Is homogenisation of Australian temperature data any good?

Part 3. Meekatharra, Western Australia

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> The ACORN-SAT project is deeply flawed, unscientific and should be abandoned.
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Summary

Homogenised data for 112 Australian Climate Observations Reference Network – Surface Air Temperature (ACORN-SAT) sites are used by the Bureau of Meteorology, CSIRO, state governments, WWF, the Climate Council, to convince themselves, kiddies for climate action, and everyone else that the climate is warming irrevocably due to CO_2. However, that is not the case at Meekatharra, Western Australia, where dodgy measurement practices and data homogenisation are used to create warming in maximum temperature (Tmax) data that is unrelated to the climate.

Joining disparate datasets to form long series is fraught with uncertainty. The condition of instruments, their protection from direct and indirect heat, and local effects such as watering, shade etc., together with diligence in taking and reporting observations all impact on trend and change. The most insidious way to cheat is to adjust for changes that made no difference, selectively ignore some that did, and use faulty data from inter-correlated neighbouring sites to adjust faults in ACORN-SAT.

While the 12m by 5.4m carrier equipment building constructed on the eastern side of the Meekatharra post office yard in 1946 was bound to affect temperatures measured there since 1927, the effect of moving to the aerodrome in 1950, and to the meteorological office (MO) in the 1970s is less certain. BomWatch protocols were used to verify that homogenisation methods used by Bureau of Meteorology scientist Blair Trewin, who developed ACORN-SAT, were sound.

Adjusting for a change in 1934 that was not significant, ignoring that the Aeradio site was watered, and that a period of overlap from 1972 was used to smooth the move to the MO site, allegedly in *about* 1975, for which no adjustment was made, created trends in homogenised data that were unrelated to the climate. Furthermore, data for the total of 18 sites used to homogenise Meekatharra Tmax, were not homogeneous.

Trewin's assumption that comparator sites selected on the basis of inter-site correlations would be broadly homogeneous around the time site changes occurred, and therefore that comparator series derived from multiple reference stations could provide a "*high level of robustness against undetected inhomogeneities*" is demonstrably not true. As there is no change in the climate across all the datasets examined, and faulty data are routinely used to adjust faults in ACORN-SAT, the ACORN-SAT project is deeply flawed, unscientific and should be abandoned.

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1. Introduction

> Maximum temperature time-series consist of an ambient background signal, which is assumed to be constant; variation due to rainfall, which is the causal or deterministic covariable, and unexplained residual variation reflecting the weather the wider climate. Disaggregating the total signal into component parts is the key to determining climatic trend and change.
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Files held by the National Archives of Australia (NAA) show a site for the post office at Meekatharra was acquired in 1901 and a post office commenced operating in a ‘non-official’ capacity in 1906. A 1939 photograph shows a substantial building on the corner of Main Street (the Great Northern Highway) and High Street that included a 4-bedroom postmaster’s residence (Figure 1). The yard behind was occupied by a lavatory, wash-house, and a 12m by 5.4 (5.5 m to the ridge) carrier equipment building adjacent to the eastern boundary, which housed a generator, battery-room, workshop and switching gear that was planned in March 1945 and built (together with a new lavatory) before 1950. A line-yard and linesman’s workshop (office, store-rooms etc.) was located on a separate title behind the post office, which in the 1970s became the site of a microwave tower and automatic telephone exchange.

Figure 1. The Meekatharra post office and residence in 1939 (NAA photograph).

In 1943 the WW-II Air Board approved construction of a jointly funded Royal Australian Air Force (RAAF)/United States Army Air Force (USAAF) aerodrome about 5 km SE of Meekatharra on the inland transport route between Perth, the secret bomber base at Corunna Downs near Marble Bar, and Darwin (Figure 2).

Figure 2. RAAF Avro Anson A4-38 at the original Meekatharra landing ground on 25 June 1938 during an inspection tour of potential aerodrome sites (National Library of Australia photograph). Although flat, featureless and wind-blown, the landing ground close to town was not selected as the site for the new RAAF/USAAF aerodrome.

Planned as part of a defensive perimeter, specifications called for all-weather runways capable of handling fighter aircraft and heavy bombers. However, due to its isolation, the cost of sealing the 4960-foot S-W and the 7157-foot E-W runways (1500m and 2200m) increased from £43,498 to £80,000. The ‘bare base’ aerodrome was ready for use by January 1944. An aerial photograph taken near the end of the dry season on 11 September 1949 and a 1952 aerodrome survey showed the location of the Aeradio office, a path leading to the meteorological enclosure, a hydrogen hut and theodolite stand used for tracking weather balloons; the powerhouse, meteorological/seismograph hut, caretaker’s cottage, terminal etc. (Figure 3). Notably, the photograph shows a substantial area covering the earth-mat that grounded the radio antenna array was watered, probably to improve electrical connectivity with the dry soil.

Although not a busy aerodrome, Meekatharra also served as an alternative landing ground in case those around Perth became unserviceable due to inclement conditions. It was relinquished by the RAAF to the Department of Civil Aviation (DCA) after the War, and in 1993 ownership transferred to the Shire of Meekatharra.

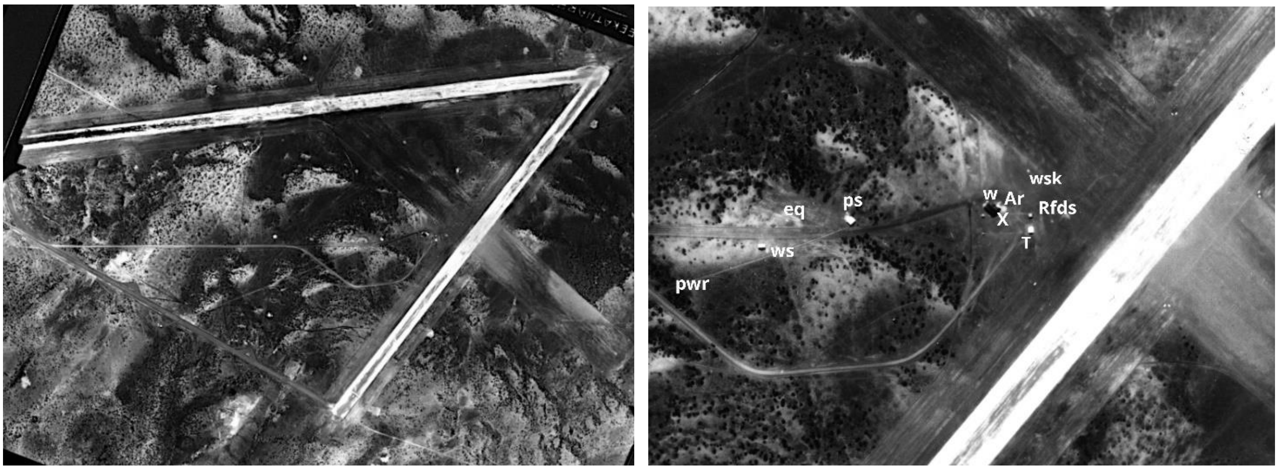

Figure 3. An aerial photograph of the Meekatharra aerodrome dated 11 September 1949 (National Library of Australia) and an expanded view of the operational precinct (right) showing workshop (ws), equipment store (eq), power station (ps), windsock (wsk), Royal Flying Doctor Service hanger (Rfds), terminal (T), and the underground power line (pwr) to the distance measuring equipment (DME) and caretaker's residence, outside the frame. The Aeradio office (Ar) is nearby an area that was watered (w) probably to improve performance of the buried earth-mat that grounded the 70-foot high (21 m) radio aerials. "X" marks the position of the meteorological enclosure.

Situated at the end of the railway from Geraldton, Meekatharra was chosen as a high-priority RAAF base because it could be rapidly re-supplied. Famously referred to as *the end of the earth* by Australia's former Prime Minister, Malcolm Fraser when his aircraft was diverted from Perth to Meekatharra in 1977 due to inclement weather, Meekatharra is now the epicentre of a mining boom in Western Australia and the airport serves as a hub for its fly-in fly-out workforce and a base for the Royal Flying Doctor Service (RFDS).

Monthly average temperature and rainfall for Peak Hill (BoM ID 7070), a mining settlement about 110 km NW of Meekatharra is available from the Bureau of Meteorology (BoM) from 1898 and in deriving the initial 1993[1] homogenised High-Quality dataset (HQ_1), Simon Torok abutted Peak Hill and Meekatharra post office data to create a longer series. In his 1996 PhD thesis[2] Torok noted that the Peak Hill site "*moved 65 miles to new PO* (at Meekatharra, site ID 7046) *for better observers*" in January 1926, and that the Stevenson screen was in poor condition. Also, that in June 1944 the screen was a "*bit high*" and that in January 1946 building works (the carrier equipment building and lavatory) had occurred in the post office yard.

According to site-summary metadata, weather observations by RAAF Aeradio staff commenced at the aerodrome in 1944, five years before observations transferred from the post office allegedly on 25 April 1950. However, only sporadic daily rainfall data from 1944 is available from the BoM.

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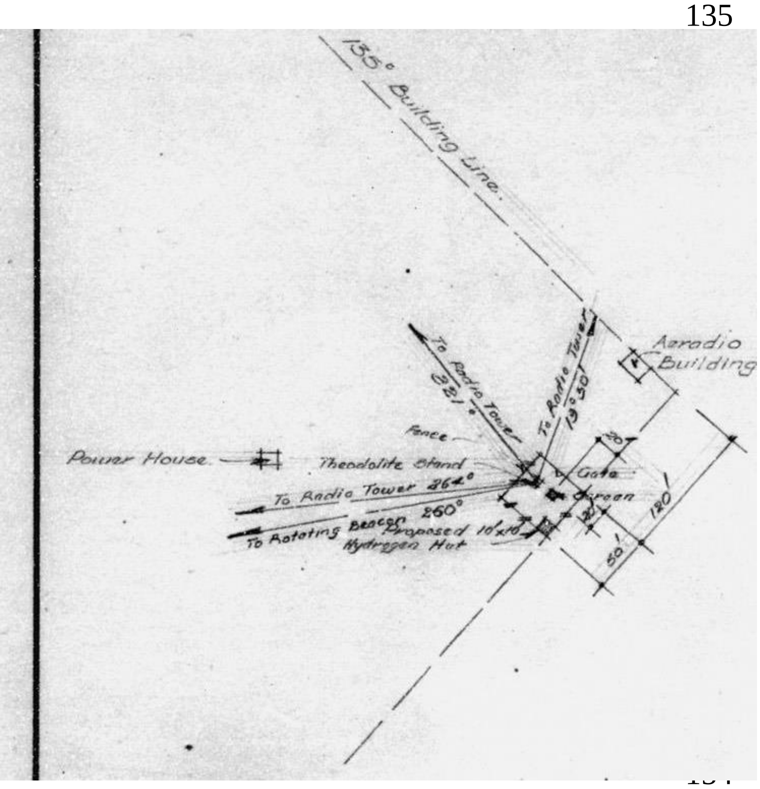
[1] Torok, S.J. and Nicholls, N. (1996). A historical annual temperature dataset for Australia. Aust. Met. Mag., 45, 251-260.

[2] Torok SJ (1996). Appendix A1, in: "The development of a high-quality historical temperature data base for Australia". PhD Thesis, School of Earth Sciences, Faculty of Science, The University of Melbourne.

Aeradio staff re-deployed from the RAAF in June 1946 to either DCA Flight Services (radio) and the BoM (meteorology), and plans held by the NAA show the office was upgraded to accommodate additional staff and an Officer-in-Charge in 1955. The meteorological enclosure, which included a hydrogen shed, Stevenson screen and theodolite stand was 37m southwest of the office (Figure 4). (Accurate survey of coordinates and height of the theodolite stand was essential for calculating wind-speed, direction, and altitude of manually tracked weather balloons relative to the datum, which was mean sea level at Geraldton.)

While BoM site-summary metadata gives coordinates of the 1944 site as Latitude -26.6108°, Longitude 118.5444°, which places it on the northern side near the current terminal, aerodrome plans and the 1939 aerial photograph cross-referenced by Google Earth Pro show it was located on the southern side at about Latitude -26.6111°, Longitude 118.5447°. Satellite images show the 1500m S-W runway was closed, two 1,000 gallon (3,700 litre) WW-II fuel tanks buried under the RFDS-hanger apron were removed and the Aeradio office was demolished before March 2003.

Figure 4. An undated Civil Aviation Historical Society & Airways Museum photograph showing the post-1955 Meekatharra Aeradio office viewed from the south (the taxiway is on the right) adjacent to the apex of three 70' (21m) high aerial towers; and below, a sketch plan from NAA dated 4 June 1950 showing the fenced meteorological enclosure containing the hydrogen hut, theodolite stand and the Stevenson screen about 37m SW of the office.



An aerial photograph taken on 2 April 1981 shows that with the exception of the RFDS hanger (which had been replaced), most of the WW-II buildings had been demolished and a new terminal and control centre was established adjacent to the long E-W runway on the western side and a new meteorological office (MO) was located adjacent to the airport entrance. An NAA search of the term "*Meekatharra meteorological*" revealed the BoM owned four houses in Meekatharra. Other holdings included an equipment file (1964 to 1983), files relating to construction of the new MO (1971 to 1975); archived weather reports (1971 to 1983), and various administration files.

Critical to understanding changes in the data, file-titles also show that a new meteorological enclosure, met-hut, instruments, theodolite stand and windshield used to assist launching weather balloons were installed at the new MO site in 1972. However, most items are in Perth and few are open for inspection. As the new office probably had not been completed by 1972, there can be little doubt that parallel temperature observations at both the previous and the new site were used to smooth the transition, and this occurred possibly until 1974. (Although plans had been made for a new building in 1972, the contract was apparently not awarded until 1973).

Previously an HQ site[1], Meekatharra is one of 112 Australian Climate Observations Reference Network – Surface Air Temperature (ACORN-SAT) sites[2] used by BoM and CSIRO to monitor Australia's warming. Twenty-five of those sites are in WA (Figure 5). It is therefore important to verify that data are sound (daily observations were precise and consistently observed), that metadata (data about the data) is accurate, and that adjustments made to account for site and instrument changes are robust (replicable). Replicate analysis of the same data using objective statistical methods underpins the scientific method and provides assurance that methods used by BoM scientists to homogenise data are unbiased by *a priori* narratives.

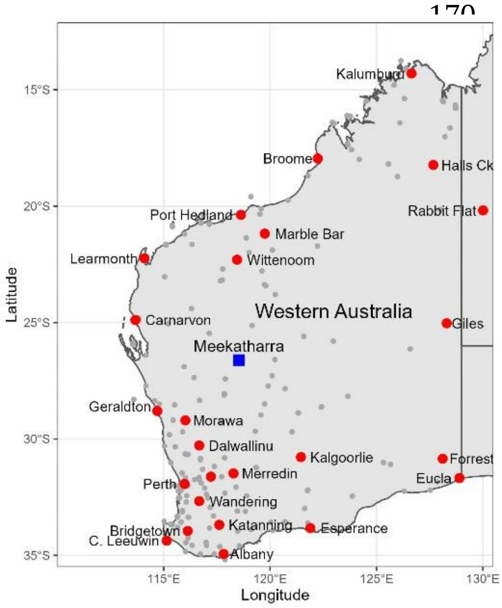


Figure 5. Meekatharra is one of 25 ACORN-SAT sites in Western Australia (red circles). Grey circles show weather stations having >10-years of maximum temperature data are mostly concentrated in the southwest agricultural region.

ACORN-SAT metadata states that the current site is located at the Meteorological Office on the western side of the airport over bare red soil with patchy low grass. The Catalogue shows a photograph of the office (dated 7 August 2010) but not the site. It says, the site began operating in 1950 with no significant overlap with the post office, and that it moved 1.1 km *east* in *about* 1975. However, originally on the eastern side of the airport, the site probably moved due *west*. Also, as the MO site operated from 1973, 1975 probably marked when the old site closed. Distance and direction provided by ACORN-SAT is also inconsistent with site-summary metadata.

A Milos automatic weather station (AWS) installed on 7 February 1991 became the primary instrument on 1 November 1996 and following a period of overlap from 1998, the Milos was replaced by an Almos AWS in 2001. A 60-litre Stevenson screen replaced the former standard 230-litre Screen on 2 May 1996[3], which was during the time the Milos AWS was operating but before the AWS became the primary instrument. While the AWS and the Stevenson screen changed, ACORN-SAT metadata stated there were no documented moves at the MO site.

This report aims to verify that trends and changes in maximum temperature (Tmax), and temperature extremes at Meekatharra are similar to those reported by Bureau of Meteorology (BoM) scientist Blair Trewin, who following the earlier HQ update by Della-Marta et al. (2004) developed ACORN-SAT.

The question is whether Trewin's homogenisation methods are unbiased and that trends in homogenised data truly reflect the climate.

[1] Della-Marta, P., Collins, D. and Braganza, K. (2004). Updating Australia's high quality annual temperature dataset. *Aust. Met. Mag*. 53, 15-19 https://www.cmar.csiro.au/e-print/internal/braganza_x2004a.pdf

[2] Trewin, Blair (2012). A daily homogenized temperature data set for Australia. *Int. J. Climatol.* 33, 1510-29 DOI: 10.1002/joc.3530

[3] Table 5 in: The Australian Climate Observations Reference Network – Surface Air Temperature (ACORN-SAT): Observation practices. (Bureau of Meteorology 2012). (40 pp)

2. Methods

Methods of analysing temperature data should be physically based, objective, replicable and not able to be influenced by *a priori* narratives.

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Daily temperature data for the post office and airport, and monthly rainfall data were downloaded from BoM's Climate Data Online facility. Temperature data were merged as per ACORN-SAT and annual averages and other attributes were summarised into an Excel compatible csv-format using the statistical package R (v4.1.2)[1]. (Monthly HQ data had been archived previously). Statistical analysis was undertaken using the *Rcmder*[2] and *emmeans* packages[3] as outlined for Parafield[4] and Marble Bar[5]. Step-change analysis was undertaken using STARS (Sequential Three-step Analysis of Regime Shifts[6]). Raw data and packages are in the public domain, and a downloadable Excel workbook containing data used in the study is available from www.bomwatch.com.au

Daily rainfall, Tmax, Tmin, and estimated pan evaporation from 1900 were also downloaded for the Latitude Longitude cell encompassing Meekatharra (-26.60, 118.55) from SILO (https://www.longpaddock.qld.gov.au/silo/) and summarised using R into a year by month csv-format dataset. As SILO data are interpolated, they may better represent the general climate.

3. Results

3.1 The general climate

Inland from the ocean and surrounded by desert, the climate of Meekatharra is dry, hot and generally inhospitable.

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First settled as a mining camp in 1896, Meekatharra lies 500 km east from Shark Bay in central Western Australia south of the Gibson Desert and west of the Great Victoria Desert. Average Tmax ranges from 38.2°C in January to 19.3°C in July, and minima from 23.8°C in January to 7.1°C in June (Figure 6).

While annual rainfall is less than Marble Bar (225 vs. 363mm/yr), rainfall data are highly skewed (long-tailed) with 32% of years contributing over 50% of the total rainfall since 1900. The driest year was 1944 (44.4mm), the wettest was 2000 (525.5mm), and 8% of years received <100mm/yr.

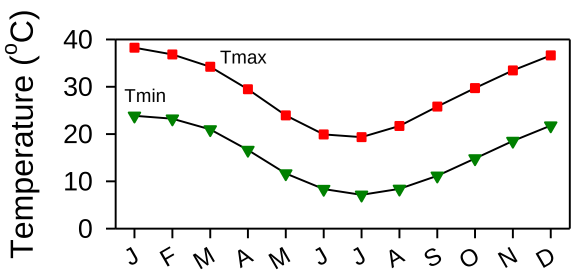

Figure 6. Average monthly maximum and minimum temperatures at Meekatharra (SILO data).

Rainfall is low in all months, particularly after August, and as monthly evaporation exceeds rainfall by a factor >2 there is zero likelihood of a sustained positive soil moisture balance. Furthermore, rainfall occurs in episodes: years that are relatively dry interspersed by years that are relatively rainy, which are unpredictable in timing and duration. Rainfall was generally low from 1934 to 1960 (Figure 7).

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[1] R Core Team (2022). https://www.R-project.org/.
[2] https://socialsciences.mcmaster.ca/jfox/Misc/Rcmdr/
[3] https://www.rdocumentation.org/packages/emmeans/versions/1.8.2
[4] https://www.bomwatch.com.au/data-quality/part-1-methods-case-study-parafield-south-australia-2/
[5] https://www.bomwatch.com.au/data-quality/part-2-marble-bar-the-warmest-place-in-australia-2/
[6] https://sites.google.com/view/regime-shift-test

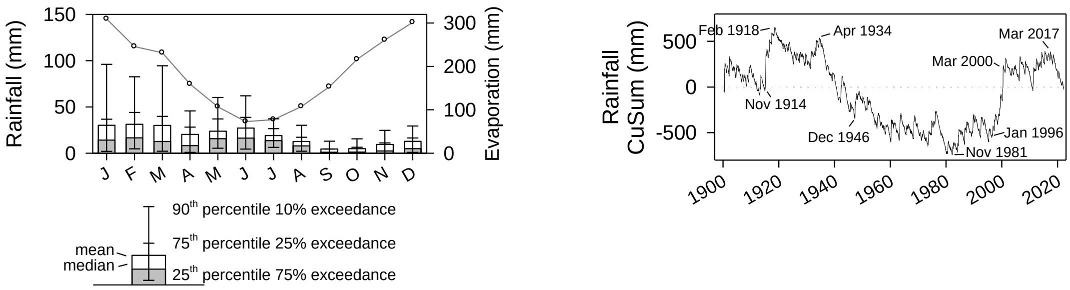

Figure 7. Average and percentile monthly rainfall distributions and potential evaporation (left) and rainfall episodicity as indicated by cumulative sums of differences from the long term monthly grand mean (CuSum). The period from April 1934 to about 1960 was cumulatively dry (the CuSum declined), near-average conditions prevailed from 1960 to November 1981 (the curve showed no consistent trend), and from 1981 to March 2000 the climate was relatively moist (the curve ascends). Dry conditions again prevailed from March 2017 (summarised from SILO data).

1.1 Partitioning climate and site change effects

> Partitioning variation due to rainfall from discontinuities caused by site changes is the key to understanding climate-related trend and change.
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Tmax depends on rainfall and consistent with the First Law of Thermodynamics, dry years are warm and the drier it is the warmer it gets. Evaporation of rainfall removes latent heat from the environment by convection, which is locally cooling, while the remaining portion of the heat balance warms the air in contact with the ground by advection, and is measured during the heat of the day by maximum thermometers housed in Stevenson screens.

Tmax data were examined from two perspectives:

1. Consistent with the First Law Theorem, average Tmax is ***expected*** to be linearly, inversely related to rainfall. Statistical significance (P) and goodness of fit (R^2_{adj}) objectively describe robustness of the relationship and should rainfall fully explain Tmax, *rainfall-domain* residuals would be independent, normally distributed with equal variance across their range. Lack of significance evidences a problem with the data, which could be from somewhere else for instance, or other factors such as watering or problems with observers, screens or instruments may nullify the signal.
2. Linear regression also partitions variation due to rainfall from residual variation caused by non-rainfall effects. Analysed as time-series, persistent step-changes in residuals (re-scaled for convenience by adding grand-mean Tmax), identify background changes that have occurred in parallel with observations. Objective analysis requires that changes in data are detected using independent statistical methods; and that where possible, they cross-reference to what is known about the site *post hoc* (i.e., that analysis is informed by the data not *vice versa*).

The relationship between Tmax and rainfall at Meekatharra was highly significant ($P < 0.001$); rainfall reduced Tmax by 0.055°C/100mm and explained 38.8% of Tmax variation ($R^2_{adj} = 0.387$) (Figure 8(a)). Step-changes in raw Tmax detected in 1946, 1976, 1984 and 1998 (Figure 8(b)) are potentially confounded with rainfall, which is deterministic on Tmax. Therefore, their timing could be related to persistent changes in the weather, not changes in the post office yard, or at the airport where the site moved in the 1970s, a 60-litre Stevenson screen was installed in May 1996 and AWS instruments changed in 1998.

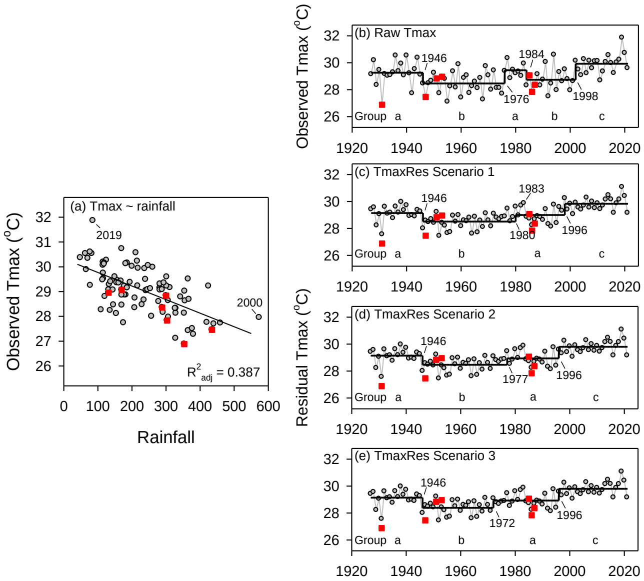

Figure 8. Step-changes in raw Tmax (b) and rescaled Tmax residuals ((c) to (e)) detected by STARS. Sequential differences in means were highly significant (P < 0.01). Numbers of daily observations <355/yr are indicated by red squares.

While a range of STARS settings consistently detected step-changes 1946 and 1996, the move to the MO, allegedly in *about* 1975 could not be confidently resolved. The various homogenisation iterations, including by Torok and Nicholls (1996)[1] ignored that the site moved in the 1970s. However, being the time-series mid-point, change at that time could critically affect overall trend.

As some step-changes were positive and others negative, segments were compared to identify those with statistically similar means (identified Figure 6 (b) to (e) by the same subscript). Un-grouped and grouped data were analysed separately as scenarios. In addition, a changepoint was inserted in 1975, and a final scenario deleted the 1970s changepoint altogether. Aerial photograph and satellite image overlays confirmed that the site at the MO had remained in the same place since at least 1981 (Figure 9).

Figure 9. An overlaid re-scaled portion of the 1981 aerial photograph (opacity 0.75) shows the MO site immediately below the point marked 'X' was in the same place as it was in recent Google Earth Pro satelite images.

The scenario that best describes the data is that with the highest R^2_{adj} and the smallest Akaike information criterion (AIC). (The AIC is *an estimator of prediction error and thereby relative quality of statistical models for a given set of data*[2].) Use of objective methods and criteria provides confidence that changepoints were not applied arbitrarily. Analysis of the scenario depicting changepoints in 1946, the forced changepoint in 1975, and that in 1996 (Appendix 1, Case 6) is shown in Figure 10.

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[1] Torok, S.J. and Nicholls, N. (1996). A historical annual temperature dataset for Australia. Aust. Met. Mag., 45, 251-260.
[2] https://en.wikipedia.org/wiki/Akaike_information_criterion

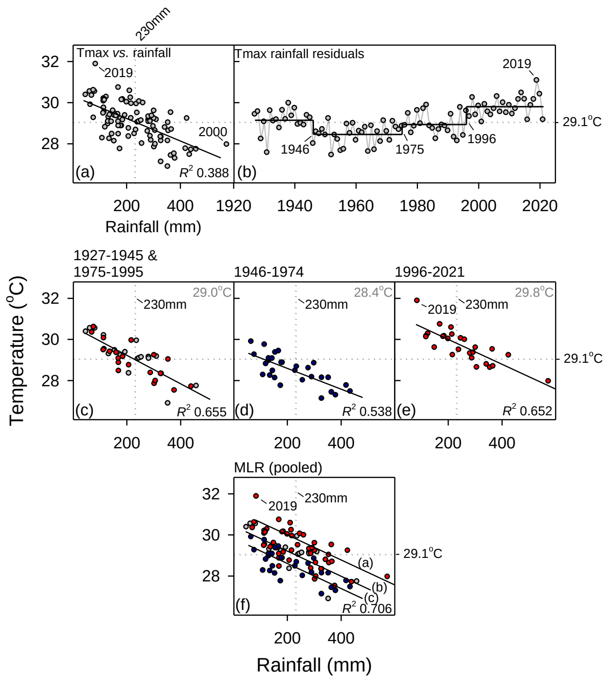

Figure 10. The analysis sequence for Appendix 1, Case 6 (forced step-change in 1975). While the linear regression relationship in (a) is highly significant (P > 0.001) and rainfall reduces Tmax 0.054°C/100mm, as rainfall only explains 38.8% of Tmax variation naïve analysis may have failed to account for another variable. In addition to the 1975 changepoint that was forced onto the data, STARS detected step-changes in rescaled residuals (data minus the regression equation, rescaled by the grand-mean) in 1946 and 1996. Tested using one-way analysis of variance and pairwise comparisons, means for segments 1927 to 1945 and 1975 to 1995 were the same and were therefore re-evaluated as a single category in (c). Free-fit relationships relative to dataset averages are shown for segment-groups in (c) to (e).

Categorical multiple linear regression (MLR) of the pooled dataset (Figure 10(f)) verifies that segmented responses to rainfall were the same (segmented regressions were parallel), that rainfall-adjusted segment means were different (segmented relationships were offset), and that pooled relationships were statistically significant, with scenarios and rainfall explaining >50% of Tmax variation (in this case R^2_{adj} =0.706). Furthermore, MLR residuals were found to be independent, normally distributed with equal variance across categories, indicating all factors are accounted-for and analysis is complete. Importantly, as no trend or other systematic signals were detected in MLR residuals there is no evidence that the climate has changed or warmed. *Post hoc* analysis found data for 2019, allegedly the hottest year on record, was over-range by 1.24°C compared to the value predicted for that year (31.86°C vs 30.62°C ± 1.01°C_{PI}), and was therefore likely to be an artefact.

Files held by the NAA show that in anticipation of building the new met-office (which was probably not completed until 1974), a new site was established there in 1972 and that a period of overlap with the previous site was used to smooth the eventual transition. However, while inferred by the titles of BoM's files, the move could not be confidently confirmed by available site-summary and ACORN-DAT metadata. Further, as the MO is on the western side of the airport, it could not have moved *east* in *about* 1975 as claimed by ACORN-SAT. Also, unless the Aeradio office was disbanded beforehand, it could not have been in the vicinity of the current terminal either. While ignoring a changepoint in the 1970s gives a much inferior fit, the Akaike information criterion suggests Scenario 3 (a step-change in 1972), which aligned both with metrication and establishment of the new site, to be the most likely candidate (Appendix 1).

As the change in 1972 is a critical determinant of overall trend (especially if expressed as anomalies relative to 30-year averages calculated between 1961 to 1990), in-depth investigation of data, supported by *post hoc* attribution and cross-referencing of all available sources of information, vindicates the methodology used by BomWatch to evaluate the maximum temperature time-series.

1.2 Precision of daily observations

Daily data are assumed to be consistently precise, which is often not the case.

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The precision with which daily data are reported is indexed by the frequency of decimal fractions and for data observed consistently to one decimal place, each decimal fraction (x.0, x.1, … x.9)) would represent 10% of the total number of fractions/year, and their average would be 0.45 ((∑x.0 + x.1 +.. x.9)/10).

However, Monte Carlo simulations show that because the second decimal place was not preserved when Fahrenheit data entered the Bureau's database, whole-degrees Fahrenheit converted to Celsius, back-transform from the database (i.e., from °C to °F) in the ratio of about 55% x.0 and 22% each of x.9 and x.1. Also, data observed in whole and ½°F, back-transform from °C to °F in the ratios of about 30% x.0, 9% to 11% x..9 and x.1; and, about 26%, x.5 and 10% x.4 and x.6. (If stored to 2-decimal places, °F-data would back-transform to their original value.) To be clear, precision is an index of accuracy, training and diligence, which may or may not impact on long-term Tmax trend. However, observations consistently rounded up or down to the next index by observers (whole °F or °C, or 1/2°C) may result in bias (Figure 11).

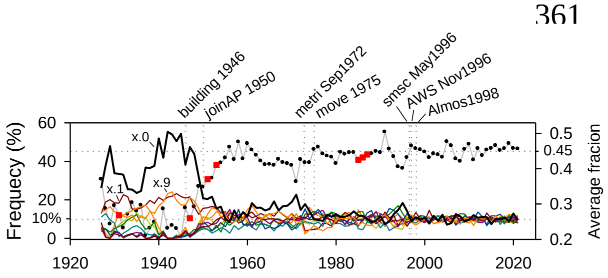

Figure 11. Frequency of decimal fractions (left axis), and average frequency (right axis) show post office data were observed mainly in whole and ½°F, and that precision improved step-wise: on moving from the PO to the Aeradio office in 1950, following metrication on 1 September 1972, which coincided with commencement of the overlap, and, following the AWS becoming the primary instrument on 1 November 1996.

Suggestive of a change in protocols or observers, whole and ½°F was over-represented (>*c.* 60%) at the expense of other fractions from about 1957 to the end of the overlap in 1975; however, the reason for the change is obscure.

1.3 Site changes affect temperature extremes

Tmax temperatures near the tails of data distributions are daily values/yr <5th and >95th day-of-year dataset percentiles (Lo and Hi extremes respectively). Extremes are expected to vary with rainfall, thus their Hi//Lo ratio is expected to be homogeneous and show no trend.

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As rainfall is causal on Tmax and shows no trend, counts (N) per year of daily temperatures less than the 5th and exceeding the 95th day-of-year (1 to 366) dataset percentiles (Lo and Hi extremes respectively) are expected to vary randomly in the long-term, while their ratio (Hi_N/Lo_N) is expected to be homogeneous and show no trend. However, as ratios are not symmetrical (i.e., not normally distributed) about their mean, they were $\log_{10}$-transformed prior to analysis using STARS.

STARS analysis shows that while the move alleged by ACORN-SAT corresponded with the end of the overlap, data from 1946 to 1975 were likely affected by shade or watering, initially at the post office and after 1950 at the airport (Figure 12). Noting that time-wise error is not estimated by STARS, and that rainfall from 1996 to 2005 ranked generally within the upper quartile (i.e., that background conditions were relatively mild), the up-step in 2005 *most likely* had its origins in the change from a 230-litre to a 60-litre Stevenson screen in 1996, and replacement of the Milos AWS with the Almos in 1998.

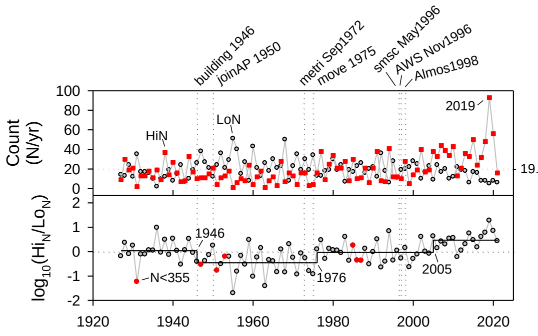

Figure 12. Counts/year of daily Tmax < 5th and >95th day-of-year percentiles and their $\log_{10}$-transformed ratio tracks the tails of daily data distributions. Step-changes in 1946 and 1976 are directly attributable to site changes. As the abrupt up-step in 2005 followed a period of relatively mild conditions from 1996, it was likely related to the change to the 60-litre screen and AWS in 1996.

2. Homogenisation of maximum temperature data

Homogenisation is compromised by correcting for site changes that made no difference while ignoring some that did, and making adjustments to data that are disproportionate to individual site change effects.

Read on …

Simon Torok (1996) merged data for Peak Hill, some 100 km north of Meekatharra with post office and airport data to derive a dataset spanning from 1910 to 1993. As he made no adjustments after 1946, changes at the airport that impacted on data were assumed to reflect the climate. Torok's adjustment file shows Tmax at Peak Hill was on average 0.1°C cooler than at the post office, and inexplicably, that post office data were on-average 0.6°C cooler from 1927 to 1933 and 1.1°C cooler from 1934 to 1946 than at the airport. Adjusting for those differences, but not changes at the airport including the 1970s move to the MO, resulted in a homogenised Tmax trend of 0.06°C/decade to 1993 (Figure 13).

Adopting the same datasets and adjustments, Torok's HQ_1 dataset was updated to HQ_2 to 2012 by Della-Marta et al. (2004). While trend increased slightly (0.06 to 0.11°C/decade) the additional 19-years of data improved significance of the trend coefficient from P = 0.06 for HQ_1 to P < 0.001 for HQ_2.

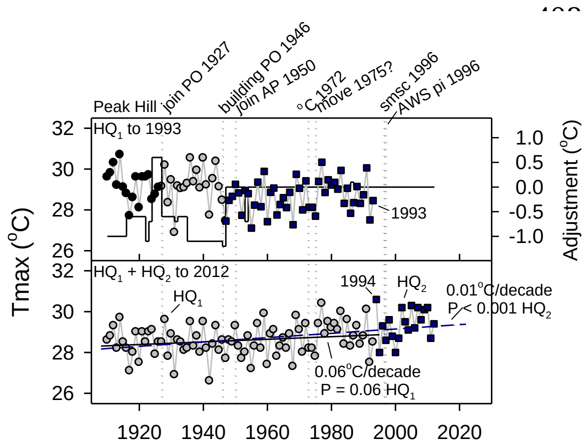

Figure 13. Raw data for Peak Hill (ID 7070), Meekatharra post office (PO) and airport (AP) abutted to form a continuous series, and adjustments applied by Simon Torok (horizontal lines) to create the original High-Quality homogenised HQ_1 series. Adjustments prior to 1946 combined with ignoring the move in *about* 1975 resulted in a Tmax trend of 0.06°C/decade. Della-Marta et al. (2004) adopted the same changes and extended HQ_1 by 19-years to derive HQ_2. They likewise made no adjustment for the alleged move in 1975 and ignored potential effects of the small screen (smsc), and the AWS becoming the primary instrument (pi) in 1996.

However, as trend to 2012 was due to ignoring that the site moved in the 1970s, that the former 230-litre screen was replaced with a 60-litre one and the AWS became the primary instrument in 1996, it was unrelated to the true climate. Further, should the 'trend' homogenised into the data maintain its trajectory, average maximum temperature would exceed 29.5°C by 2030, which is about 1.3°C warmer than in 1910. Although trend projected forward may agree with model predictions, ever-increasing daily extremes would rapidly become unrealistic.

While previous homogenisation iterations applied annual or monthly adjustments, Trewin's ACORN-SAT methodology aimed to adjust data distributions so daily data are "*more homogeneous for extremes as well as for means*"[1]. ACORN-SAT aimed to skew daily data so the tails of data distributions closely aligned with those of reference series derived from inter-correlated neighbouring sites. Changes to previous methods included that breakpoints were detected using multiple tests, and that effects of site changes on extremes were adjusted by matching percentiles of data distributions with those of reference series using complex methods and *transfer functions*. Compared to STARS, which detects multiple step-changes in dataset means[2] which are verified *post hoc*, the greater number of statistical tests used by Trewin cannot be expected to generate increased confidence that change occurred (i.e., *post hoc* verification is more important than the number of tests).

It is noteworthy that Trewin's homogenisation methods do not straightforwardly analyse discontinuities in the tails of data distributions *vis-à-vis* Figure 12, or persistent changes in frequency spectra (frequencies within temperature classes) and relate those to site changes as shown in Figure 14.

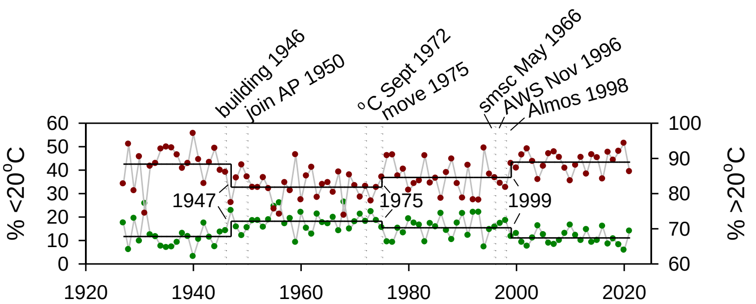

Figure 14. Frequency of daily Tmax/yr <20°C (lower curve, left axis), is the inverse of frequencies >20°C (upper graph, right axis). STARS analysis detected step-changes in 1947, related to the new building at the PO, in 1975 consistent with cessation of smoothing the transition from the Aeradio to the MO site, and in 1999 immediately after the 60-litre screen was installed and the AWS became the primary instrument.

Although daily observations/yr less than the dataset 1st quartile declined step-wise, and those >3rd quartile increased, incremental evaluation of daily data aggregated into classes less than about 20°C detected few consistent change points. The average frequency of daily temperatures >37.8°C (100°F) increased slightly by 1.09% of days/yr in 1969 but not significantly (P = 0.17) and due to out-of-range data in 2019, from 15% to 18% of days/yr in 2003 (P = 0.011). Adjusted directly by their magnitude, residuals for frequency classes shown in Figure 14, and others, showed no trend or change due to unexplained factors. Adjusting for the effect of some but not all site and instrument changes on tails of daily data distributions using complex methods and *transfer functions* potentially distorts resulting homogenised datasets so averages and extremes agree with models, but do not reflect the true climate.

In summary, given that that Tmax depends on rainfall, that metadata is imprecise, and that observational precision was not consistent, realigning data distributions relative to a reference series comprised of highly correlated neighbours, so extremes are homogeneous is unlikely to result in unbiased trends or reliable trends in extremes.

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[1] See: BRR-032.pdf (bom.gov.au)

[2] See: https://www.beringclimate.noaa.gov/regimes/rodionov_overview.pdf

2.1 Revisiting the problem of inter-correlated comparator sites

> Embedded residual cycles in first-differenced daily or average monthly data inflates the significance of Pearson's linear correlation coefficient and invalidates the test. Like linear regression, the test assumes that data-pairs are strictly independent and not affected by outliers. Furthermore, ACORN-SAT selection criteria identified comparator sites that mostly had parallel faults. The use of faulty data to correct faults in ACORN-SAT data has no statistical or scientific merit.
>
> Read on …

Compared using first-differenced data, Trewin's ACORN-SAT methods use highly intercorrelated neighbouring sites for detecting breakpoints in target site data and also for making adjustments. However, as Tmax cools from summer to winter, and warms from winter to summer, the first-difference transformation of monthly or daily data *does not* remove underlying seasonal cycles, which is a prerequisite for unbiased correlation analysis. (Embedded cycles or trends inflate the significance of the Pearson linear correlation coefficient and invalidates the test.) Removing seasonal cycles beforehand by deducting monthly or day-of-year averages would greatly change inter-site correlations and consequently the list of stations used by Trewin to create reference series. In any case, the selection of highly correlated neighbours from the pool of possible contenders is highly likely to identify sites having parallel faults.

Of the 18 sites used to homogenise the four ACORN-SAT v.2 breakpoints listed in Table 1, eight were used more than once, and fewer were available going back in time. Also, the general climate at Emu Creek Station, which was the furthest away towards Learmonth, and that of wheat-belt sites such as Merredin and Kellerberrin were unlikely to be similar to Meekatharra. Of those selected, only Merredin and Kalgoorlie-Boulder Airport were also ACORN-SAT sites (Figure 15).

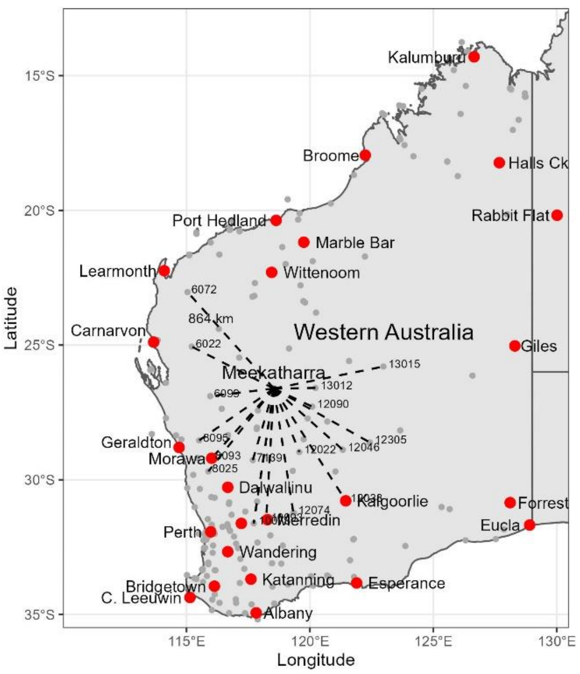

Figure 15. The radar-plot locates the 18 comparator sites listed in Table1 used to homogenise changepoints in Meekatharra Tmax. ACORN-SAT sites are highlighted; site numbers are provided for reference.

Each of the sites listed in Table 1 were analysed using BomWatch protocols to evaluate the ACORN-SAT hypothesis that comparator sites selected on the basis of inter-site correlation, would be "*broadly homogeneous around the time of the potential inhomogeneity*" (Trewin, 2012[1] p. 44), and that "*the use of multiple reference stations provides a high level of robustness against undetected inhomogeneities at individual reference stations*" (Trewin 2018[2], p. 12). Results are shown in Appendix 2.

All sites listed in Table 1 were affected by station moves and changes and in many cases step-changes in Tmax ~ rainfall residuals aligned with those at Meekatharra. Variation explained by rainfall alone was variable and less than 0.50, and in some cases, relationships were not

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[1] Techniques involved in developing the Australian Climate Observations Reference Network – Surface Air Temperature (ACORN-SAT) dataset. CAWCR Technical Report No. 049.

[2] The Australian Climate Observations Reference Network – Surface Air Temperature (ACORNSAT) version 2. Bureau Research Report – BRR032.

significant. Furthermore, after accounting for residual step-changes (which were all significant), only six of the 18 sites exceeded the threshold whereby site changes and rainfall together explained >50% of Tmax variation.

For example, of the ten sites used to homogenise for the screen change in 1996, seven were affected by step-changes that occurred within 5-years of the changepoint; of those, five were within 4-years and four were within 2-years.

Table 1. The 18 sites used by ACORN-SAT v.2 to adjust the four changepoints in Meekatharra Tmax data. Un-bolded text indicates those used more than once. $R^2_{(1)}$ refers to the Tmax ~ rainfall base case; $R^2_{(2)}$ refers to Tmax ~ Shift + rainfall, where Shift is a categorical variable defining segments whose between segment means were not the same. Superscript^{1} indicates significant (P >0.05) interaction, i.e., where slopes were not homogeneous. (Summarised from Appendix 2.)

Changepoint	BoM ID	Name	Latitude	Longitude	$R^2_{(1)}$	$R^2_{(2)}$
New screen, 2 May 1996	**12090**	Yeelirrie	-27.2842	120.0931	0.401	0.560
	13012	Wiluna	-26.5914	120.2258	0.192	0.423
	12022	Cashmere Downs	-28.9700	119.5686	0.404	0.559
	6099	Murchison	-26.8956	115.9567	0.091	0.468
	12046	Leonora	-28.8879	121.3302	0.359	0.735
	12305	Laverton Aero	-28.6133	122.4236	0.254	0.673
	6022	Gascoyne Junction	-25.0544	115.2100	0.098	0.314
	7139	Paynes Find	-29.2708	117.6836	0.196	0.441
	6072	Emu Creek Station	-23.0314	115.0414	0.149	0.482^{1}
	13015	Carnegie	-25.7964	122.9753	0.093	0.460
Move 25, April 1950	**12038**	Kalgoorlie-Boulder Airport	-30.7847	121.4533	0.326	0.582
	8095	Mullewa	-28.5367	115.5142	0.268	0.505
	10093	Merredin Research Station	-31.4994	118.2242	0.336	0.420
	8025	Carnamah	-29.6883	115.8857	0.347	0.485
	10073	Kellerberrin	-31.6183	117.7217	0.735	0.737
Building PO, 1 January 1946	**12074**	Southern Cross	-31.2319	119.3281	0.211	0.448
	12039	Kalgoorlie Post Office	-30.75	121.4667	0.010^{ns}	0.210^{ns}
	12038	Kalgoorlie-Boulder Airport	-30.7847	121.4533		
	10093	Merredin Research Station	-31.4994	118.2242		
	8093	Morawa	-29.2103	116.0089	0.256	0.432
	10073	Kellerberrin	-31.6183	117.7217		
Statistical detect, 1 January 1934	12074	Southern Cross	-31.2319	119.3281		
	8095	Mullewa	-28.5367	115.5142		
	10093	Merredin Research Station	-31.4994	118.2242		
	8093	Morawa	-29.2103	116.0089		
	10073	Kellerberrin	-31.6183	117.7217		

Trewin's key assumption, which underpins his ACORN-SAT methodology, that comparator sites selected on the basis of inter-site correlations would be broadly homogeneous around the time site changes occurred at Meekatharra is therefore not supported. Consequently, his claim that comparator series comprised of multiple reference stations could provide a "*high level of* *robustness against undetected inhomogeneities*" is also not true. To the contrary, use of reference series derived from faulty data to correct faults in ACORN-SAT data has no scientific nor statistical merit.

Notes relating to some of the sites listed in Table 1, abstracted from Simon Torok's (1996) PhD thesis provide little encouragement that data are likely to be useful for depicting long-term climatic trend and change (Appendix 3). In addition, site-summary metadata for sites analysed in Appendix 2 was generally unhelpful in diagnosing inhomogeneities. For example, no site details were available the Kalgoorlie Post Office. Also, metadata consistently overlooked when 230-litre Stevenson screens were replaced by 60-litre ones even though across most sites including Meekatharra, recent step-changes in Tmax-rainfall residuals were related to the changed screen size and not the climate.

Discussion and conclusions

As the climate at Meekatharra and the 18 sites used to homogenise Meekatharra Tmax data has not warmed or changed, and as faulty data are routinely used to adjust faults in ACORN-SAT data, the ACORN-SAT project is deeply flawed, unscientific and should be abandoned.

Read on …

While homogenisation is an essential prerequisite to determining unbiased trend and change, the processes developed by Bureau scientists from Neville Nicholls to Blair Trewin, is not straightforward and may be manipulated to create bogus, pre-determined trends. Weaknesses identified in the various approaches are:

i. Reliance on incomplete and misleading metadata to identify or verify times when site changes may have impacted on data;
ii. The arbitrary selection of changepoints that may or may not have made a difference;
iii. The lack of statistical control in the detection and adjustment of changepoints using correlated comparator sites whose data are not homogeneous, and the absence of *post hoc* verification of ACORN-SAT data.

For example, all homogenisation iterations of Meekatharra Tmax adjusted for a change at the post office in 1934 that was not significant (apparently according to Torok, because "the screen was a bit high"), but they also ignored the highly significant change associated with the 1970s move to the MO which was smoothed using overlap data from 1972 to 1975, thus:

Segment	Rainfall-adjusted mean Tmax	Difference (SE) (°C)	Turkey P level
1927-1933	28.9°C		
1934-1946	29.2°C	+0.31 (0.254)	0.733
1946-1974	28.5°C		
1975-1995	29.0°C	+0.50 (0.144)	0.001

Adjusting for a change in 1934 that made no difference and failing to mention the overlap from 1972 to 1975 and not adjusting for it, is disingenuous in the extreme. As the files in the NAA were Bureau files, it is clear that from Neville Nicholls to Blair Trewin, senior scientists within the Bureau failed to undertake the site research they said they did.

(While the rainfall adjusted difference was +0.31°C, Torok adjusted pre-1934 data by +0.54°C, ACORN-SAT v2 by +0.57°C and ACORN-SAT v.2.1 by +0.59°C.) Together with ignoring the move to the MO, it was this, and the magnitude of some other adjustments (some of which did not align), that created the trends in homogenised data shown in the lower panel of Figure 16.

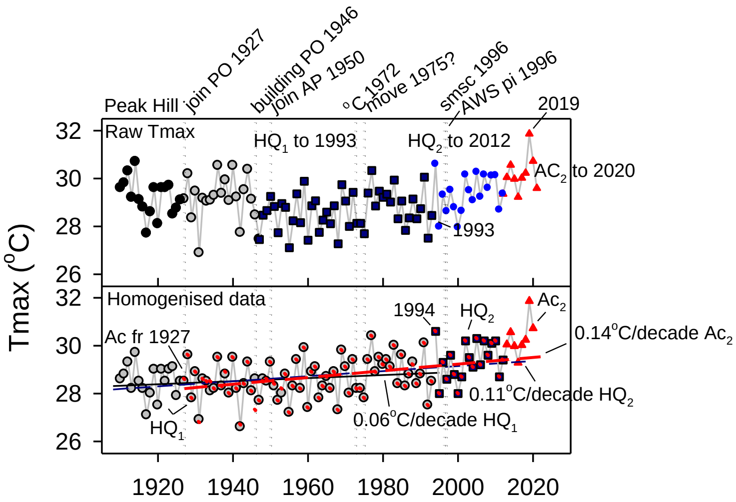

Figure 16. A composite graph showing (top panel) segments of raw Tmax associated with homogenisation iterations (HQ_1 and HQ_2 from 1910, and ACORN-SAT v.2 (Ac_2) from 1927) and in the lower panel, effect of successive iterations on homogenised data and resulting linear trends (ACORN-SAT v.2 segments are dotted and shaded red.

Use of confounded (Tmax + rainfall) data adds an additional layer of uncertainty to the changepoint detection problem. For instance, it raises the question whether it was the site or the rainfall that changed in 1934. While providing a valid initial assessment of data fitness, removing the confounded rainfall signal using naïve linear regression also removes that uncertainty (contrast Figure 8(b), with Figure 8(c) to (e)). For example, as much as Blair Trewin would will it to be true in his numerous publications and appearances on *The Conversation*[1], it could not be claimed that at the conclusion of the overlap from 1973, the step-change in 1976, or the change in 1996 caused by the introduction of 60-litre Stevenson screens and AWS, was due to climate change and warming.

For sites where the Tmax ~ rainfall relationship is not significant, or R^2_{adj} is below about 30% (>0.30), or for MLR, R^2_{adj} <0.50, either a variable is missing, or, due to low precision, lackadaisical practices, poor site maintenance including broken screens or ageing thermometers, data are too rough for use in detecting trend or change. While BomWatch protocols verify the outcome of step-change analysis using multiple linear regression (Figure 10 and Appendix 2), supported *ad hoc* by segmented rainfall- and time-domain analysis and inspection of MLR residuals, evidence is lacking that Trewin's homogenisation methods are rigorous or that outcomes are verifiable on a site-by-site basis, which is essential for quality assurance of ACORN-SAT.

It is clear that for Meekatharra and the 18 sites analysed in Appendix 3, that all datasets consist of two overlaid signals: rainfall, which is deterministic on Tmax, and an underlying ambient signal against which data-to-day temperatures are measured. Changes in ambience due to a site or instrument change results in an additive temperature change - a step-change as distinct from a trend. While transient factors such as watering may add interference, or changes in observers may affect precision, it is unlikely that those factors alone could affect long-term trend in data.

Examining data from multiple perspectives (e.g., Figure 11 and Figure 12), and in the frequency domain (Figure 14) assists diagnosing issues related to data quality. It is evident for example, that increasing temperatures and temperature extremes over recent decades is attributable to replacing the former 230-lite Stevenson screen with a 60-litre one in May 1996, and supplanting manual observations with the more precise and sensitive Almos AWS, which became the primary instrument after 1 November 1996. It cannot be ruled out that maintenance of the site and Stevenson screen deteriorated as staff were withdrawn, or that a former wooden 60-litre screen

[1] https://theconversation.com/profiles/blair-trewin-3692/articles

was replaced by a plastic one having smaller, more numerous louvers that restrict air-flow across the temperature probe on windless hot days.

A key outcome of the research is that due to temperatures declining from summer to winter and increasing from winter to summer first-differenced data embed a cycle which invalidates the Pearson linear correlation assumption that data-pairs are not co-linked by a third variable such as a cycle or trend. Furthermore, as shown in Appendix 2, choosing comparator datasets on that basis likely selects sites having parallel faults. The assumption underlying ACORN-SAT that comparator series comprised of multiple reference stations could provide a "*high level of robustness against undetected inhomogeneities*" is therefore categorically disproven.

As there is no change in the climate across all the datasets examined, and faulty data are routinely used to adjust faults in ACORN-SAT data, the ACORN-SAT project is deeply flawed unscientific and should be abandoned.

Disclaimer

Rules relating to scientific conduct by members of the Australian Meteorological and Oceanographic Society of which the Author is a member and of which Blair Trewin was President, specifically state that "*Members involved in scientific activities should base those activities on sound scientific principles*" and that "*Plagiarism, fabrication or falsification of data, and other misleading behaviour are all unacceptable*" (https://www.amos.org.au/about/rules-and-regulations/amos-code-of-conduct-2/).

Unethical scientific practices including the homogenisation of data to create false narratives undermines trust and is not in the public interest. 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.

Acknowledgements

Impetus for this research arose from the creepiness, that spearheaded by WWF, and teachers they should be able to trust, school children from primary school to Year 12; students at university, and the public at large have been groomed relentlessly by BoM, CSIRO, the Australian Museum, IPCC, the Climate Council and high-ranking professors to believe that the world is facing a tipping-point due to global warming caused by CO_2, which is not true.

Dr Neville Nicholls, who commenced as a cadet meteorologist with the Bureau of Meteorology in 1970[1] and later in 1986 was a member of the World Climate Research Programme when Dr John Zillman was Australia's permanent WMO representative oversaw BoM scientist Simon Torok's PhD and (also co-supervised Blair Trewin's PhD), which underpinned much of the Bureau's subsequent homogenisation effort. A contributor to the World Economic Forum[2], Nicholls is currently Emeritus Professor at Monash University and he is acknowledged for stirring my interest in the dark-art of using data homogenisation to create bogus climatic trends and changes. The damage wrought by elite scientists to the integrity of science in Australia, the national economy and the wellbeing and employment prospects of future generations in the name of climate change is deplorable.

[1] https://www.eoas.info/biogs/P003289b.htm
[2] https://www.weforum.org/agenda/authors/neville-nicholls

Development of decimal fraction frequencies as a precision metric resulted from discussions with Chris Gillham (https://www.waclimate.net/). Others who contributed ideas and discussion included Geoffrey Sherrington, Ken Stewart (https://kenskingdom.wordpress.com/) and Tom Berger (http://www.elastictruth.com/). David Mason-Jones is gratefully acknowledged for providing invaluable editorial assistance.

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Dr Bill Johnston

11 December 2022

Appendix 1.

Multiple regression analysis of Tmax scenarios shown in Figure 6.

Initial analysis of each paired case (Cases 2 to 5) identified step-change segments whose group means were the same ($P > 0.05$). Groups amalgamated on that basis were reanalysed, with results shown sequentially below. Thus, the 5 segments in Case 2, rawTmax (top panel in Figure 6), resolved into three significantly different groups who's within-group means were the same. These were reanalysed as Case 2a. $ShMax_{res}$ refers to step-changes detected in rescaled residuals (second and lower panels in Figure 6). In each case, four initial groups resolve into three. Cases 6 and 7, tests for a site move in 1975 vs. no significant effect. (While *na* refers to not available, *nd* refers to not done.)

Scenario	Rain coeff. (°C/100 mm)	Number of groups	Pred. means (°C)[1]	R^2_{adj}	RSE[2]	AIC[3]
1. Tmax ~ rainfall	-0.055	na	na	0.388	0.727	na
2. Tmax ~ ShMax + rain	-0.053	5	nd	0.683	0.523	nd
2a. Tmax ~ ShMax(a) + rain Contrast Gp_1 vs Gp_3: + 0.69°C	-0.049	3	1: 29.0 2: 28.5 3: 29.6	0.646	0.553	162.78
3. Tmax ~ $ShMax_{res1}$ + rain	-0.061	4	nd	0.697	0.512	nd
3a. Tmax ~ $ShMax_{res1}$(a) + rain Contrast Gp_1 vs Gp_3: + 0.77°C (1946, 1980, 1996)	-0.061	3	1: 29.1 2: 28.5 3: 29.8	0.694	0.514	149.04
4. Tmax ~ $ShMax_{res2}$ + rain	-0.060	4	nd	0.703	0.507	nd
4a. Tmax ~ $ShMax_{res2}$(a) + rain Contrast Gp_1 vs Gp_3: + 0.78°C (1946, 1977, 1996)	-0.060	3	1: 29.0 2: 28.5 3: 29.8	0.702	0.508	146.73
5. Tmax ~ $ShMax_{res3}$ + rain	-0.061	4	nd	0.717	0.494	nd
5a. Tmax ~ $ShMax_{res3}$(a) + rain Contrast Gp_1 vs Gp_3: + 0.80°C (1946, 1972, 1996)	-0.062	3	1: 29.0 2: 28.4 3: 29.8	0.715	0.496	142.35
6. Tmax ~ $ShMax_{1975}$ + rain Contrast Gp_1 vs Gp_3: + 0.79°C (1946, **1975**, 1996)	-0.061	3	1: 29.0 2: 28.4 3: 29.8	0.706	0.504	145.12
7. Tmax ~ $ShMax_{1946\&1996}$ + rain Contrast Gp_1 vs Gp_3: + 0.69°C (**1946, 1996 only**)	-0.060	3	1: 29.1 2: 28.6 3: 29.8	0.672	0.533	155.79

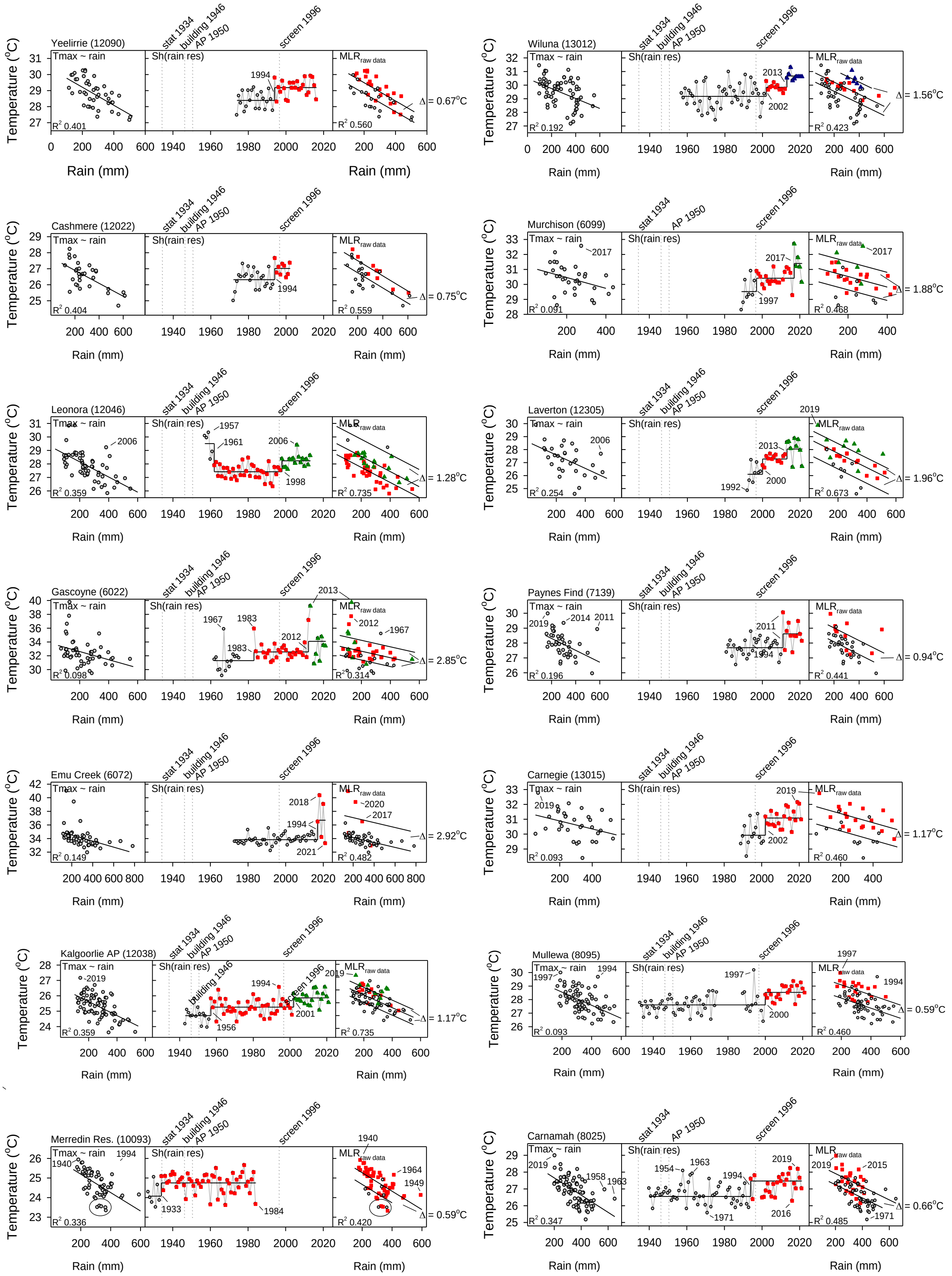
[1] Segment means predicted by the *emmeans* package. In all cases differences are significant.

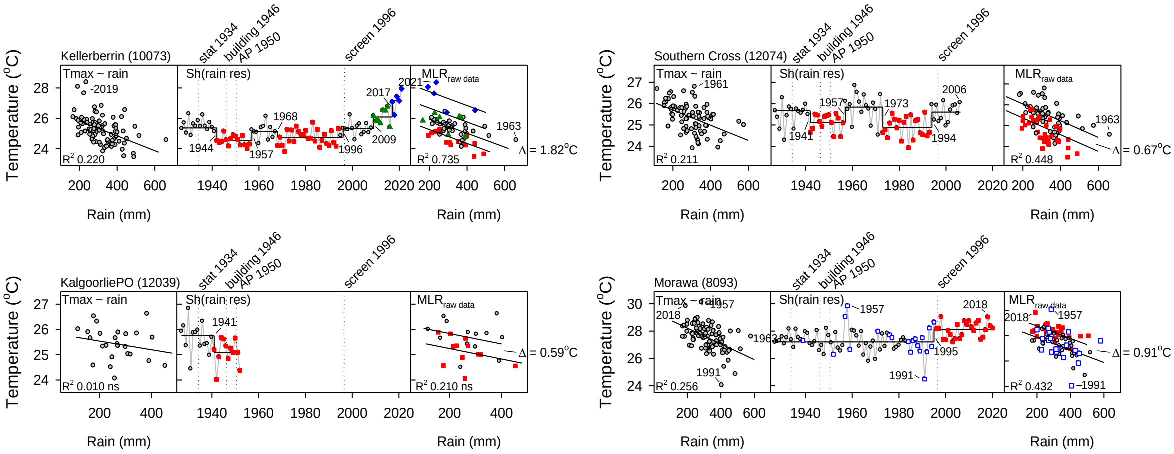
[2] Residual standard error. The model accurately predicts Tmax with an error equivalent to the RSE. A small value indicates a relatively better fit.

[3] Akaike information criterion (see text).

Appendix 2.

Analysis of comparator datasets used by ACORN-SAT v.2 to homogenise Meekatharra Tmax, listed in Table 1.




Kellerberrin (10073)
Southern Cross (12074)
KalgoorliePO (12039)
Morawa (8093)
stat 1934
building 1946
AP 1950
screen 1996
Tmax ~ rain
Sh(rain res)
MLR raw data
Temperature (°C)
Rain (mm)
Δ = 1.82°C
Δ = 0.67°C
Δ = 0.59°C
Δ = 0.91°C
R² 0.220
R² 0.735
R² 0.211
R² 0.448
R² 0.010 ns
R² 0.210 ns
R² 0.256
R² 0.432

Appendix 3.

Screenshots of notes for sites in Table 1 mentioned in Simon Torok's PhD Thesis.

Kellerberrin 10073
10/1913: First correspondence
1910s: Observer problems.
06/1935: New screen after being in poor state of repair.
01/1939: Min problems due to reading of wrong end of thermometer.
05/1971: Move 30m N to better exposure.
11/1971: Move 6m W of PO.
1979–85: No moves.
10/1985: Move 500m E of PO

Merredin 10092 and 10093
Not much information but seems good quality.
08/1915: First correspondence. Entry problems.
05/1957: Move 150m SE from old site.
01/1966: Move to excellent site due to downgrading.
03/1986: Site cleared after becoming overgrown.

Kalgoorlie 12038 and 12039
1907: Thermometer shelter falling to pieces and needs replacing.
03/1913: First correspondence. Quite a few reading problems in 1910s.
05/1923: Screen poor with iron parts replacing wood.
12/1936: Screen moved 100 yards as it was enclosed by sheds.
01/1943: Move to MO.
11/1943: Moved slightly as building will occur.

Leonora 12046, 12158 and 12300
11/1919: First correspondence. Screen painted and fixed.
1934: Entry problems as observer not instructed.
1936: Site closed as "the readings are taken by girls".
1950: Move to new site which is built up and only fair.
03/1972: Move to new site away from buildings.
02/1983: Small move back towards PO.
1985–7: Temporary site.

Southern Cross 12074

09/1913: First correspondence.
1910s: Entry problems and poor site.
04/1923: Yard covered with pumpkins.
12/1943: New screen.
10/1961: Possible move.
10/1972: Move 35m WNW to rear of PO.

Laverton 12219 and 12045

12/1934: First correspondence.
05/1935: Screen poor, new one sent.
06/1965: Site has become cluttered and is close to tin shed and tank.
06/1967: Site moved to better exposure.
01/1969: Move to excellent site.

Wiluna 13012

11/1912: First correspondence. New min after beading in old.
10/1921: Screen fixed but has been facing SW.
12/1941: Very old screen replaced.
06/1944: Thermometers replaced.
11/1965: Screen has been moved and painted silver.
06/1973: No change in poor site. Vehicles park nearby.
09/1991: Site still cluttered so move planned