating to Figure 5. As explained previously data for 1973 was ignored. (Sh refers to the Shift$_{factor}$ variable; ns = *P*>0.05.)

Model	Coef. (°C/100mm)	*P*	R^2_{adj}	Segment	RainAdj means and (SE) (°C)	RSS ($R^2_{partial}$)	
(i) Tmax ~ rain (Intercept 36.28°C)	-0.222	<0.001	0.307			26.11	Sh_{STARS}[1] 2013; *P*<0.0001, 1.11°C
(ii) Tmax ~ rain							
1965-2012 (36.00°C)[2]	-0.211	<0.001	0.381				
2013-2022 (36.46°C)	-0.119	0.136	0.163				
(iii) Tmax ~ Sh + rain (Intercept 37.01°C)	-0.197	<0.001	0.568	1965-2012	34.4[(a)] (0.080)	15.995	Interaction
				2013-2022	35.5[(b)] (0.173)	(61.2%)[3]	Tmax ~ Sh_{res} * rain
				Delta	1.12 (0.191)		ns
(iv) Tmax ~ Year	(°C/decade)			1965-2012			*P* = 0.14 (ns)
	0.125	0.055[(ns)]	0.048	2013-2022			*P* = 0.40 (ns)

[1] STARS: Sequential t-test analysis of regime shifts (https://academic.oup.com/icesjms/article/62/3/328/658905)
[2] Intercept
[3] Partial R^2: the step-change factor explained 61.2% of variation *not* explained by rainfall alone.

It is unlikely that the climate abruptly warmed by 1.12°C in 2013 independently of rainfall. The step-change could be due to a fault with the AWS, a change in instruments including cessation of backup manual observations, watering in the vicinity, or the screen may have been replaced *in situ* with a new wooden or plastic screen. No trend or change in MLR residuals could be attributed to another factor such as CO_2, coalmining, electricity generation or anything else.

3.3.1 Analysis explained

> This section briefly discusses the BomWatch approach.
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> Read on …

While in accordance with the First Law Theorem Tmax implicitly depends on rainfall, a variety of factors predominantly related to site and instrument changes potentially affect observations. Average Tmax may also be affected by lackadaisical observing practices: missed data, parallax error resulting from thermometers being habitually viewed at an angle to the horizontal, observing the wetted perimeter rather than the meniscus, or observing to the nearest whole or ½ degree. The state of the site may also affect observations: whether the screen is clean and free of peeling paint, that thermometers are serviceable and in good condition and that the local environment is not artificially cooled by watering. Having a 'feel' for data is therefore an important first step in undertaking analysis.

Figure 5(a) showed Tmax depends on rainfall such that dry years are warm and the drier it is the hotter it gets. It follows that variation in individual datapoints comprise a portion related to rainfall (the deterministic weather-related part) and a remainder related to other factors including those mentioned above. For each datapoint, the rainfall-related portion is the value *predicted* or *fitted* by the least-squares line shown in Figure 5(a), as given in Table1(i) by the relationship Tmax = 36.28 – 2.2E-03*rainfall[1].

As the equation represents the line of best-fit that describes just the rainfall response and that it only explained 30.7% of Tmax variation, the fit is likely to be smoother relative to the data from which it was derived (Figure 6). Note that the naïve Tmax ~ rainfall relationship does not take account of the step-change in 2013.

[1] In scientific notation, 2.2E-03 is the same as 0.22°C/100 mm (i.e., 0.0022*100)

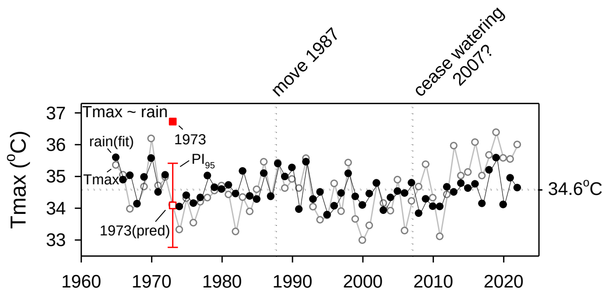

Figure 6. The portion of the Tmax signal attributable to rainfall (i.e., the 'fits', closed circles) overlaid on observed Tmax (open circles). Residuals are calculated as differences between pairs of points.

Figure 6 also shows Tmax data for 1973 (36.73°C, solid square), and the same datapoint *predicted* by rainfall (962.2mm) for that year together with 95% *prediction* intervals (Pi$_{95}$). Thus, while the value of 34.09°C is estimated, the true value lies between 32.77°C and 35.42°C.

Reiterating, *fitted* values in Figure 6 are synonymous with values *predicted* for each Tmax datapoint using rainfall as the predictor, and if variation in Tmax is fully explained, rainfall-domain residuals (Tmax minus predicted values) would be independent, normally distributed with equal variance, implying the absence of underlying systematic effects. It is the residuals (i.e., the non-rainfall portion of the Tmax signal) that are evaluated separately for systematic changes (timewise inhomogeneities) using STARS[1] in Figure 5(b) and to aid explanation, also in Figure 7.

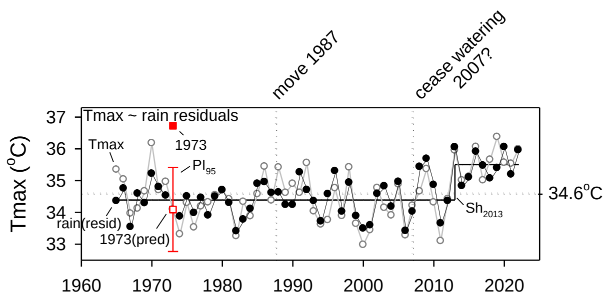

Figure 7. The single step-change in Tmax ~ rainfall residuals (solid circles and horizontal line vis-à-vis Figure 5(b)) overlaid on observed data (open circles).

In statistical parlance, residuals are that part of the Tmax signal *not* explained by the deterministic covariable, rainfall. The up-step in 2013 shows residuals embed at least one systematic change indicative of a site related inhomogeneity.

Two scenarios were compared: (i) a step-change in 2008, which could possibly be due to cessation of watering (as suggested by ACORN-SAT metadata), and, (ii) the permanent up-step in the mean in 2013. As metadata was vague and the possible change 2008 reversed in 2010 and 2011, and the statistical outcome was also less precise (R^2_{adj} = 0.544 vs. 0.568; AIC[2] = 100.28 vs. 97.29), the 2008 scenario was rejected (Figure 8) leaving only the 2013 scenario summarised in Table 1(iii).

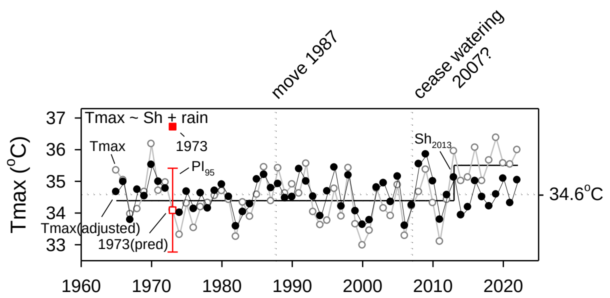

Figure 8. Observed Tmax (open circles) superimposed by the 2013 step-change scenario, overlaid by values predicted by the full Tmax ~ Sh_{factor} + rainfall) model (solid circles). Inclusion of the shift variable provided an unbiased estimate of the magnitude of the change, and also objectively adjusted for the up-step.

Multiple linear regression (Table 1(iii), Figure 5(e)) confirmed that the segmented relationships in Figure 5(c) and Figure 5(d) were offset (rainfall adjusted means were different), and parallel (interaction was not significant) thus, segmented responses to rainfall were the same. Also, that residuals embedded no additional systematic signals, including trend. As multiple linear regression residuals were normally distributed, independent with equal variance across categories, variation in the data was fully explained.

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[1] Rodionov, S.N. (2004). A sequential algorithm for testing climate regime shifts. *Geophysical Research Letters*, 31(9). https://doi.org/10.1029/2004GL019448

[2] https://en.wikipedia.org/wiki/Akaike_information_criterion

3.3.2 *Post hoc* evaluation

Post hoc evaluation aims to verify analysis assumptions and outcomes.

Read on …

Both models: Tmax ~ rainfall, and Tmax ~ Sh_{factor} + rainfall are compared in Figure 9 relative to observed data[1]. While R^2_{adj} provides a statistical summary of the extent to which the independent variables: rainfall and the step-change, explain Tmax, Figure 9 shows portions of data distributions that are ill-fitting, in this case possibly due to irregular watering, departure from the 1:1 line, possibly indicating lack of linearity, and also outliers to respective relationships[2].

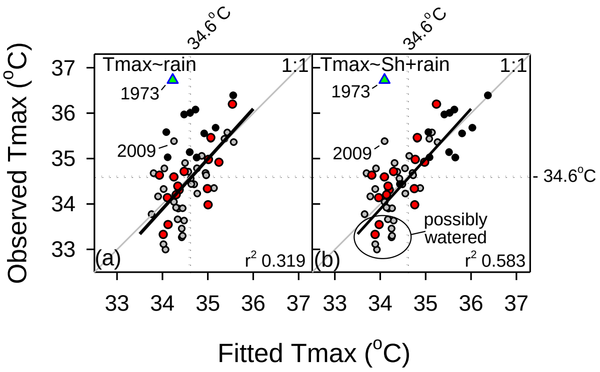

Figure 9. Scatterplots comparing observed Tmax with values predicted/fitted by respective statistical models: rain alone in (a), and Sh_{factor} + rainfall in (b). Closely fitting data would fall on the 1:1 line. Values circled were predicted to be warmer than data observed and were probably affected by watering. Pre-2013 data are indicated by grey circles, N <330 observations/yr are indicated by red circles, and black circles indicate post-2013 data. Data for 1973 was ignored. The r^2 statistic is the square of Pearson's linear correlation coefficient in this case.

While fitted data show considerable variance (vertical spread from the 1:1 line; Figure 9(a)) probably related to lackadaisical practices including missing observations, the Sh_{factor} variable (Figure 9(b)) corrected for the up-step which aligned post-2013 fitted data (black circles) more closely with those observed. Although immaterial, drift in the least squares line-of-best-fit reflects cool-bias resulting from irregular dry-season watering.

3.4 Extremes and trends in extremes

The rainfall-adjusted frequency of Hi-extremes increased 4.4-fold relative to Lo-extremes after 2013.

Read on …

Extreme temperatures are daily values that occur in the tails of daily data distributions: i.e., numbers of daily values/yr less than the 5th and greater than the 95th day-of-year dataset percentiles (Lo and Hi extremes respectively). Transformed to the log_{10} scale so data are normally distributed, their Hi_N/Lo_N ratio is expected to vary randomly in time (Figure 10).

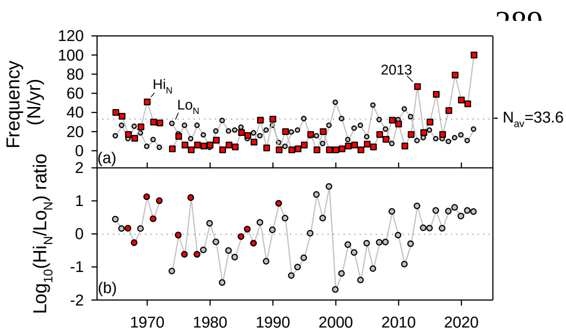

Figure 10. Frequency/yr of daily Tmax less than the 5th and greater than the 95th day-of-year dataset percentiles (a), and their Log_{10}-transformed Hi_N/Lo_N ratio (b). Highlighted data in (b) indicate N <330 observations/yr.

A significant relationship with rainfall (P=0.006) (Figure 11(a)) indicated variation in Hi_N/Lo_N frequencies in Figure 10 embedded a rainfall signal, which as shown previously may mask site-related effects.

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[1] See Pineiro et al (2008). How to evaluate models: Observed vs. predicted or predicted vs. observed? *Ecological modelling*, 216, 316–322. doi:10.1016/j.ecolmodel.2008.05.006

[2] https://stats.stackexchange.com/ 461 questions/104622/what-does-an-actual-vs-fitted-graph-tell-us

The effect of rainfall on the Log10(HiN/LoN) ratio was removed by deducting the linear fit and re-scaling residuals by adding the log_{10}-ratio grand-mean prior to testing using STARS (Figure 11).

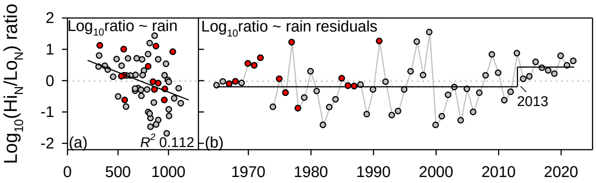

Figure 11. Confounding between $Log_{10}(Hi_N/Lo_N)$ and rainfall in (a) was removed. Rescaled residuals were analysed for non-rainfall inhomogeneities using STARS (b). (N <330/yr are highlighted.) The step-change is therefore not rainfall related.

The estimated log10 difference of 0.64 (0.233_{SE}) indicates the rainfall-adjusted ratio stepped-up by a factor of 10^0.64 = 4.37. This reflected that inclusive of missing daily observations and watering, numbers of raw Hi_N data counts were 5.8 times higher than Lo_N counts after 2013.

Ignoring data for 1973, missing observations in other years and the probable effect of watering on moderating daily Tmax, the rainfall-adjusted frequency of Hi-extremes increased some 4.4-fold relative to Lo-extremes after 2013.

4. Homogenisation of Victoria River Downs Tmax

Metadata used in the homogenisation process is untrustworthy, contradictory and confusing.

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As outlined in the Introduction, site-summary and ACORN-SAT metadata is inconsistent with respect to replacement of the original 230-litre Stevenson screen with a 60-litre one, said to have been in 1968 (AcV2.x); timing of a statistical change in either 1976 (AcV1) or 1974 (AcV2.x); the site having moved in August 1987 (AcV1), for which AcV2.x made no adjustment; and the effect of watering, which was only mentioned in AcV2.x. Adjustments made to AcV1, which ended in December 2011, were not the same as those for AcV2.1, which ended in December 2017 (Figure 12 verses Figure 13).

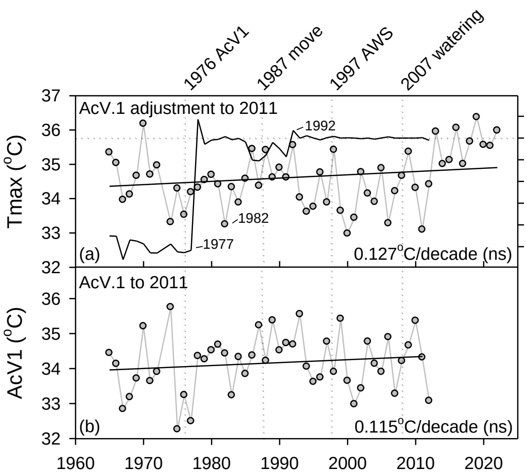

Figure 12. Adjustments applied to Victoria River Downs Tmax (thin line right axis in (a)) and the resulting AcV1 dataset (b). Metadata does not mention why adjustments ceased in 1992. Watering was said to have been discontinued after 2007.

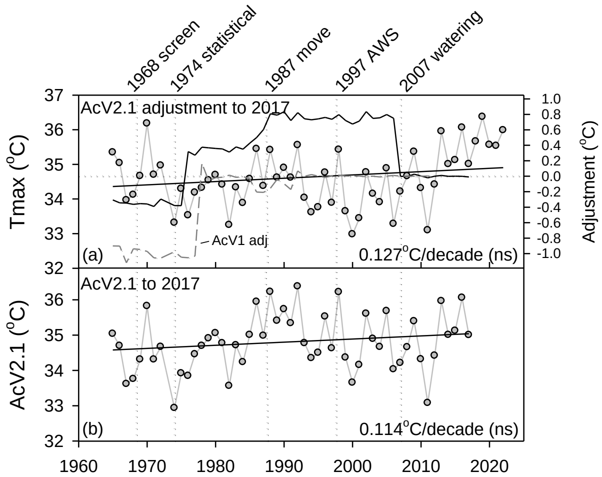

Figure 13. Adjustments applied to raw Tmax data (continuous line) to derive AcV2.1, overlaid on those shown previously for AcV1 (grey dashed line), and the resulting AcV2.1 dataset (b). Note that while adjustments differ in timing and magnitude, the resulting AcV2.1 trend is the same as for AcV1.

AcV2.3 adjustments are shown overlaid on those previous in Figure 14. While timing of the AcV1 up-step in 1977 was moved back to 1975 (AvV2.1) then 1973 (AcV2.3), subsequent data were adjusted progressively higher. Furthermore, while maintaining a similar overall trend, the various adjustments and their timing appear to bear little relationship to changes noted in site-summary and ACORN-SAT metadata, or the single changepoint detected by BomWatch in 2013 (as shown in Figure 5 and discussed in Section 3.3.1).

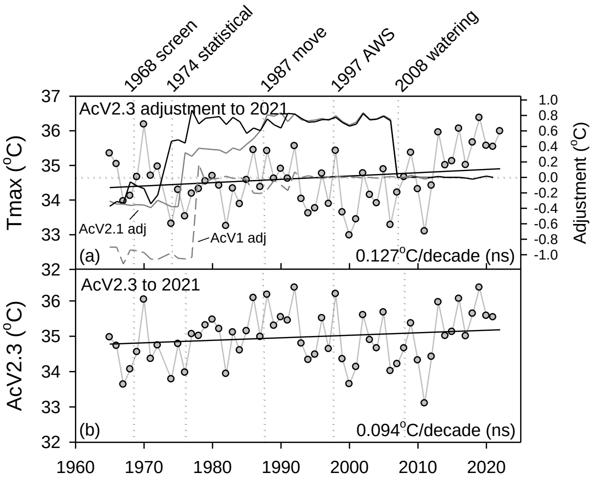

Figure 14. Adjustments applied to raw Tmax data (thin black line) to derive AcV2.3, overlaid on those made previously for AcV1 (grey dashed line) and AcV2.1 (solid grey line), and the resulting AcV2.1 dataset (b).

For no apparent reason, each of the three rounds of homogenisation applied markedly different adjustments at different times, yet paradoxically derived similar Tmax trends. This raises the questions: (i), how well do ACORN-SAT changepoints fit the raw data they aim to adjust, and (ii), how well do homogenised data reflect local weather and climate?

Should homogenisation breakpoints (Figures 12 to 14) be more appropriate for the data than the single changepoint detected in Tmax ~ rainfall residuals by STARS in Figure 5, it is expected that relationships between homogenised Tmax and rainfall would be significant (*P* <0.05), and that rainfall would explain markedly higher proportions of variation in homogenised Tmax (Table 2) compared to the Tmax ~ rainfall case (Table 1(i)). While ACORN-SAT trends were similar but not significant (ns), relationships with rainfall for homogenised data was less by 5 to 10% compared to that of unadjusted raw data. The poorer fit suggests that homogenisation adjustments are *ad hoc* and not appropriate for the dataset.

Table 2. Trend statistics and goodness of fit (R^2_{adj}) with rainfall, for homogenised Victoria River Downs Tmax compared with relationships for raw data (shaded, from Table 1).

	Tmax ~ Year			Tmax ~ rainfall		
Series	Coefficient (°C/decade)	*P*	R^2_{adj}	Coefficient (°C/100mm)	*P*	R^2_{adj}
Tmax$_{raw}$	0.127	0.055 (ns)	0.048	-0.222	<0.001	0.307
AcV1$_{1965-2011}$	0.115	0.182 (ns)	0.018	-0.148	0.007	0.133
AcV2.1$_{1965-2017}$	0.114	0.120 (ns)	0.029	-0.172	<0.001	0.167
AcV2.3$_{1965-2022}$	0.094	0.129 (ns)	0.024	-0.171	<0.001	0.198

Scatterplots of observed data (*y*) verses values predicted or fitted by a model (*x*) are said to be one of the richest forms of model validation and visualisation (refer Figure 9). Perfectly predicted values would lie directly along a 1:1 line, with a least-squares fit overlaying the 1:1 reference. In contrast, an ill-fitting model would be identified by the least-squares line being offset or skewed, and by correlation between predicted and observed (Pearsons linear correlation coefficient, r^2, which indicates dispersion), being less than for a control. In this case the control is the naïve Tmax ~ rainfall case (i.e., Tmax predicted by rainfall alone).

Compared to most other ACORN-SAT datasets, Victoria River Downs is relatively short. However, as time passes it is expected that adjustments made by ACORN-SAT will maintain a trend approaching 0.15°C/decade (1.5°C/Century), which is the rate at which the earth is predicted to warm. The trend coefficient is also expected to become more significant (i.e. that *P* <0.05). However, continuing to adjust past data, as data accumulates into the future, paradoxically increases the likelihood that while trend may become more significant and in-line with expectations, relationships between homogenised Tmax and rainfall will further deteriorate. Due to this conundrum, ACORN-SAT must eventually fail.

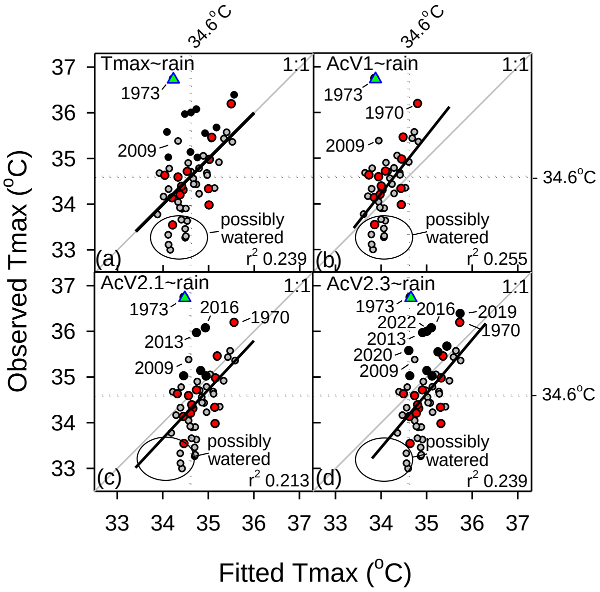

Figure 15. Scatterplots showing Tmax predicted by rainfall (x-axis) verses observed Tmax (y-axis) for three iterations of homogenised data (AcV1 (b), AcV2.1 (c), and AcV2.3 (d)), compared with the naïve Tmax ~ rainfall case (a). Pearson's linear correlation coefficient squared (unadjusted r^2) was calculated for all data, including 1973, which is an outlier. Note that data for AcV1 ended in 2011, which is before the 2013 up-step. Note also that post-2013 data (black circles) were not adjusted in (a), or by AcV2.1 (data to 2017), or AcV2.3 (data to 2022), but were adjusted by the Shift variable in Figure 9(b). Red circles indicate data for years when N<330 observations/year.

Table 3 compares ACORN-SAT scenarios with that shown previously for the same data in Table 1(iii).

While at first glance *P*-levels and R^2_{adj} seem comparable, particularly for AcV1, rainfall adjusted differences are ether not significant (AcV1) or they are similar to other group-means (i.e., responses are largely coincident – *vis-à-vis* Table 1 in the Marble Bar report[1]). Referred to as Type II error (the error that occurs when one fails to reject a null hypothesis that is false[2]), inclusion of non-significant factors as explanatory variables inflates significances and values of R^2_{adj}, which is a form of *P*-hacking.

Table 3. A statistical comparison of multiple linear regression outcomes for each of the homogenisation scenarios shown in Figures 12 to 14 and that for Table 1(iii) (shaded), which is the control scenario. (Changepoints as specified in ACORN-SAT documentation.)

Model	Coef. (°C/100mm)	*P*	R^2_{adj}	Segment	RainAdj means and (SE) (°C)	
Tmax ~ Sh_{res} + rain	-0.197	<0.001	0.568	1965-2012	34.4$^{(a)}$ (0.080)	Interaction
(Intercept 37.01°C)				2013-2022	35.5$^{(b)}$ (0.173)	Tmax ~ Sh_{res} * rain
[Table 1(iii) control]				Delta	1.12 (0.191)	ns
(i) Tmax ~ Sh_{Ac1} + rain	-0.198	<0.001	0.568	1965-1975	34.4$^{(a)}$ (0.188)	Interaction
(Intercept 35.90°C)				1976-1987	34.3$^{(a)}$ (0.167)	Tmax ~ Sh_{Ac1} * rain
				1988-2011	34.4$^{(a)}$ (0.120)	ns
				Delta	0.02 (0.227)^{ns}	
(ii) Tmax ~ $Sh_{Ac2.1}$ + rain	-0.211	<0.001	0.360	1965-1968	34.3$^{(ab)}$ (0.300)	Interaction
(Intercept 36.05°C)				1969-1972	34.7$^{(ab)}$ (0.305)	Tmax ~ $Sh_{Ac2.1}$ * rain
(to 2017)				1973-2006	34.3$^{(a)}$ (0.102)	ns
				2007-2017	35.0$^{(b)}$ (0.179)	
				Delta	0.73 (0.227)^{ns}	
(iii) Tmax ~ $Sh_{Ac2.2}$ + rain	-0.222	<0.001	0.493	1965-1968	34.3$^{(ab)}$ (0.300)	Interaction
(Intercept 36.05°C)				1969-1972	34.7$^{(ab)}$ (0.305)	Tmax ~ $Sh_{Ac2.2}$ * rain
(to 2021)				1973-2006	34.3$^{(a)}$ (0.102)	ns
				2007-2021	35.4$^{(b)}$ (0.179)	
				Delta	0.73 (0.355)^{ns}	

[1] https://www.bomwatch.com.au/wp-content/uploads/2022/12/Marble-Bar-back-story-with-line-Nos.pdf
[2] See: https://en.wikipedia.org/wiki/Type_I_and_type_II_errors

5. Discussion

> The questions are whether trends and changes in observed Tmax reflect site and instrument changes or the true climate; and whether adjustments made by iterations of ACORN-SAT (AcV1 to December 2011, AcV2.1, December 2017, and AcV2.4, December 2022) are unbiased.
>
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The First Law of Thermodynamics that energy is neither created nor destroyed is fundamental to calculating warming of the planet. At the local scale, removal of latent heat from the environment by evaporation and convection of local rainfall leaves more or less heat to be advected as sensible heat to the local atmosphere, which is measured during the heat of the day at the standard height of 1.2m by thermometers held in Stevenson screens. A dynamic balance is therefore expected between mean annual Tmax and rainfall, such that dry years are warm and the drier it is the warmer it gets.

Statistical significance of the Tmax/rainfall coefficient (P), and variation explained by rainfall (R^2_{adj}) (Table 1(i)) indicate conformity with the First Law Theorem, while STARS analysis of Tmax ~ rainfall residuals tests if the non-rainfall portion of the Tmax signal is homogeneous. Significant shifts (inhomogeneities) in re-scaled residuals (P<0.05), which cannot be specified in advance, are indicative of non-rainfall changes likely related to site-changes. Outliers are adjudicated using influence plots on a segment-by-segment basis (Table 1(ii)) or overall, during the categorical multiple linear regression verification phase (Table 1(iii)). Each step in the BomWatch process is transparent, objective and replicable across multiple datasets, and supported by subsidiary investigations including residuals analysis and *post hoc* tests (Table 1(iv)).

As the weakest point in the acquisition of climate data is poor and unreliable metadata, the main strength of the BomWatch approach is objectively analysing Tmax ~ rainfall residuals for evidence of site-change effects. As rainfall is the physically causal covariable, investigating Tmax requires that its effect be removed at the outset.

Ignoring data for 1973, which was an obvious outlier, the up-step detected by STARS in Tmax ~ rainfall residuals (1.11°C in 2013) was identical to that determined by categorical multiple linear regression (1.12°C, 0.191_{SE}, P <0.001), which also verified that segmented responses to rainfall (the coefficients) were the same (responses were parallel) and that rainfall adjusted segment means were different (data segments were offset). Rainfall reduced Tmax 0.197°C/100mm and the step-change and rainfall together explained 56.8% of Tmax variation (R^2_{adj} = 0.568). Furthermore, the Sh_{factor} explained 61.2% of variation that was not explained by rainfall alone, which indicates the shift was predominant. *Post hoc* analysis found unequivocally that although not significant (P = 0.055), the overall Tmax trend of 0.125°C/decade was spuriously related to two non-trending segments interrupted by an abrupt step-change in 2013 that could not be caused by a change in the climate (Table 1(iv)).

Trend in Victoria River Downs Tmax was due to the step-change in 2013, and with that and variation due to rainfall accounted-for, no additional signals remained that could be attributed to CO_2, coalmining, electricity generation or anything else.

Whatever happened in 2012/13, whether it was the removal of thermometers and the cessation of manual observations, a change related to processing of the data, replacement of a 230-litre screen with a 60-litre one, or a wooden 60-litre screen with a plastic one, it caused a 4.4-fold increase in the frequency of daily observations >95th day-of-year percentiles (upper-range extremes) relative to counts of lower range extremes (Section 3.4). Upper-range extremes were 5.8 times more likely after 2013 than before 2013. Except for noting the cessation of watering *around 2007* for which an ACORN-SAT adjustment was made, site-summary and ACORN-SAT metadata provide few insights that could explain the 2013 up-step. As the earliest Google earth Pro satellite images is August 2013, images are not informative. We are therefore left with a verified statistical change with no corroborating explanation as to what occurred.

Unlike the BomWatch approach, timeseries analysis undertaken using Excel or other spreadsheet applications is unable to partition between variation due to rainfall and residual variation including inhomogeneities that occur in parallel with observations. Spreadsheet applications are also not suited to undertaking categorical multiple linear regression, or interaction analysis, which is essential for confirming that responses of data segments identified by STARS to rainfall are parallel (that interaction is not significant) and offset (that rainfall-adjusted segment means are different). Analysing timeseries using spreadsheet applications may be misleading, it is not recommended.

5.1 Homogenisation

Metadata on which the BoM's homogenisation methods are based is fragmentary and inconsistent. Consequently, iterations of ACORN-SAT homogenisation are markedly different both in timing and the magnitude of adjustments made (Figures 12 to 14; see also the segments defined by ACORN-SAT changepoints listed in Table 2). Comparisons showed past data were cooled and/or warmed to varying extents toward the present, which is a trick that affects trend.

Adjusting post-2013 data <u>*down*</u> by the magnitude of the up-step (1.12°C) would eliminate distorted claims that record-hot days and years, and average Tmax is inexorably increasing. STARS and categorical multiple linear regression residuals show this is not the case. While ACORN-SAT adjustments may stabilise and improve the significance of calculated trends (and possibly moderate data quality problems), relationships with rainfall become 10 to 18% less precise (Table 2).

Furthermore, as ACORN-SAT Tmax is expected to better reflect the climate than the raw data from which it was derived, scatterplots comparing Tmax with the homogenised data predicted by rainfall *should* indicate a close 1:1 fit. However, this was not the case either (Figure 15). 'Spread' as indicated by the square of the correlation coefficient, was less, while least-squares lines indicated marked drift or skew away from the 1:1 reference.

Finally, ACORN-SAT changepoints listed in the Catalogue were evaluated using the same BomWatch procedures outlined in Section 3.3.1. While homogenised-Tmax rainfall coefficients successively increased (which is unexpected), in most cases there were no clear differences between segments (Table 3(i) to (iii)). It is therefore concluded that changepoints adjusted by ACORN-SAT were not relevant to the data.

The political narrative supported by ACORN-SAT will eventually be shown to be false, either as more ACORN-SAT sites are analysed using rigorous BomWatch protocols, or as time passes and BoM scientists run out of options for making adjustments that seem plausible, or which cause fundamental Tmax ~ rainfall relationships to completely break-down. The question then arises: just how many more analyses are needed, or how many years need to pass, before ACORN-SAT is shown to be irrevocably too unsound, unscientific and unbelievable to continue? As the ACORN-SAT project is unsalvageable, for the sake of the reputation of those involved, it should be abandoned in its entirety.

5.2 Implications

The practical, scientific and political implications of BomWatch research are far-reaching, with much previously published research shown to be invalid or based on the false premise that maximum temperature in Australia is increasing.

The practical implication is that most of the messaging, including by activist professors at the Climate Council, Tim Flannery's fiction *We are the weather makers*[1] (funded for distribution to school children in 2005/06 by the former President of WWF Robert Purves via his Purves Environment Fund), materials being taught in schools and universities and broadcast wholesale to the public by the ABC, commercial television, and newspapers including *The Guardian* and once-trusted ex-Fairfax papers including *The Sydney Morning Herald* and *The Age*, is fake.

The whole agenda has been made up and carried forward since the call went-out from the World Meteorological Organisation in about 1989 to find data that supported future Intergovernmental Panel on Climate Change (IPCC) narratives. Neville Nicholls and protégés at the BoM heeded the call by creating trends in homogenised data that supported the warming hypothesis (otherwise known as *The Science*).

The scientific implication is that along with models used to predict the future, thousands of scientific papers and reports that depend on the warming narrative, are worthless.

Studies related to the effect of 'a warming world' on health, on agriculture, tourism, urban planning, the Murray-Darling Basin, the Great Barrier Reef, urban water supplies, species extinctions, and for converse reasons, on mining and resource use, are based on a premise that has been fabricated by consensus from the beginning.

The political implication is that the billions of dollars that have been spent on, or are intended to be spent, in order to limit warming to the mythical value of 1.5°C sometime in the future, is entirely wasted. As *The Science* is underpinned by data that has been concocted to support it, and as the limits to manipulating past-data will become increasingly implausible going forward, the whole edifice must eventually collapse. Despite the best efforts of Blair Trewin and others at the BoM, Flannery and his brotherhood at the Climate Council, and professors and leaners at Australian universities, the point of collapse will probably be reached within a decade, possibly sooner than 2030.

Finally, as Tmax depends on rainfall, which in Australia is stochastic (unpredictable) and episodic (occurs in episodes), without knowing rainfall in advance, it is impossible to predict the trajectory of Tmax going forward.

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[1] (Candlewick Press, ISBN 9780763636562 (ISBN10: 0763636568))

Disclaimer

Unethical scientific practices including the homogenisation of data to support political narratives undermines trust in science. While the persons mentioned or critiqued may be upstanding citizens, which is not in question, the problem lies with their approach to data, use of poor data or their portrayal of data in their cited and referenceable publications as representing facts that are unsubstantiated, statistically questionable or not true. The debate is therefore a scientific one, not a personal one.

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