Climate of the Great Barrier Reef, Queensland

Part 1. Climate change at Gladstone - a case-study

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Summary

- Data for Gladstone Radar in Queensland was used to case study an objective method of analysing trend and changes in temperature since 1958. The three-stage approach combines step-change and covariance analysis to resolve site-change and covariate effects simultaneously, and is applicable across the Australian Bureau of Meteorology's climate-monitoring network.
- Accounting for site and instrument changes leaves no residual trend or change in Gladstone's climate.

1. Introduction and background

In this age of fake-news it is vital to use transparent, objective and unbiased methods to detect trends and changes in the climate. It is essential that:

- The approach is physically based, statistically sound and robust.

  Provided the process is underpinned by accepted physical principles, alignment with those principles provides a measure of soundness of the data.

- Methods are robust and replicable.

  Robust methods ensure reanalysis of the same or similar datasets results in comparable outcomes, while inbuilt checks ensure integrity of the approach.

- Study of particular datasets is not influenced by prior knowledge; neither can analysis be gamed to achieve pre-determined outcomes.

  The approach is unbiased and outcomes are independently verifiable.

Part 1 of this series uses data for Gladstone Radar (Bureau ID 39326; 1958 to 2017) to case-study application of energy balance principles to analysing temperature (T) datasets for other sites including Cairns, Townsville and Rockhampton, which are ACORN-SAT[2] sites representative of the northern, central and southern sectors of the Great Barrier Reef and which contribute to calculating Australia's warming.

Located in Happy Valley Park within the city of Gladstone, approximately 500 km north of Brisbane, the site at Radar Hill Lookout (Latitude -3.8553, Longitude 151.2628) lies west of the city centre and port facilities. Daily data downloaded from the Bureau's climate data online facility were summarised into annual datasets (Appendix 1).

Site-summary metadata states that observations commenced in November 1957; a Fielden automatic weather station (AWS) was installed in 1991; the radar was upgraded in 1972 and 2004; the A-pan evaporimeter and manual thermometers were removed in 1993 (so manual observations ceased); a humidity probe installed in 1993 was replaced in 2002 and the temperature probe installed in 1991 was replaced in 2004. Aerial photographs (QAP5850056[3]

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[1] Dr. Bill Johnston's scientific interests include agronomy, soil science, hydrology and climatology. With colleagues, he undertook daily weather observations from 1971 to about 1980.

[2] http://www.bom.gov.au/climate/change/acorn-sat/documents/ACORN-SAT-Station-adjustment-summary.pdf

[3] Queensland aerial photographs (QAP) are accessible online at: https://qimagery.information.qld.gov.au/

(2002)) and Google Earth Pro satellite images show the met-office was demolished and replaced between 2003 and 2006 (Figure 1). Site diagrams show the Stevenson screen relocated between 2004 and 2005 but metadata does not mention when a 60-litre Stevenson screen replaced the former 230-litre one or when the current Almos AWS was commissioned. Missing data from when thermometers were removed in 1993 to 2000 showed out-of-range values were culled and that the AWS was probably replaced in late 2000.

The study aims to determine whether trajectory of the data reflect site and instruments changes or changes in the climate.

Figure 1. The Gladstone Radar met-office on 17 May 2003 (left; portion of QAP5850057) and 4 January 2006 (Google Earth Pro satellite image). The Stevenson screen and AWS cabinet visible in the satellite image near (x) was relocated from behind the office during the intervening period. Images are comparably scaled and aligned. Trees up to 6 m in height surround the cleared area. The site was reconfigured when the office was demolished in 2004.

2. The physical basis

2.1 Maximum temperature

Consistent with the First Law of thermodynamics, evaporation cools the local environment by removing energy as latent heat at the rate of 2.45 MJ/kg of water evaporated, which at dryland sites can't exceed the rainfall (± 5%; dewfall may not be measured for example, neither is runoff or drainage below the root zone).

As 1-mm rainfall = 1 kg/m^2, evaporation of Gladstone Radar median rainfall (841 mm) accounts for 2060 $MJ/m^2/yr$ of available net energy (the balance between incoming short-wave solar radiation and long-wave emissions), which is 27.6% of average solar exposure (7470 $MJ/m^2/yr$) as estimated since January 1990 using satellite and albedo data. Assuming that at annual timesteps cyclical gains and losses by the landscape (ground heat flux) cancel-out, the remaining portion not used for evaporation, is advected to the local atmosphere as sensible heat and is measured as maximum temperature (Tmax) by thermometers held 1.2 m above the ground in a Stevenson screen. Thus the First Law theorem predicts that dry years are warm and the drier it is the warmer it gets.

In the parlance of the statistical package R[1], for a consistent well maintained site, dependence of Tmax on rainfall (Tmax ~ rainfall) is likely to be statistically significant (P_{reg} <0.05) and explain more than 50% of Tmax variation (R^2_{adj} >0.05). However, if site control is poor or

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[1] https://www.r-project.org/

observations are lackadaisical, significances and variation explained is less and in the extreme case that Tmax is random to rainfall, data don't reflect the weather and are not useful for tracking trends and changes in the climate. Thus in keeping with the First Law theorem, statistical significances of coefficients and variation explained objectively characterise data fitness.

2.2 Minimum temperature

Minimum temperature (Tmin), which occurs in the early morning usually around dawn, measures the balance between heat stored by the landscape the previous day and heat lost by long-wave radiation to space overnight. Although affected by cloudiness/humidity, which reduce emissions, and local factors such as inversions and cool-air drainage, a statistically significant dependent relationship is expected between Tmin and Tmax.

To summarise, while rainfall (which also proxies cloudiness) directly reduces Tmax via the water cycle (Figure 2(a)), rainfall's relationship with Tmin may not be significant (Figure 2(b)). In contrast, the relationship between Tmin and Tmax (sometimes expressed as the diurnal temperature range (DTR)) is expected to be linear and robust (i.e. significant (P_{reg} <0.05) with more than 50% of Tmin variation explained) (Figure 2(c)).

For both Tmax and Tmin, poor site control (local changes and inconsistencies including poor maintenance and nearby disturbances such as watering) and omitted variable bias (failing to account for a known systematic effect) are the two main factors affecting significance (P) and statistical precision (R^2_{adj}). In Figure 2, as rainfall explains just 7.2% of Tmax variation and Tmax explains only 37.7% of variation in Tmin, other factors are likely to impact on the naïve case. Covariate analysis aims to discover what those factors are and attribute their effect.

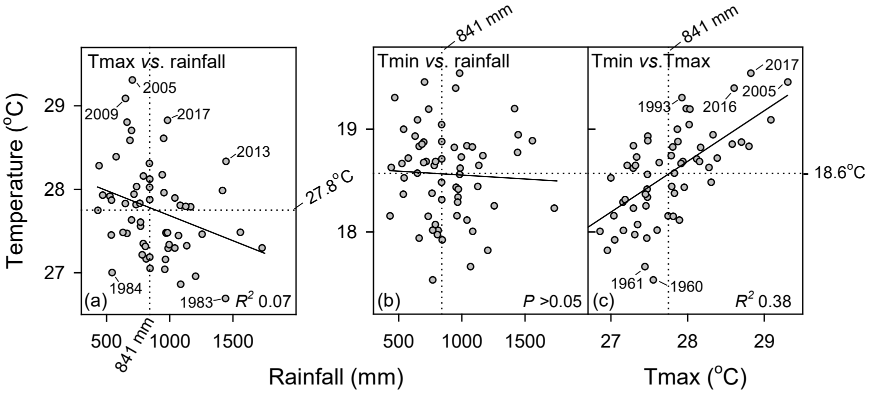

Figure 2. Naïve relationships between Tmax and Tmin and rainfall, and Tmin and Tmax. Median rainfall and average Tmax and Tmin are indicated by dotted lines. Values that appear to be out of range relative to that year's rainfall (or Tmax) are indicated. Tmin and rainfall are uncorrelated (P_{reg} >0.05).

3. Statistical methods

3.1 Overview

As site and instrument changes occur in parallel with observations, trend and change is confounded within the signal of interest. Stepwise analysis separates the confounded signals, tests for changes in residuals and verifies they are associated with site changes. The aim is to provide an unbiased explanation of the process, which is the evolution of temperature through time.

The 3-stage approach involves:

(i) Exploratory data analysis tests the significance (P_{reg}) and strength (R^2_{adj}) of relationships between Tmax, Tmin and rainfall, and Tmin and Tmax using naïve linear regression (Figure 2). However, only relationships that are statistically significant are of interest (Figure 2(a) and Figure 2(c)).

Linear regression partitions overall variation in temperature into that attributable to the covariate (deterministic variation represented by the straight lines in Figure 2) and the residual component, which although expected to be random, potentially embed site-change and other systematic effects.

(ii) Re-scaled for convenience by adding grand-mean T, randomness of residuals is evaluated using an objective statistical test of the hypothesis that mean-T is constant (i.e. that rescaled residuals are homogeneous).

Permanent step-changes or (Sh)ifts in re-scaled residuals indicate the background heat-ambience of the site or something related to the instrument changed independently of the covariate. Detected step-changes are cross-referenced where possible to metadata, historic site information and aerial photographs otherwise statistical inference is the only evidence that data are not homogeneous. (If residuals are random there are no inhomogeneities.)

(iii) Step-change analysis is verified using multiple linear regression of the T-covariate relationship with step-change scenarios specified as category variables (*viz.* T ~ $\mathrm{Sh}_{\mathrm{factor}}$ + covariate).

Possible outcomes are: (a), Sh_{factor} *means are the same and interaction*[1] *between* Sh_{factor} *and the covariate is not significant [segments are coincident, in which case they are indexed the same and reanalysed]; (b),* Sh_{factor} *means are different and interaction is not significant [segmented responses to the covariate is the same (i.e. lines are parallel)* and *the covariate-adjusted difference between segment means measures the 'true' magnitude of the discontinuity]; (c) interaction is significant [responses are not consistent;* Sh_{factor} *specification is irrelevant or changepoints are redundant (*Sh_{factor} *changepoints don't reflect the data)]; (d), T is random to the covariate [observations are not consistent, don't reflect the weather and can't reflect the climate].*

Multiple linear regression residuals (i.e. data minus significant $\mathrm{Sh}_{\mathrm{factors}}$ and covariate effects) are exported and examined for normality, equality of variance across categories, independence (autocorrelation) and serial clustering. Trend of individual segments is checked to assure the step-change model is appropriate.

3.2 Statistical tools

Sequential t-test analysis of regime shifts (STARS)[2] is used for step-change analysis of both raw-T and re-scaled residuals (https://www.beringclimate.noaa.gov/regimes/) and the *R* packages[3] *Rcmdr* and *lsmeans* are used for linear and multiple linear regression and to test differences between segment means holding the covariate constant (at its median (rainfall) or average (Tmax) level). Additional tests (normality, independence, clustering, Kruskall-Wallis (non-parametric) 1-way analysis of variance on ranks) etc. are performed using the statistical application PAST from the Natural History Museum, University of Oslo (https://folk.uio.no/ohammer/past/). As data and statistical tools are in the public domain analyses is fully replicable.

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[1] The R function *lm* is used to fit linear models (i.e. estimate coefficients from data and evaluate the overall model fit); Type II analysis of variance (*car* package) conducts hypothesis tests on coefficients; a separate test (of the form Tmax ~ $\mathrm{Sh}_{\mathrm{factor}}$ * covariate) evaluates equality of regression slopes while *lsmeans* tests differences between segment means controlling for the covariate.

[2] https://pdfs.semanticscholar.org/7746/6a6af18275339c2ef0bf4959e1c20b3b82cd.pdf

[3] https://www.rcommander.com/; https://cran.r-project.org/web/packages/lsmeans/lsmeans.pdf

3.3 Comparison of change scenarios

Multiple linear regression is used to compare $\mathrm{Sh}_{\mathrm{factor}}$ scenarios and whether documented site changes ($\mathrm{Sh}_{\mathrm{Site}}$) are significant or if other changepoints better fit the data. While all combinations are evaluated, the disciplined outcome is that segmented regressions are offset and parallel (Section 3.1 (iii (b)). It's possible for example, that the main site change was in 1991 when the AWS was installed; or in 1993, when manual observation ceased; or in 1993 **and** 2004 when the met-office was demolished (Figure 1). Alternatively, there was a Tmax step-change in 2004 and a Tmax rainfall-residual step-change in 2001 (which is not cross-referenced by available metadata; however, as the step-change aligns with cessation of removing out of range values, it is likely the AWS was replaced and a 60-litre Stevenson screen installed in place of the previous 230-litre one). Step-change scenarios that plausibly fit Tmax data are shown in Figure 3.

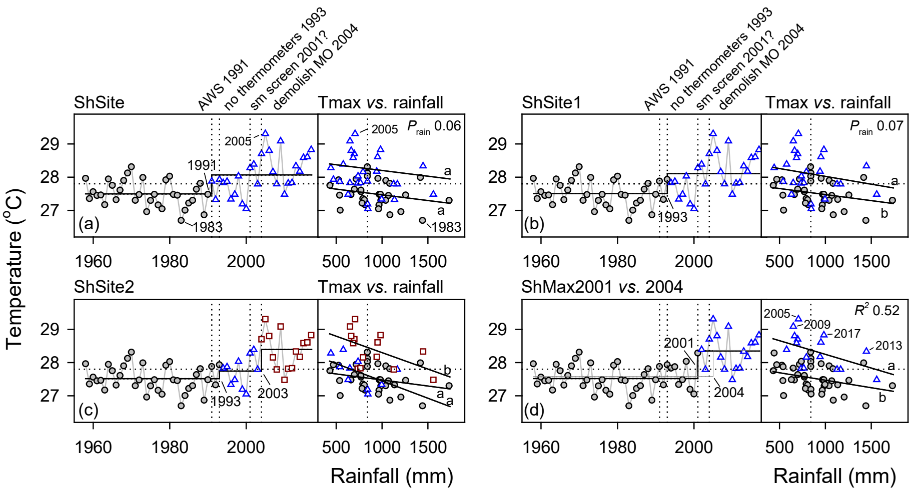

Figure 3. Horizontal lines plausibly explain persistent changes in Tmax. Except for the 2001 shift in (d), which was detected statistically using STARS; to illustrate possible scenarios, others were calculated manually. Multiple linear regression tests if Tmax is correlated with rainfall overall and if differences in median-rainfall adjusted means are the same (differences are indicated by letters beside each line). In all cases interaction was not significant, which confirms that free-fit lines were parallel.

The same site changes potentially affect Tmin. In addition, there is a shift in Tmin *vs*. Tmax-residuals in 1973, 1983 and 1999 (ShMinMaxRes) and first-round analysis found no difference in segment means from 1973 to 1982 and 1999 to 2017 (thus regressions were coincident). Another scenario results from combining those segments (ShMinMaxRes1). There is also a shift in raw-Tmin in 1979, which could reflect the weather or something else.

Analysis sets out to construct a design-overlay for an experiment whose data are available but 'treatments' and when they were applied are unknown. It is important the problem is approached without bias (i.e. all possibilities are considered) and that analysis is independent and statistically disciplined (i.e. that covariate coefficients are significant, adjusted segment means are different indicating lines are offset and interaction is not significant).

So the question is: which scenario best explains each dataset?

Scenario analyses are summarised in Table 1. For Tmax, the expected physical dependence of Tmax on rainfall is not significant (*P* >0.05) for scenarios (ii) and (iii), which indicates hypothesised step-changes are irrelevant (significance is reduced relative to (i), which is the base-case). Although the covariate is significant for scenario (iv) the hypothesised change in 1993 is not (rainfall adjusted segment means pre- and post-1993 (to 2003) are the same. Scenarios (v) and (vi) appear to be equivalent; however variation explained by Scenario (vi) is higher (51.7% *vs*. 43.4%), and the Akaike information criterion (AIC)[1] (which measures the relative quality of alternative models applied to the same dataset) is lower, indicating Scenario (vi) is the better (more parsimonious) fit. (AIC is not given where factors and or the covariate are not significant.)

Table 1. Multiple linear regression of Tmax and Tmin step-change scenarios. Non significance (ns) of the covariate indicates lack of agreement between the statistical model and the First Law theorem.

Tmax *vs*. rainfall	Change years$^{\text{Significance}}$	Covariate (P) (R^2_{adj})	AIC	Covariate coefficient
(i) Tmax ~Rainfall	na	0.02 (0.072)	100.43	-0.060°C/100 mm rainfall
(ii) ShSite	$1991^{P<0.001}$	0.055 (ns)		
(iii) ShSite1	$1993^{P<0.001}$	0.74 (ns)		
(iv) ShSite2	1993^{ns} & $2004^{P<0.001}$	0.003 (0.486)		
(v) ShMax	$2004^{P=0.001}$	0.003 (0.434)	71.70	-0.069°C/100 mm rainfall
(vi) ShMaxRes	$2001^{P<0.001}$	<0.001 (0.517)	**62.16**	-0.057°C/100 mm rainfall
Tmin *vs* Tmax				
Tmin ~ Tmax	na	<0.001 (0.377)	48.50	0.49°C$_{\text{min}}$/°C$_{\text{max}}$
(i) ShSite	$1991^{P<0.033}$	<0.001 (0.415)	45.70	0.39°C$_{\text{min}}$/°C$_{\text{max}}$
(ii) ShSite1	1993^{ns}	<0.001		0.40°C$_{\text{min}}$/°C$_{\text{max}}$
(iii) ShSite2	1993^{ns} & 2004^{ns}	<0.001		0.45°C$_{\text{min}}$/°C$_{\text{max}}$
(iv) ShMinMxRes	1973, 1983 & 1999	<0.001 (0.695)		0.59°C$_{\text{min}}$/°C$_{\text{max}}$; segment means 1973-82 and >1999 are the same.
(v) ShMinMxRes1	1973, 1983 & 1999	<0.001 (0.688)	**8.88**	0.54°C$_{\text{min}}$/°C$_{\text{max}}$; comb. 1973-82 & >1999
(vi) ShMinMxRes2	$1973^{P<0.001}$ & $1999^{P<0.018}$	<0.001 (0.661)	13.92	0.59°C$_{\text{min}}$/°C$_{\text{max}}$
(vii) ShMin	1979	<0.001 (0.547)	30.36	0.40°C$_{\text{min}}$/°C$_{\text{max}}$

There is no other way to cut-and-dice the data consistent with the requirements that covariate coefficients are significant and segmented regressions are parallel and offset by a difference that reflects response to the site-change. Furthermore, Scenario (vi) regression residuals are normally distributed, independent, and variance is the same across categories (residuals are homoscedastic). With those three assumptions satisfied, no additional systematic factors are influential on Tmax and there is no residual trend.

The step-change in 2001 (0.83°C median-rainfall adjusted) is responsible for the raw-Tmax trend (0.16°C/decade; P_{unc} <0.001) and as trend before and after the changepoint is not significant the step-change model best fits the data. Although when the met-office was demolished in 2004, year-to-year variability seemed to increase, suspected replacement of the AWS operating with a 60-litre screen in 2001 is the likely cause of the up-step.

First-round analysis found average-Tmin for the segment from 1973 (corresponding with metrication on 1 September 1992) to 1982 (Figure 4 (a)) was the same as from 1999 to 2017 (18.65°C (SE 0.080) *vs* 18.49 (0.065)). Although the slope of the first mentioned regression is

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[1] Burnham, K.P, Anderson, D.R and Huyvaert, K.P. 2011. AIC model selection and multimodel inference in behavioral ecology: some background, observations, and comparisons. Behav Ecol Sociobiol 65, 23-35. doi 10.1007/s00265-010-1029-6)

skewed higher by 1973 and 1980 data (Figure 4 (b); Table 1, Tmin Case (iv)) as they were coincident they combine into a single category (Table 1, Tmin Case (v)). Second-round analysis (Figure 4 (c)) shows regressions are parallel and offset; Tmin increases 0.59°C/°C$_{\mathrm{Tmax}}$ and with Tmax held at its long-term average (27.6°C) the cumulative Tmin difference from the start of the record is 0.28°C. Furthermore, multiple linear regression residuals and individual data segments in Figure 4 (a) are untrending. Although data for 1960, 1974, 1983 and 2010 are likely outliers (but not excluded), the overall raw-Tmin trend of 0.16°C/decade (P_{unc} <0.001) is spuriously due to site and instrument changes not the climate.

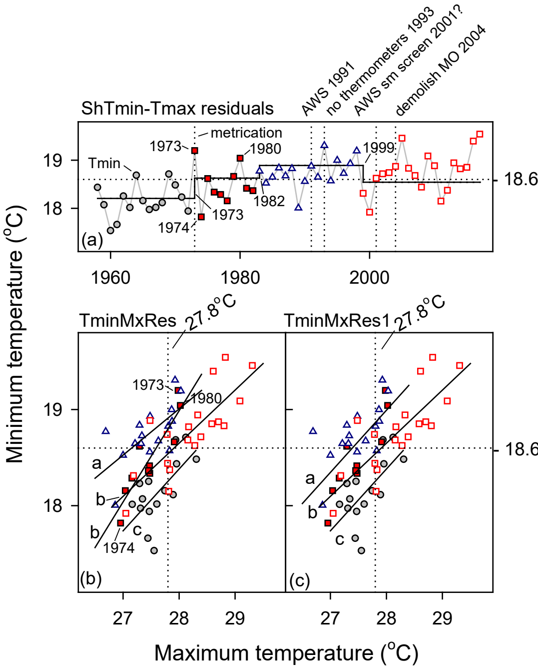

Figure 4. Step-changes in re-scaled Tmin-Tmax residuals detected by STARS were aligned with documented (and suspected) site and instrument changes *post hoc* (a). STARS is a blind test of the null hypothesis that the cumulative rescaled mean is unchanged. The Tmin upstep in 1973 corresponds with a possible movie out of the way of a new radar tower installed in May 1972 and also replacement of the Fahrenheit thermometers with Celsius ones from 1 September. The 1982 changepoint appears to correspond with clearing the yard between 1969 and 1992. Note that while (b) shows four free-fit regressions one for each segment in (a); mean-Tmin between 1973 (filled red squares) and 1982, and 1999 and 2018 (open red squares) was the same; segments were thus re-coded and re-analysed in (c).

4. Discussion

4.1 Metadata is incomplete and can't be trusted

Analysis of time-series presumes data are free of extraneous effects so that trend and changes reflect the climate alone. Aerial photographs show the area behind the met-office was cleared and extended between 1969 and 1992 (Figure 5) and that the visual profile of the office also changed. It is likely the Stevenson screen was moved out of the way when a 30-foot (10 m) radar tower was installed in May 1972, but aside from mentioning the radar, metadata listed no other changes. As some documented site changes don't affect data and others that do may not be documented a robust independent changepoint detection method combined with *post hoc* research is an essential first step in assessing the fitness of temperature data for depicting trends and changes in the climate.

4.2 The statistical approach

The objective of the study was to outline a method for exploring trends and changes in Tmax and Tmin data, in sufficient detail that the approach is replicable and can be applied to other datasets. If multiple linear regression fully explains changes and trends in raw data, residuals are normally distributed, independent and variance is random. Analysing raw data in the time-domain (*vs*. the covariate-domain) is made difficult by confounding of site-change effects with observations. Furthermore, it is necessary that the covariate is also accounted for so apparent temperature changes are not due to sustained shifts in the covariate attributable to, for example, the El Niño southern oscillation affecting rainfall. Multiple linear regression removes covariate and step-change signals simultaneously, which provides an unbiased assessment of the data-generating process.

4.3 Site and instrument changes

For a climate-warming (or cooling) argument to prevail it must be shown unequivocally that trend or change is not biased by changes at the site between 1969 and 1992 and 2003 and 2006; installation and upgrading of weather radars and changes to the AWS and Stevenson screens. If they are influential, such changes are detectable as a shift the ambient baseline against which daily-T is measured, cooler or warmer depending on the nature of the change. Removing the effect of causal covariates (rainfall and antecedent heat) exposes underlying shifts in the baseline, which are detected objectively as non-climate related discontinuities.

The process outlined in Section 3 disaggregates the total signal into the deterministic portion attributable to the covariate and that which is unexplained, including embedded inhomogeneties and other systematic signals such as cycles and trends. Detecting those objectively, re-entering them as categorical variables and evaluating their impacts using a rules-based framework makes use of all the data, improves precision and reduces the likelihood of not detecting trends and changes that exert a measurable impact on the processes generating the data. Comparing scenarios statistically and objectively leads to a single parsimonious outcome.

The abrupt Tmax step-change of 0.83°C in 2001, which is not rainfall-related is likely due to commissioning of the current Almos AWS operating with a 60-litre Stevenson screen in either 1999 or 2000. Likewise, since the start of the record in 1958, site changes in 1973, 1982 and 1999 caused Tmin to increase 0.28°C. Multiple linear regression assumptions are not violated so the process is fully explained and as there is no residual trend, cycles or inhomogeneties, there is no evidence that the climate has changed or warmed.

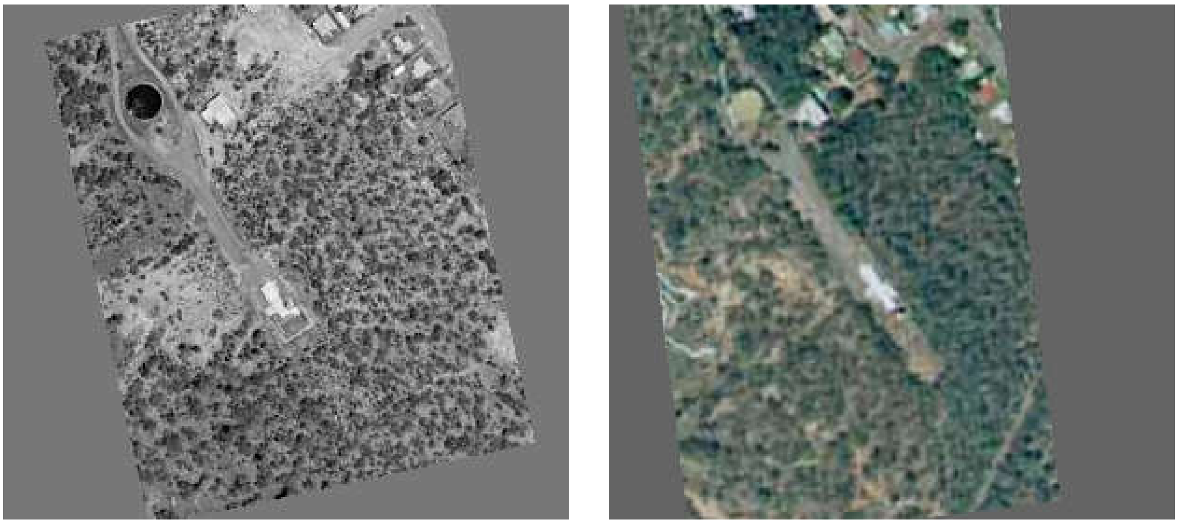

Figure 5. Aerial photographs show the met-office was enlarged and the area behind the building was cleared and extended between November 1969 (left) and January 1992 (zoomed and cropped portions of QAP204702 and QAP502722). WF44 radar was installed in on a lattice tower in May 1972 but other changes and when they occurred are not detailed in site-summary metadata. (Photos are aligned at about the same scale.)

5. Conclusions

Covariate analysis of temperature data is robust and rigorous and has been used to analyse >200 long and medium-term datasets from across Australia. The most prevalent problem is that poorly documented site and instrument changes result in spurious trends in naïvely-analysed data. Analysis with causal covariates (rainfall in the case of Tmax and Tmax in the case of Tmin) circumvents that observations are confounded with non-climate effects. Analysis in the covariate domain also sidesteps common problems inherent in direct time-series analysis such as incomplete data, outliers, data-fitness relative to statistical benchmarks and autocorrelation, unequal variance and non-normality of residuals. Time series analysis also provides no insights into the processes generating the data.

Sequential analysis is summarised thus:

(i) The strength of naïve relationships between temperature and covariates are assessed in the first instance and properties of residuals are evaluated graphically and statistically using appropriate tests.

(ii) With covariate effects removed, residuals are tested for inhomogeneties in the time domain. More than one scenario may be identified, which may or may not align with changes documented in metadata. Changepoints are specified using dummy or category variables added to the original dataset. Likewise for documented changes.

(iii) Multiple linear regression is used compare and contrast scenarios. There is only one outcome: with only significant factors included, individual regressions are offset (covariate adjusted differences are significant) and parallel (interaction is not significant thus slopes are homogeneous).

Post hoc testing examines residuals for unexplained systematic signals; data and residuals for data-segments identified in step (ii) are examined separately for trend, outliers etc. Site change effects are also verified using independent sources including aerial photographs and satellite images, historical newspapers etc., documents in archives and metadata.

As multiple linear regression residuals embed no trend, step-changes or other systematic signals it is concluded that the climate of Gladstone has not materially changed or warmed since records commenced in 1958.

Preferred citation:

Johnston, Bill 2020. Climate of the Great Barrier Reef, Queensland. Part 1. Climate change at Gladstone - a case-study. http://www.bomwatch.com.au/ 11 pp.

Appendix 1. Annual data for Gladstone Radar used in the study

Year	Rain	MaxAv	MaxN	MaxVar	MinAv	MinN	MinVar
1958	955	27.95699	365	13.64702	18.43315	365	14.20266
1959	791.4	27.34712	365	11.75717	18.06904	365	13.20006
1960	770.2	27.55492	366	16.10248	17.53115	366	17.32456
1961	1070	27.44396	364	11.74098	17.65962	364	12.58682
1962	1257.5	27.4589	365	13.10424	18.25123	365	12.67712
1963	813.8	27.16329	365	11.85804	18.01315	365	13.57444
1964	718.5	27.93962	366	15.13303	18.68333	366	14.25986
1965	432.5	27.74603	365	14.34441	18.15425	365	12.77963
1966	807.8	27.31315	365	14.60895	17.97123	365	13.33618
1967	770.2	27.60438	365	16.39004	18.01589	365	12.072
1968	1041.2	27.89399	366	18.59969	18.11284	366	16.82918
1969	842.3	28.12	365	17.63869	18.70904	365	13.81896
1970	839.6	28.3074	365	10.72481	18.4811	365	14.1467
1971	1731.6	27.29534	365	13.65023	18.22959	365	14.41786
1972	662.5	27.46913	366	10.93069	17.93798	366	12.80855
1973	1418.2	27.9825	360	11.98434	19.19917	360	11.11947
1974	1205.2	26.95562	365	11.69028	17.81918	365	15.9065
1975	988.2	27.29096	365	11.40945	18.61836	365	11.91315
1976	970.4	27.47705	366	14.2404	18.33579	366	16.77288
1977	967.2	27.15808	365	11.7586	18.2874	365	16.05319
1978	962.2	27.03945	365	17.0191	18.15589	365	16.65461
1979	527.2	27.91452	365	12.62559	18.66329	365	13.56524
1980	840.8	28.0224	366	12.3744	19.04235	366	13.49785
1981	972.8	27.47253	364	14.45781	18.41456	364	16.35712
1982	538.2	27.45068	365	13.98295	18.36548	365	16.63227
1983	1441.8	26.68904	365	12.33548	18.77151	365	13.80155
1984	544.2	27	366	12.79342	18.5235	366	13.71073
1985	782.6	27.21315	365	15.48466	18.64575	365	16.00133
1986	1040.4	27.29425	365	14.53477	18.83699	365	13.2569
1987	698.4	27.63014	365	14.19601	18.67288	365	14.45264
1988	1083.2	27.80656	366	13.74187	18.82541	366	11.40541
1989	1087.1	26.85918	365	15.57511	18.00411	365	17.03787
1990	983.8	27.47699	365	17.96167	18.55808	365	17.68596
1991	841.6	27.87342	365	9.507067	18.87753	365	13.8185
1992	1135.4	27.32131	366	15.3602	18.64563	366	15.9798
1993	469.6	27.92708	336	10.30538	19.30564	337	9.211248
1994	648.6	27.8274	354	11.85327	18.57017	352	13.22335
1995	539.6	27.86698	321	16.42016	18.99818	330	16.10863
1996	996	27.33528	360	14.34936	18.72674	359	14.56548
1997	630.2	27.48157	331	11.63199	18.93012	332	12.17776
1998	738.2	28.03015	335	14.69121	19.19304	345	14.5292
1999	842.6	27.18547	344	10.61658	18.31268	347	11.78666
2000	845.4	27.04944	360	11.49008	17.92033	364	12.61909
2001	442.2	28.28	360	11.6201	18.62527	364	13.31859
2002	577.2	28.38778	360	14.614	18.71644	365	14.1111
2003	1166.7	27.78788	363	9.807974	18.74093	364	11.1459
2004	698.2	28.70274	365	11.43675	18.87198	364	16.14428
2005	705.2	29.3074	365	15.64629	19.45726	365	14.4252
2006	663.4	28.80164	365	14.02203	18.83178	365	12.79717
2007	792.2	28.15644	365	17.56741	18.68301	365	16.12724
2008	1127	27.79342	365	14.17254	18.44027	365	15.56901
2009	650.4	29.08599	364	9.65647	19.08849	365	12.41602
2010	1559.6	27.48187	364	10.70165	18.88548	365	13.61729
2011	734.4	27.81397	365	13.7495	18.15014	365	16.94569
2012	764	27.8306	366	16.61281	18.37486	366	14.91668
2013	1446.4	28.33205	365	14.81114	18.94423	364	11.13608

2014	941.4	28.17088	364	12.137	18.82082	365	14.01753
2015	685.2	28.5843	363	12.7284	18.85234	363	14.2793
2016	951.6	28.60904	354	15.06949	19.39831	356	13.03081
2017	983.2	28.82473	364	10.41256	19.54278	360	12.27505