Is homogenisation of Australian temperature data any good?

Part 7c. Cloncurry, Queensland, Australia

Bureau of Meteorology ID 29041 (Airport), 29009 (Aero) and 29008 (PO)
Latitude -15.6614 Longitude 130.4808.

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Summary

The use of faulty data to detect and adjust faults in ACORN-SAT data is biased, unscientific, lacks statistical merit and for the reputation of all involved, the ACORN-SAT project should be abandoned.

Read on …

The 112 weather stations that comprise the Australian Climate Observations Reference Network – Surface Air Temperature dataset (ACORN-SAT) is used by the Bureau of Meteorology (BoM) monitor warming of Australia's climate. Homogenisation – the process of adjusting ACORN-SAT for site and instrument changes – requires that data for comparator sites are free of faults and biases that may impact trend and other properties. While not itself an ACORN-SAT site, maximum temperature (Tmax) observed at Cloncurry in western Queensland was used to adjust 11 ACORN-SAT sites as far afield as Tennant Creek (669km to the west), Victoria River Downs (1,109km NW) and St George (1,153km SE). **This report examines whether data for Cloncurry (1907-2023) are fit for the purpose of homogenising data for other sites.**

Ignoring years with fewer than 330 observations/year, rainfall explained 29.6% of Tmax variation (R^2_{adj}=0.296). Step-changes in residuals in 1916, 1942 and 1998 showed data were affected by underlying site related inhomogeneities. Initial analysis found rainfall-adjusted Tmax was the same from 1907-1915 and 1942-1997, but different to between 1916-1941 and 1998-2023. Data were therefore combined into three groups and re-analysed.

Second-round analysis found that while rainfall reduced Tmax 0.28°C/100 mm, rainfall-adjusted means of the three resulting groups (1907-1915 & 1942-1997, 1916-1941, and 1998-2023) were different, thereby confirming that underlying step-changes in the data were due to intervening site changes in 1916, 1942 and 1998, not changes in the weather. While the 1916 change could not be attributed, the change in 1942 aligned moving the site from the post office to the airport. The step-change in 1998 was due establishing a new site and replacing the former 230 litre Stevenson screen with a 60 litre one.

The overall Tmax trend from 1907 to 2023 of 0.124°C/decade was due to site changes that caused Tmax to step-up 0.95°C (±0.24°C) independently of the climate. Furthermore, with the effect of rainfall and site changes accounted for, no residual trend remained that could be attributed to CO_2, coalmining, internal-combustion engines, electricity generation or anything else.

All Australian weather stations have moved and changed and most sites have been poorly researched and documented. Using data that are not homogeneous, to make adjustments to multiple ACORN-SAT datasets is biased, has no statistical or scientific merit and should be abandoned.

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

1. Introduction

Cloncurry in western Queensland was a crossing-place on the Cloncurry River and a trading outpost for camel-trains servicing settlements and isolated homesteads in central Australia. Following the discovery of a copper lode in 1867 the Great Australian Mine commenced operations in 1869[1] and a mining town established nearby. The town was surveyed in 1876, proclaimed in 1884, a post office established probably in 1887, and Queensland's Northern Line Railway from Townsville reached Cloncurry in 1907. Although lying dormant for many years, the Great Australian Mine is currently being operated by True North Copper, which is headquartered in Cairns.

Temperature and rainfall observations commenced at the Cloncurry post office in 1888; however, only average monthly maxima, minima (Tmax and Tmin) and monthly rainfall are available from the Bureau of Meteorology (BoM). Due to a data-gap from 1896, continuous temperature data are only available from 1907 until observations at the post office ceased in 1951. According to Torok (1996)[2] a Stevenson screen supplied in February 1889 was replaced in May 1908. First correspondence with the BoM was in September 1908 immediately after it assumed responsibility for meteorology following Federation. The site moved in September 1944 (files at the National Archives of Australia indicate an equipment building was constructed and extensions were made to the post office). Also, that observations were made at the aerodrome from January 1950, and in 1976 the site "moved back" (presumably to the Post Office) "for composite fill-in of data" (Figure 1). The town site, which now only records daily rainfall and is no longer at the post office, has been re-named *Cloncurry McIllwraith St* (BoM ID 29008).

Figure 1. The Cloncurry post office in the 1940s (National Archives of Australia).

Amalgamated Wireless Australasia Ltd (AWA) established an Aeradio office at the airport on behalf of the Air Board in 1939 (callsign VZCY) to monitor aircraft flying the Brisbane-Darwin route and on to London. Staffed by radio operators and technicians and BoM-trained weather observers and forecasters, with its powerhouse, aerials and meteorological equipment the set-up was substantial (Figure 2). Aeradio (which became Flight Services) closed in the mid-1970s when functions transferred to a new Flight Services Unit at Mt Isa airport. Re-purposed in the interim as the passenger terminal, the Aeradio building was demolished and replaced in the 1980s.

The first full-year of daily weather observations for Cloncurry Aero (ID 29009) was 1942 and following a break from May 1975, observations re-commenced in May 1978 at another site (ID 29141). As this was a very broken record with some months completely missing, data from 1982 to 1996 were unreliable and not used in the study. Thermometers were removed and the site was moved toward the centre of the airport when an automatic weather station (AWS) was installed on 22 March 2001.

An aerodrome plan cross-referenced to 1963 and 1960 aerial photographs and Google Earth Pro satellite images located the original met enclosure at Latitude -20.6691°, Longitude 140.5082°,

[1] https://en.wikipedia.org/wiki/Cloncurry,_Queensland

[2] Torok S.J. 1996. *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, Australia. 547 pp.

some distance from coordinates provided by the BoM's site-summary metadata (-20.5717°, 140.5083).

While not an Australian Climate Observations Reference Network – Surface Air Temperature (ACORN-SAT) site, Tmax data for the airport was used by ACORN-SAT to homogenise Boulia (38003) for changes in 1965 and 1970 (move); Charleville (44021) in 1949 (move); St George (43109) in 1962 (statistical); Longreach (29009) for changes in 1942, 1949 and 1960; Normanton (29063) in 1956 (move); Richmond PO (30045) in 1952 and 1965 (move); Tennant Creek (15135) in 1963 (move), and Victoria River Downs (014825) for a screen change on 9 June 1968. The second airport site (29141) was used to adjust for moves at Boulia in 1999 and Burketown (29077) in 2002, and Camooweal (37010) in 1998 (Figure 3).

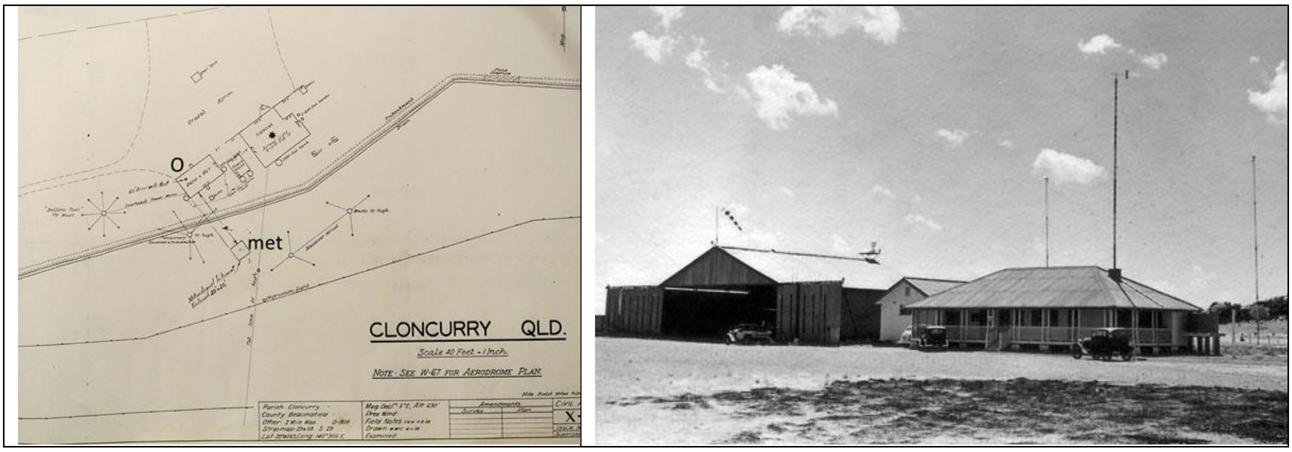

Figure 2. A 1939 aerodrome plan (left) locates the meteorological enclosure 90-feet (28 m) southeast of the office "O", which faced the apron. On the right, the Aeradio/met office with its 60-foot (18m) anemometer mast in about 1940, the adjacent powerhouse and hanger, with aerials and the met-enclosure behind (courtesy of the Civil Aviation Historical Society (CAHS) Airways Museum, Essendon).

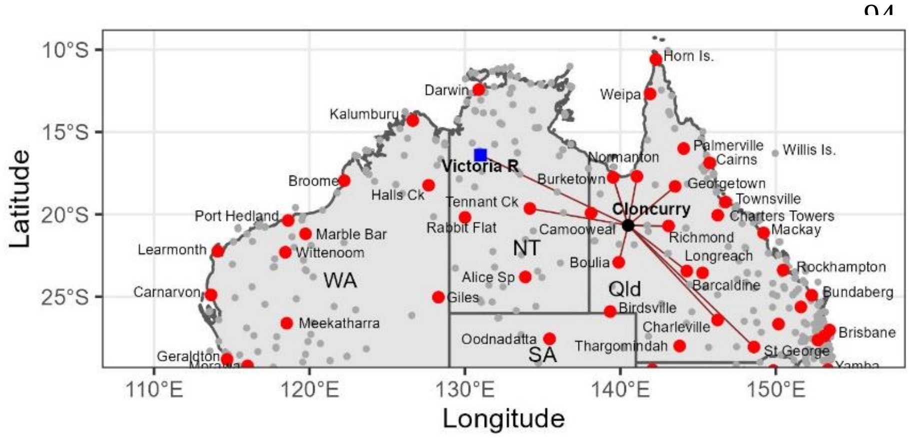

Figure 3. Although not an ACORN-SAT site (red buttons), Cloncurry was used to homogenise ACORN-SAT data as far away as Victoria River Downs (1,109km) and St George (1,153km). Cloncurry is 260km from Camooweal. Grey dots show non-ACORN sites with >10 years of Tmax observations.

Selected on the basis of first-differenced linear correlation with the target site, although up to nine others may be used to homogenise ACORN-SAT data, it is imperative that comparator datasets are sound and that data truly reflect the climate (i.e., that they are not affected coincidently by inhomogeneities attributable to site and instrument changes). This study investigates whether combined post office and airport data for Cloncurry are homogeneous and fit for the purpose of adjusting ACORN-SAT.

2. Background

Problems previously identified in the homogenisation of data for Marble Bar, Halls Creek and other ACORN-SAT sites include that: (i), metadata used to identify/verify changepoints is incomplete and possibly deliberately misleading; (ii), comparator datasets are not quality-assured so data are homogeneous; and, (iii), that comparator datasets selected on the basis that their first-differenced data are highly correlated with those of target-site data[1] are likely to embed parallel faults. Such major and obvious flaws should be sufficient for the Bureau to abandon its homogenisation methods, but this has not happened.

The history of the Cloncurry post office is not well-documented. For instance, while the Stevenson screen allegedly moved in September 1944, there is no mention that a carrier-wave building was constructed in the post office yard in 1932. An oblique aerial photograph shows that by the 1940s the post office yard was occupied by buildings and tall trees; however, site-summary metadata contains no site plan. At the airport, while a 1941 aerodrome plan shows the met-enclosure beside the apron, the plan in Figure 1, and the photograph in Figure 4 shows the enclosure was to the rear of the office. As metadata cannot be trusted to be accurate or up-to-date, analysis is best undertaken using objective methods that do not rely on faulty BoM metadata.

Figure 4. The Cloncurry Aeradio weather station in October 1965 comprised of a standard 230-litre Stevenson screen (right), an A-pan evaporimeter suspended off the ground on a pallet but apparently without a bird-guard, a copper-clad Dines pluviometer in the background (used to record rainfall intensity), and a standard 8-inch (203 mm) raingauge. Note that the site is dusty and bereft of groundcover. (Photograph courtesy of CAHS.)

3. Methods

3.1 Data preparation and processing

Mean monthly temperature and monthly rainfall for the post office was obtained from the BoM's Climate Data Online facility and found to be identical to a previously archived dataset used by Simon Torok to homogenise Cloncurry Tmax from 1888 to 1981 (footnote 3, p 2). As data were missing from 1895 to 1906, the post office dataset effectively commenced in 1907. Mean Tmax and annual rainfall were calculated from monthly post office data.

Daily Tmax and monthly rainfall for sites at the aerodrome (Aero, ID 29009) 01 July 1939 to 23 May 1975; and Airport (ID 29141) from 01 May 1978 to the present) were also downloaded. Daily observations were abutted from 1978, and the statistical program R[2] was used to prepare a multi-attribute annual summary. Annual rainfall for the post office and airport were combined from 1942, missing months were infilled using values from neighbouring sites, and with those years flagged, data were aligned to form a single (but incomplete) dataset spanning 117-years.

Daily temperature, rainfall and pan evaporation (Epan) for the grid-cell centred on Latitude -20.70°, Longitude 140.50° was also obtained from SILO (https://www.longpaddock.qld.gov.au/silo/) and summarised into monthly average temperature, and monthly rainfall and Epan. As SILO data are spatially interpolated, they may better represent the wider climate.

SILO data were used to calculate rainfall and evaporation statistics and assuming an available soil water capacity (AWC) of 100 mm, a cascading monthly water balance. Evapotranspiration (Ep) was

[1] Torok, S.J. and Nicholls, N. 1996. A historical annual temperature dataset for Australia. *Aust. Met. Mag.*, 45, 251-260; p. 257.

[2] The R project for statistical computing (https://www.r-project.org/).

set at 0.8Epan for AWC>50%, then as estimated soil water content (SWC) declined below 50%AWC, 0.4Epan, and 25%AWC, 0.2Epan. Rainfall + previous month's residual in excess of the AWC was assumed to be lost as surpluses (runoff or drainage below the reach of plant roots).

3.2 Statistical methods

As the site has moved at least three times and trend in the consolidated dataset is potentially confounded with non-climate effects, it is inadvisable to analyse data directly as time-series using spreadsheet applications such as Excel.

BomWatch protocols outlined in the Gladstone study: http://www.bomwatch.com.au /climate-data/climate-of-the-great-barrier-reef-queensland-climate-change-at-gladstone-a-case-study/ are not constrained by time-series assumptions. Missing data are permissible, and problems related to autocorrelation, heteroscedastic (non-constant) variance and non-normal residuals are avoided. Furthermore, covariance analysis with rainfall exposes outlier data: data that may be made up, strings of ill-fitting data, or data imported from somewhere else.

Briefly, naïve linear regression of the form Tmax ~ rainfall provides initial goodness-of-fit statistics (P and R^2_{adj}) and partitions variation in Tmax into that attributable to the causal covariable, rainfall (i.e., the fitted values), and the residual non-rainfall portion of the signal, which is expected to satisfy ordinary linear regression (OLS) assumptions of normality, independence and equal variance. If rainfall fully explained Tmax the rainfall coefficient would be negative and highly significant, and for a reasonable dataset variation explained (R^2_{adj}) is expected to exceed 0.50 (50%). Should variation explained be less than 50%, something is wrong. Data may be of poor quality, imported from somewhere else or made-up, or a variable may be 'missing' from the analysis.

Although rainfall-domain residuals may satisfy OLS assumptions, they may also embed inhomogeneities in the time-domain – discontinuities and other effects related to site and instrument changes that are confounded with observations but are not attributable to the weather. The strength of the BomWatch approach is that the dominant weather part of the Tmax signal is peeled away by the Tmax ~ rainfall relationship leaving residual effects to be analysed independently as time series using sequential t-test analysis of regime shifts (STARS)[1].

Re-scaled for convenience by adding the Tmax grand-mean, discontinuities (step-changes or shifts) in residuals are detected by comparing the mean of sequentially accumulated data with the mean of those before using a t-test of differences between groups. As rainfall effects have been removed, shifts detected by STARS, (which may be positive or negative) are unlikely to be climatic in origin. In addition to site relocations, step-changes in residuals may be due to unknown factors including poor site control and deterioration, replacement of 230-litre Stevenson screens with 60-litre ones (which is mostly not documented), changed observation practices, and changes in observers and data processing methods. Where possible, step-changes in data are cross-referenced to site-summary metadata, and documents, maps, photographs and aerial photographs held by the National Archives and National Library of Australia, and other sources.

Verification is undertaken using categorical multiple linear regression (MLR) of the form: Tmax ~ $(Sh)ift_{factor}$ + rainfall, where $(Sh)ift_{factor}$ factorises step-change segments identified by STARS. Pooled MLR straightforwardly evaluates that rainfall-adjusted category means are different (segmented regressions are not coincident), category-by-rainfall interaction is not significant (regression slopes are parallel) and therefore that segmented responses to rainfall are the same.

[1] STARS: Sequential t-test analysis of regime shifts (https://academic.oup.com/icesjms/article/62/3/328/658905)

MLR is undertaken using R and the *Rcmdr* and *emmeans* packages available from the Comprehensive R Archive Network[1].

Fitness of individual data segments is also evaluated separately using the same criteria that response to rainfall is expected to be negative, significant (P <0.05), with R^2_{adj} >0.50 (i.e., >50%). The step-change *vs*. trend model is further verified by testing segments for timewise trend, outliers are identified graphically using influence plots, observed vs. fitted data expose outliers, lack of fit and bias (drift) relative to a 1:1 line. Because they use same-site data and rigorous, objective methods, BomWatch protocols are much superior and consistent than homogenisation methods used by the BoM.

As effects are additive, changes in the climate would be evidenced by trend or change in MLR residuals that was not explained by site changes and rainfall acting simultaneously.

4. Results

4.1 The general climate

Climate at Cloncurry is hot, dry, seasonally semi-arid, with cool, clear 11°C to 14°C winter-days and humid, warm to very warm conditions in summer (>30°C to >38°C). Median annual rainfall is 500mm and the inter-quartile or average rainfall-range is 325m to 581 mm.

Figure 5 shows monthly rainfall exceedances, potential evaporation (0.8*Epan), and a summation of historic post-1900 rainfall relative to the long-term mean.

Potential evaporation is factors higher than rainfall across all months. Rainfall is highly skewed; thus, mean monthly rainfall generally exceeds the median. The 10 wettest years accounted for about 25% of rainfall received from 1900 to 2021; half the total was accounted for by 26 of the 122 years of record. As potential evaporation in January exceeds average rainfall by a factor of 2, and with a low chance of rain from March to October, there is little likelihood that plants would grow out-of-season.

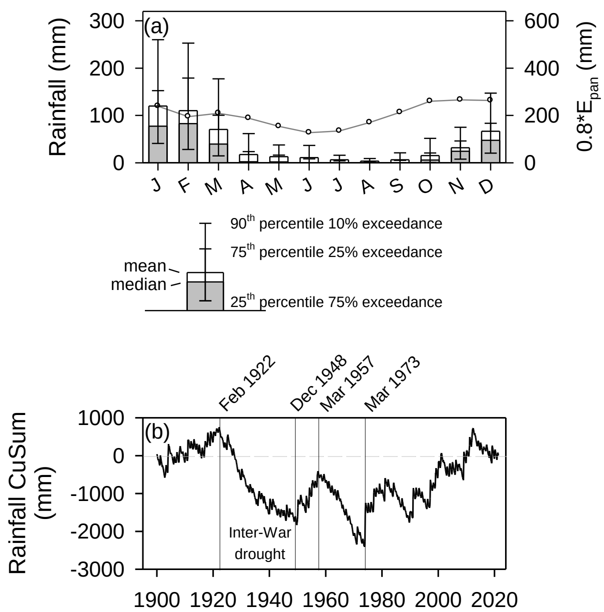

Figure 5(a). Monthly rainfall distribution and exceedances (1900 to 2020; SILO data) compared with potential evaporation (Epan*0.8). Cumulative deviations from the long-term mean (CuSum) (b) show periods when rainfall was cumulatively low (the curve declines), above the average (it ascends) or about average (the curve is relatively level). Cumulatively dry conditions from February 1922 to December 1948 and from March 1957 to March 1973 have not been eclipsed in recent decades and there is no indication that the climate is becoming drier or that rainfall is becoming less reliable.

Cumulative deviations from the long-term mean (CuSum) shows rainfall is clustered into moist/dry epochs of varying severity with the longest dry period having been the inter-War drought from February 1922 to December 1948. The longest run of relatively benign conditions was from March 1973 to the present. Although rainfall is highly seasonal, stochastic and episodic, there is no indication that it is declining or likely to decline in the foreseeable future.

[1] https://cran.r-project.org/web/packages/

By taking potential evaporation into account, the monthly water balance highlights the relentlessness of the devastating inter-War drought but lessens the apparent severity of the reduction in rainfall from 1957 to 1967 (Figure 6). Recent droughts (the Millennium drought and the post-2016 rainfall downturn) were orders of magnitude less-severe than from 1924 to 1948.

Although documented extensively by Foley (1957)[1], in their keenness to re-write Australia's climate history, BoM and CSIRO scientists have consistently ignored historic climatology, particularly the hot, dry conditions experienced during the inter-war drought. Since 1947 when drought ended, the climate at Cloncurry and elsewhere through Queensland, eastern Australia generally and southwest into South Australia has been relatively benign.

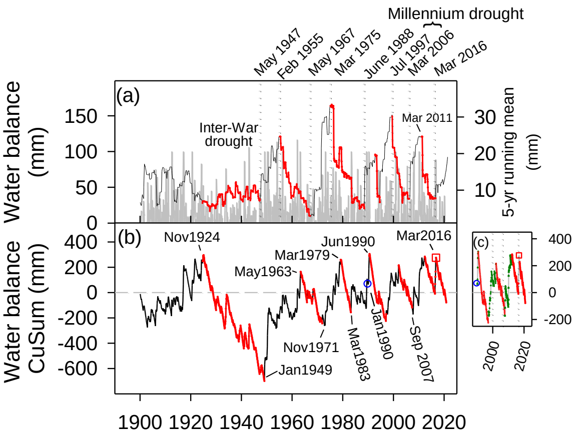

Figure 6. Monthly water balance (background bars; left axis in (a)) simulates interaction between rainfall and potential evaporation. The 5-year running mean (right axis) accentuates periodicity and intensity (amplitude). Temporal clustering into dry/moist epochs is indicated by the CuSum curve in (b) with dry periods highlighted in red.

Although amplitudes (severity) are variable, periodogram analysis of the 5-year running mean in Figure 6(a) suggests droughts and associated high temperature recur at intervals of between 15 and 20 years. As there is no statistically detectable change, claims by climate scientists that that droughts are becoming more frequent, more widespread or more intense due to anthropogenic warming is not substantiated by data.

4.2 Tmax trend and change

While due to missing observations data were unreliable from 1975 to 1981, then ceased until 1996, naïve linear regression suggests Tmax is increasing 0.12°C/decade, which is within the bandwidth of climate model predictions (Figure 7). However, as Tmax data are contributed by at least three sites, they are unlikely to be homogeneous. In addition, the original 230-lite Stevenson screen was probably replaced by a 60-litre screen at an unknown date. Manual observations ceased after thermometers were removed on 22 March 2001 and the site was fully automated. As BoM metadata is deficient of important detail, analysis is best undertaken using physically-based protocols and objective statistical methods.

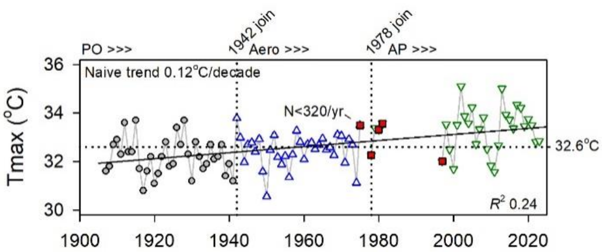

Figure 7. Naïve linear regression suggests Tmax is increasing at the rate of 0.12°C/decade. Red squares indicate <320 observations/yr.

Applying the methods outlined in Section 3.2, linear regression of the form Tmax ~ rainfall was highly significant (Figure 7(a), Table 1(i)). However, while trend is negative, only 39.1% of Tmax variation was explained. Thus, data quality is exceptionally poor, or explanatory variables are missing.

Ignoring years when N<320 observations/yr, step-change analysis of re-scaled Tmax ~ rainfall residuals found significant step-changes in 1916, 1942 and 1998 (Figure 7(b)), which from 1907

[1] Foley, J.C. 1957. *Droughts in Australia: Review of records from earliest years of settlement to 1955*. Bureau of Meteorology Bulletin 43. 281 pp, with appendices.

defined four data segments. As their relationship with rainfall was not significant, early data from 1907 to 1915 are unlikely to be reliable. For the remaining three segments, as rainfall explained between 45% and 67% of Tmax variation, data were of reasonable quality ((Figure 7(c) to (e), Table 1(iii)).

First-round multiple linear regression analysis found that the mean of data before 1916 was the same as from 1942 to 1998 (Table 1(iv)). Segments therefore combined into a single category. Second-round analysis (Table 1(v)) found category means (1907-1915 & 1942-1997, 1916-1941 and 1998-2023) were different (offset) and interaction was not significant, therefore responses to rainfall (the coefficients) were the same. The net effect was that site changes between 1907 and 2023 caused Tmax to step-up 0.95°C (±0.124$_{Sed}$) independently of the climate.

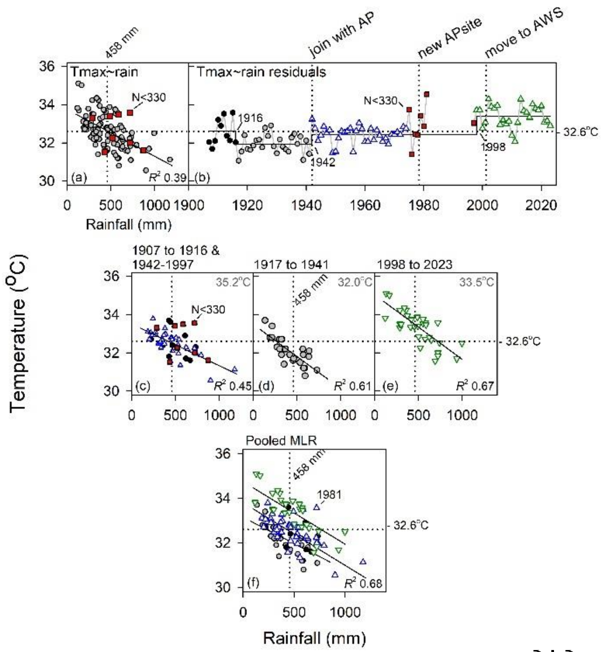

Figure 7. Composite analysis of Cloncurry Tmax.

The overall Tmax trend of 0.12°C/decade was spuriously caused by statistically significant up-steps that parsed the dataset into three non-trending segments (Table 1(vi)), with the first tranche of data (1907 to 1916) being the least reliable. As data are not homogeneous, naïve trend does not reflect the true climate. Furthermore, accounting site changes and rainfall simultaneously left no trend or change in multiple linear regression residuals that could be attributed to CO_2, coalmining, internal-combustion engines, electricity generation or anything else.

4.3 Post hoc evaluation

Scatter plots of observed data (on the vertical axis) verses values fitted (or predicted) by statistical models (on the x axis)[1] are one of the richest forms of data visualisation (https://stats.stackexchange.com/ questions/104622/what-does-an-actual-vs-fitted-graph-tell-us).

Should a model fully explain the data, fitted values would align with those observed along the diagonal 1:1 line. 'Spread' from the 1:1-line indicates lack of fit, skew away for the line and apparent bias, while outliers are dispersed peripherally around the data-cloud. The square of Pearson's linear correlation coefficient (r^2) would also be less for the poorer-fitting of alternative models (Figure 8).

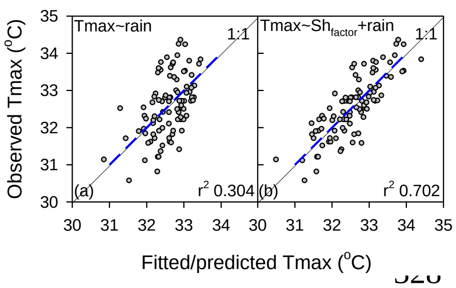

Figure 8. Scatterplots of observed data verses values predicted by respective models

Although, as expected, the least-squares line overlies the 1:1 reference, the naïve Tmax ~ rainfall relationship is a poorer fit (Figure 8(a)) than the 'full' Sh$_{factor}$ + rainfall model, where Sh$_{factor}$ adjusts for inhomogeneities in the data (Figure 8(b)). In addition, the reduction in the residual sum of squares between the naïve and 'full' model in Table 1, shows that the Sh$_{factor}$ variable accounts for 57.1% of variation not accounted for by rainfall alone (i.e., the (Sh)ift variable predominates).

[1] https://sci-hub.se/https://doi.org/10.1016/j.ecolmodel.2008.05.006

Table 1. Statistical summary. Sh_{res} refers to the $(Sh)ift_{factor}$ variable defining data segments, RSS refers to residual sum of squares and partial R-square ($R^2_{partial}$) estimates the proportion of variation explained by the $Sh(ift)_{factor}$ that is not explained by rainfall alone (calculated as: $[(RSS_{full} - RSS_{rain})/ RSS_{full})*100]$.

Model	Coef. (°C/100mm)	*P*	R^2_{adj}	Segment	Adj x̄ (±95% CI) (°C)[1]	RSS ($R^2_{partial}$)	Notes
(i) Tmax ~ rain (all)	-0.233	<0.001	0.266				
(ii) Tmax ~ rain (NoBad²)	-0.246	<0.001	0.296			51.56	
(iii) Tmax ~ rain[2] 1907-1915 1916-1941 1942-1997 1998-2023	 -0.135 -0.208 -0.335 -0.337	 0.433 <0.001 <0.001 <0.001	 ns 0.482 0.606 0.674				
(iv) Tmax ~ Sh_{res} + rain[2] Round 1	-0.280	<0.001	0.692	1907-1915 1916-1941 1942-1997 1998-2023	32.7[a] (0.32) 32.0[b] (0.19) 32.5[a] (0.17) 33.5[c] (0.19)		
(v) Tmax ~ Sh_{res} + rain[2] Round 2	-0.280	<0.001	0.692	1907-1915 & 1942-1997 1916-1941 1998-2023 Delta($_{1 vs 2}$) Delta($_{2 vs 3}$) Delta($_{1 vs 3}$)	 32.5[a] (0.14) 32.0[b] (0.19) 33.5[c] (0.19) -0.55 (0.24) 1.49 (0.27) 0.95 (0.24)	 22.10 (57.1%)	*Combine 1907-1915 and 1942-1997.* Interaction Tmax ~ Sh_{res} * rain *P* = 0.071 (ns)
(vi) Tmax ~ Year[2] 1907-2023 1907-1915 & 1942-1997 1916-1941 1998-2023	(°C/decade) 0.124 0.002 0.011 0.010	 <0.001 0.653 0.529 0.682	 0.242 ns ns ns				

[1]Adj x̄ refers to rainfall-adjusted values; letters in parenthesis indicate differences between means;
[2] Data where N>330 observations/yr

There remains the problem of attributing step-changes in data in 1916, 1942 and 1998 to site changes. Little is known of conditions affecting observations made in the post office yard, except that according to Torok a new Stevenson screen was supplied in 1908 and that the screen was moved "for convenience" in 1944, probably out of the way of the 1932 carrier-wave building. As an oblique 1940s aerial photograph showed the yard occupied by buildings and tall trees, shade and watering probably affected data prior to the site moving to the airport in 1942. However, coordinates of the Aeradio site were not the same as those reported in site summary metadata. Data quality also declined considerably after the Aeradio/Flight Services office closed, with no useful data from 1975 to 1998.

It seems that observations at the airport recommenced in 1998 but the position of the site at that time is unclear. Also, by that time the BoM had already switched to 60-litre Stevenson screens in place of the larger one shown in Figure 4. The up-step in the data in 1998, which preceded the move to the current AWS site, is therefore probably due deploying a smaller screen that is more sensitive to transient bursts of warm air than the former 230-litre one.

5. Discussion

Consistent with the First Law of Thermodynamics, Tmax depends on rainfall such that the drier it is the hotter it gets. As rainfall is episodic (occurs in episodes of wet and dry years), and stochastic (unpredictable in timing and amount), removing its effect ensures changes detected by STARS are not attributable to sustained changes in the weather including enduring drought (Figure 6). Furthermore, as the variance of $Tmax_{raw}$ is 0.78°C^2 verses 0.56°C^2 for Tmax ~ rainfall residuals, increasing the signal-to-noise ratio by removing the rainfall effect improves the likelihood of detecting smaller changes than otherwise would be the case. With variance due to rainfall removed, STARS may detect decadal-scale changes (step-changes) as small as 0.3°C, which is similar to the confidence interval around individual observations and the level of changepoint sensitivity claimed by ACORN-SAT.

Regardless of whether they are calculated as anomalies relative to 1961 to 1990 means, first-differences or as mean-centred values, it is essential that non-climate effects are identified and corrected before comparator datasets are used to homogenise data for other sites. It is also imperative that changepoint detection methods are transparent, straightforward and objective, and unable to be 'fiddled' with an outcome in-mind.

ACORN-SAT homogenisation methods provide no assurance that comparator data are fit-for-purpose or that comparator datasets are homogeneous. Compounded by selecting them on the basis that first-differences are significantly correlated with data they are used to adjust, comparator-data are likely to embed similar faults to those of the target. For instance, changes in Cloncurry Tmax in 1916, 1942 and 1998 (Figure 7(b), Table 1(v)) must ultimately contribute to adjustments made to the 12 ACORN-SAT datasets that Cloncurry data were used to correct. Selecting comparators on the basis of inter-site correlations also undermines the reasoning by Blair Trewin that "*the use of multiple reference stations provides a high level of robustness against undetected inhomogeneities at individual reference stations*"[1], which could only be the case if comparators were selected randomly without bias. Inter-site correlation is unscientific and an obvious data-hack.

Moreover, adjusting ACORN-SAT using 10 from a pool of 40 correlated comparators ensures that no homogenised datasets are strictly independent of each other, or independent of the other sites used in their adjustment. Inter-site comparisons involving ACORN-SAT, and/or comparisons between ACORN-SAT and the wider network, reinforces bias and undermines assurances that homogenised data reflect the true climate. It is also highly unlikely that trends and change calculated using ACORN-SAT data, would be markedly different from trend and change calculated using the AWAP network[2]. **Justified using circular statistical reasoning, BoM's homogenisation methods lack transparency, objectivity, statistical independence, and replicability, which are the hallmarks of the scientific method.**

The notion that faulty data could be used to detect and adjust faults in ACORN-SAT data lacks statistical merit and is fundamentally unscientific. For the professional reputation of all involved including those who rely on homogenised (or AWAP) data to calibrate models, the ACORN-SAT project is deeply flawed and should be abandoned.

6. Conclusions

Tmax data for the Cloncurry post office, and sites at the airport (the original Aeradio site, another site after observations re-commenced in December 1978 and by the AWS, commissioned on 22 March 2001) were analysed using BomWatch protocols to assess trend and change. Tmax data

[1] Trewin, Blair (2018). *The Australian Climate Observations Network – Surface Air Temperature (ACORN-SAT), Version 2,* p. 12 (BRR-032.pdf (bom.gov.au)).

[2] AWAP: Australian Water Availability Program dataset used by Trewin (2018) to compare trends in ACORN-SAT with trends calculated for the wider network (See Section 7, in the abovementioned Trewin Version 2 report).

for Cloncurry were used to adjust 11 surrounding ACORN-SAT sites including Tennant Creek (669km to the west), Victoria River Downs (1,109km NW) and St George (1,153km SE).

Rainfall-domain analysis preserved inhomogeneities in Tmax ~ rainfall residuals, which, adjusting for autocorrelation, were detected by a t-test of differences in the mean of sequential data. Between 1907 and 2023, step-changes in 1916, 1942, and 1998 defined four data segments. Assessed separately for significances, slope coefficients and goodness of fit (R^2_{adj}), except for data from 1907 to 1915, segmented-Tmax satisfactory reflected local weather (P_{slope}<0.05; R^2_{adj} >0.50).

As segment means were the same, data for 1907-1915 and 1942-1997 were combined into a single category. Final-round, categorical multiple linear regression confirmed rainfall-adjusted segment means were different (individual relationships were not coincident) and that as category by rainfall interaction was not significant, response to rainfall was the same (slope coefficients were homogeneous). Subsidiary analysis confirmed that data consisted of non-trending segments disrupted by discontinuities that were unrelated to the climate.

In net terms, between 1907 and 2023, site changes caused Tmax to step-up 0.95°C (±0.24°C). Furthermore, accounting for site changes and rainfall simultaneously left no trend or change in multiple linear regression residuals that could be attributed to CO_2, coalmining, internal-combustion engines, electricity generation or anything else.

Homogenisation methods used by the Bureau are biased by using comparator data that are not homogeneous to detect and adjust inhomogeneities in target site data. The failure to provide accurate metadata (or to scan and provide station files online); to objectively investigate soundness of comparator datasets; and selecting comparators on the basis of first-differenced inter-site correlation with the ACORN-SAT dataset they aim to adjust lacks objectivity, and has no scientific or statistical merit.

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DataPack: CloncurryData.xls

Disclaimer

Unethical scientific practices including homogenising 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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