NIWA
Taihoro Nukurangi

Homogeneity of temperature and rainfall observations at Blenheim

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Prepared by:
S Stuart

For any information regarding this report please contact:

Stephen Stuart
Climate Scientist
Climate Variability
+64-4-386 0353
Stephen.Stuart@niwa.co.nz

National Institute of Water & Atmospheric Research Ltd
Private Bag 14901
Kilbirnie
Wellington 6241

Phone +64 4 386 0300

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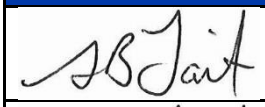
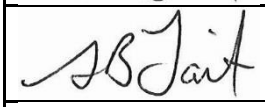
	Reviewed by:	Andrew Tait, Principal Scientist - Climate
	Formatting checked by:	Andrew Tait, Principal Scientist - Climate
	Approved for release by:	Brett Mullan, Principal Scientist - Climate

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Executive summary

Climate observations at Blenheim date back to the earlier part of the 20th century, with rainfall observations beginning in 1927 and temperature observations beginning in 1932. However, observations were performed at a number of different sites during this period. Changes in the location, exposure and instrumentation of an observing site can cause offsets in climatic data. This creates some uncertainty when analysing long-term trends in climate. Climate observations can be homogenised using statistical methods to enable more accurate analysis of long-term trends.

This report begins with a brief history of climate observations at Blenheim, which identifies the dates of site changes from station metadata. The homogeneity of temperature and rainfall observations at Blenheim is examined using statistical software, looking for potential discontinuities with reference to long-term observations at nearby climate stations. Temperature adjustments are derived to compensate for the estimated effects of site changes at Blenheim in 1979, 1985 and 1996. Rainfall is left unadjusted. Technical information is provided in the Appendix.

The analysis presented here is as accurate as possible given the nature of this project, which was funded by a small advice Envirolink Grant (MBIE contract number C01X1621). Future work could involve more detailed analysis of the homogeneity of neighbouring stations and Blenheim rainfall observations.

The following data from the National Climate Database has been provided to the Marlborough District Council to accompany this report:

- Daily maximum temperatures and daily minimum temperatures at Blenheim stations from March 1943 to December 2016, applied with homogeneity adjustments as described in Table 2.
- Unadjusted daily rainfall totals observed at Blenheim stations from March 1943 to December 2016.

1 Station history

Information about climate and rainfall observations at Blenheim was taken from Fouhy et al. (1992), Salinger (1981), NIWA archives (i.e., the "Orange Folder" for Blenheim G13592) and the NIWA Climate Database (CliDB, https://cliflo.niwa.co.nz). This information is summarised in Table 1. Rainfall observations began at Marlborough College (Site 1) in April 1927; records ceased here in July 1938. In May 1939, rainfall observations began at the Marlborough Catchment Board (Site 4). Climate observations, which include temperature, began at Site 2 (Blenheim, agent 4331) in April 1932 in the grounds of Wairau Hospital in Blenheim. Climate observations were moved a short distance in May 1942 to a large flat field on the west side of Maxwell Road extension (Site 3), opposite the hospital. Climate observations ceased here at the end of December 1946. In February 1947, climate observations began in the yard of the Marlborough Catchment Board in Nelson Street (Site 4).

Observations moved around 10-15 m (Val Wadsworth, personal communication) in mid-August 1979 to a yard on the southern fringe of a residential area (Site 5). A temporary climate site operated approximately 1 km away at Marlborough Research Centre (Blenheim Research, agent 4310, Site 6) during August and September of 1985, providing a 1-month overlap with Site 5. Observations began at Site 7 in early October 1985, 2 m from Site 6, and continued until May 1996.

Temperature and rainfall observations from the electronic weather station at Site 8 (Blenheim Research Ews, agent 12430) are archived in CliDB from June 1996 to the present. CliDB metadata state that Blenheim Research Ews "replaces G13494 [Site 7] at same location, some overlap exists", but no overlap at Sites 7 and 8 was found in the monthly or daily observations of temperature or rainfall in CliDB.

Due to the early site changes at Blenheim in 1942 and 1947, and uncertainty over the location of the January-February 1947 observations in CliDB[1], the composite temperature and rainfall series for Blenheim in this report begin in March 1947, using observations from Sites 4 to 8.

[1] CliDB contains monthly temperature values for Blenheim (agent 4331) in January and February 1947, but it is not clear which site contributed these values, as they are missing in the NIWA "orange folder" for Blenheim (network number G13592). It might be possible to determine the source site by examining additional archives such as the original daily meteorological returns for Blenheim.

Table 1: Information about temperature and rainfall observations at Blenheim. (Column 1) the site label used in the text; (Column 2) the site name, and (in parentheses) the 'agent number' and 'network number' used by the NIWA Climate Database (CliDB) to identify the station; (Column 3) additional remarks about the site location; (Columns 4 and 5) the periods of contribution of temperature and rainfall observations at this site to the data recorded under this agent number in CliDB.

Site Label	Site Name (Agent / Network No.)	Location	Period of contribution to Agent in CliDB	
			Temperature	Rainfall
Site 1	Blenheim (4331 / G13592)	Marlborough College	-	Apr 1927 to Jul 1938[2]
Site 2	Blenheim (4331 / G13592)	Wairau Hospital, in front of the old people's home	Apr 1932 to Apr 1942	-
Site 3	Blenheim (4331 / G13592)	A large flat field on west side of Maxwell Road extension.	May 1942 to Dec 1946	-
Site 4	Blenheim (4331 / G13592)	Marlborough Catchment Board, Nelson Street	Feb/Mar 1947 to 14 Aug 1979	May 1939 to 14 Aug 1979
Site 5	Blenheim (4331 / G13592)	Yard on southern fringe of a residential area.	15 Aug 1979 to Aug 1985	15 Aug 1979 to Aug 1985
Site 6	Blenheim Research (4310 / G13494)	Marlborough Research Centre, temporary site	Aug 1985 to Sep 1985	Aug 1985 to Sep 1985
Site 7	Blenheim Research (4310 / G13494)	Marlborough Research Centre, permanent site, located 2 m from temporary site	Oct 1985 to May 1996	Oct 1985 to May 1996
Site 8	Blenheim Research Ews (12430 / G13495)	Marlborough Research Centre, same location	Jun 1996 to present	Jun 1996 to present

2 Blenheim temperatures

It is common practice to adjust all the historical measurements to be consistent with the current open site (Aguilar et al., 2003). We will work backwards in time from the current open site, which is Blenheim Research Ews (agent 12430) at Site 8. The homogeneity adjustments to be applied to daily mean temperatures, daily maximum temperatures and daily minimum temperatures at Blenheim stations are shown in Table 2. The derivation of these adjustments is described in this section.

[2] Monthly rainfall totals during the period August 1938 to April 1939 are missing in the NIWA "orange folder" for Blenheim (network number G13592), but are present in CliDB for Blenheim (agent 4331) during this period. It is not clear which site contributed these CliDB values, but it might be possible to determine this by examining additional archives such as the original daily meteorological returns for Blenheim.

Table 2: Homogeneity adjustments to be applied to temperatures at Blenheim sites. Adjustments to daily minimum temperatures, daily mean temperatures and daily maximum temperatures are shown for each period of observation. Cumulative sums of adjustments are in the "Cumul. sum" columns; actual adjustments to be applied are in the "Adjust." columns.

Site Label	Site Name (Agent / Network No.)	Period	Temperature adjustment					
			Daily minimum		Daily mean		Daily maximum	
			Cumul. sum (°C)	Adjust. (°C)	Cumul. sum (°C)	Adjust. (°C)	Cumul. sum (°C)	Adjust. (°C)
Site 4	Blenheim (4331 / G13592)	Mar 1947 to 14 Aug 1979	0.36 +0.15 -0.35	0.16	0.22 -0.18 -0.06	-0.02	0.07 - 0.48 + 0.23	-0.18
Site 5	Blenheim (4331 / G13592)	15 Aug 1979 to Aug 1985	0.36 +0.15	0.51	0.22 -0.18	0.04	0.07 - 0.48	-0.41
Site 6/7	Blenheim Research (4310 / G13494)	Sep 1985 to May 1996	0.00 +0.36	0.36	0.00 + 0.22	0.22	0.00 + 0.07	0.07
Site 8	Blenheim Research Ews (12430 / G13495)	Jun 1996 to present	-	**0.00**	-	**0.00**	-	**0.00**

2.1 Statistical detection of temperature shifts

Statistical methods can be used to detect artificial shifts in climate series due to changes such as relocations of the observing instrumentation. One such method is the penalised maximal *t* test (PMT) (Wang et al., 2007; Wang, 2008), which searches for statistically significant shifts in the series mean before and after each value in a time series. However, such tests will sometimes detect shifts which cannot be traced to events documented in a station's history, and which may simply be due to natural variation rather than artificial changes. The results of such tests should therefore be interpreted with caution.

Here the PMT has been used within the RHtestsV4 software package (Wang and Feng, 2013) to analyse the homogeneity of monthly temperatures observed at Blenheim sites. The PMT was applied to a composite series constructed from unadjusted (i.e., "raw") monthly temperatures observed at Blenheim (agent 4331, April 1932 to August 1985), Blenheim Research (agent 4310, September 1985 to May 1996) and Blenheim Research Ews (agent 12430, June 1996 to December 2016).[3] Tests were performed separately on the raw monthly mean of the mean temperatures, maximum temperatures

[3] The nominal confidence level of the RHtestsV4 software was set to its default value of 95 % for all applications of the PMT in this report.

and minimum temperatures. Hereafter these 3 variables will be referred to as monthly mean temperature, monthly maximum temperature and monthly minimum temperature.

To investigate the effect of the 1996 site change, the PMT was applied to the raw composite Blenheim series using a reference series comprising averages of monthly temperatures at two highly correlated stations, Wellington Kelburn (agent 3385) and East Taratahi (agent 2612), during the period January 1982 to August 2005. These two comparison stations are located approximately 70 km and 150 km from Blenheim, respectively. The PMT detected shifts in April-May 1983, and February 1997 (Figure A-1), which are reasonably close in time to the documented site relocations in September 1985 and June 1996, thus providing some evidence for temperature shifts associated with these site changes. The RHtestsV4 software was then run again, this time prescribing the documented site change dates of September 1985 and June 1996. Slightly different temperature shifts were determined as shown in the lower half of Figure A-1.

To investigate the impact of earlier site changes, the PMT was again applied to the raw temperatures in the composite Blenheim series, this time using a reference series comprising averages of monthly temperatures at two long-term stations, Wellington Kelburn (agent 3385) and Appleby (agent 4239), each located around 70-80 km from Blenheim. This reference series begins in January 1932 and ends with the cessation of observations at Appleby in November 1996, which is relatively soon after the relocation from Blenheim Site 7 to Site 8 in June 1996. Any mean shift in temperature caused by the 1996 site change may therefore be more difficult to detect using this reference series.

Using this reference series, the PMT detected 4 shifts in both the monthly mean temperatures and the monthly minimum temperatures in the raw Blenheim composite series. These shifts were centred around March 1942, March-May 1947, January 1960-January 1961 and June-August 1983 (Figure A-2). Three of these shifts are reasonably close in time to the documented site relocations in May 1942, March 1947 and September 1985. With regard to the remaining shift detected in 1960-1961, the most relevant entry in the Blenheim station history appears to be the removal of the embankment near the Opawa River in February 1959, during the period of observations at Nelson Street (Site 4). However, in this report we will focus on documented relocations of the instrumentation. These results provide some evidence of temperature shifts associated with the documented site relocations in 1942, 1947 and 1985.

When applied to the monthly maximum temperatures in the raw Blenheim composite series, and again using the Kelburn/Appleby reference series, the PMT again detected 4 shifts (Figure A-2). The 1947 site change was not clearly detected this time, with the nearest changepoint being in March 1953. However, the detected shifts included an increase of 0.37 °C in June 1980. This is reasonably close to the documented site relocation in August 1979, and suggests there may also have been some temperature shift associated with this site change.

The RHtestsV4 software was then run again over the monthly temperatures, this time prescribing the documented site change dates of May 1942, March 1947, August 1979, September 1985 and June 1996. Slightly different temperature shifts were determined as shown in the lower half of Figure A-2.

The adjustments to be applied to the Blenheim temperatures were calculated with reference to a greater number of comparison stations, as described in the following sections.

2.2 Adjustment for site change in 1996

Observations moved from Blenheim Site 7 (Blenheim Research, agent 4310) to Site 8 (Blenheim Research Ews, agent 12430) at the same location in June 1996. To estimate the magnitude of the temperature shift associated with this site change, monthly temperatures at Sites 7 and 8 were compared to the 38 most highly correlated neighbouring stations in CliDB (Table A-1). With respect to these neighbouring stations, mean temperatures at Site 8 were on average 0.22 °C warmer than at Site 7, with daily maximum temperatures being 0.07 °C warmer, and daily minimum temperatures being 0.36 °C warmer. We therefore need to increase mean temperatures at Site 7 by 0.22 °C for consistency with the currently open site, Site 8. Similarly, we need to increase the daily maximum temperatures at Site 7 by 0.07 °C, and increase the daily minimum temperatures by 0.36 °C (Table 2).

2.3 Adjustment for site changes in 1985

In 1985, observations were relocated from near the Marlborough Catchment Board in Nelson Street (Site 5) to the Marlborough Research Centre (Sites 6 and 7) approximately 1 km away. The period of overlapping observations at Sites 5 and 6 is very short, and no overlapping observations were found in CliDB at Sites 6 and 7.[4] Therefore the temperature shift associated with the relocation to the Marlborough Research Centre in 1985 is here estimated via long-term comparisons to neighbouring stations. No estimate is made of the temperature difference between Sites 6 and 7, and these two sites will be here be treated as a single site.[5]

To estimate the magnitude of the 1985 temperature shift, monthly temperatures at Sites 5 and 6/7 were compared to the 40 most highly correlated neighbouring stations in CliDB. With respect to these neighbouring stations, mean temperatures at Site 6/7 were on average 0.18 °C cooler than at Site 5, with daily maximum temperatures being 0.48 °C cooler, and daily minimum temperatures being 0.15 °C warmer (Table A-2). To make temperatures at Site 5 consistent with the currently open Site 8, we need to apply a cumulative adjustment which also includes the adjustment already applied to Site 6/7. Thus the adjustment to mean temperatures at Site 5 is 0.22 - 0.18 = 0.04 °C. Similarly, the adjustment to daily maximum temperatures at Site 5 is 0.07 - 0.48 = -0.41 °C, and the adjustment to daily minimum temperatures is 0.36 + 0.15 = 0.51 °C (Table 2).

2.4 Adjustment for site change in 1979

To estimate the magnitude of the 1979 temperature shift, monthly temperatures at Sites 4 and 5 were compared to the 40 most highly correlated neighbouring stations in CliDB. With respect to these neighbouring stations, mean temperatures at Site 5 were on average 0.06 °C cooler than at Site 4, with daily maximum temperatures being 0.23 °C warmer, and daily minimum temperatures being 0.35 °C cooler (Table A-3). To make temperatures at Site 4 consistent with the currently open Site 8, we need to apply a cumulative adjustment which also includes the adjustments already applied to Sites 5 and 6/7. Thus the adjustment to mean temperatures at Site 4 is 0.22 - 0.18 - 0.06 = -0.02 °C. Similarly, the adjustment to daily maximum temperatures at Site 5 is 0.07 - 0.48 + 0.23 = -0.18 °C, and the adjustment to daily minimum temperatures is 0.36 + 0.15 - 0.35 = 0.16 °C (Table 2). Since the composite

[4] Observations from Sites 6 and 7 are both stored under the same agent number (4310) in CliDB, thus no overlapping observations were found in CliDB.

[5] During the 1-month overlap of August 1985, the monthly maximum temperature observed at the temporary Site 6 (Blenheim Research, agent 4310) was 0.6°C cooler than at Site 5. This is reasonably close to the -0.48 °C shift from Site 5 to the combined Site 6/7 as estimated via long-term comparisons to neighbouring stations. However, the monthly minimum temperature recorded in August 1985 at Site 6 is 1.1 °C warmer than at Site 5, which is substantially more than the +0.15 °C shift from Site 5 to the combined Site 6/7 as estimated via long-term comparisons to neighbouring stations. In the absence of overlapping observations at Sites 6 and 7, and given the very short period of observations at Site 6, we forego an estimate of the difference between Sites 6 and 7, and instead estimate the difference between Site 5 and the combined Site 6/7 via long-term comparisons to neighbouring stations.

temperature series constructed here begins with Site 4 in March 1947, this concludes the derivation of temperature adjustments for Blenheim.

3 Blenheim rainfall

To analyse the homogeneity of rainfall observations at the Blenheim sites, a composite series was constructed from monthly rainfall totals observed at Blenheim (agent 4331, April 1927 to August 1985), Blenheim Research (agent 4310, September 1985 to May 1996) and Blenheim Research Ews (agent 12430, June 1996 to December 2016). Natural logarithms were taken of these monthly rainfall totals, because the RHtestsV4 software assumes input data series have Gaussian errors (Wang and Feng, 2013). The PMT was applied to this series using a reference series comprising averages of log-transformed monthly rainfall totals at Wellington Kelburn (agent 3385) and Appleby (agent 4239). The PMT diagnosed no mean shifts in the monthly rainfall of the composite Blenheim series (Figure 1). In a separate application of the PMT, no mean shifts in Blenheim monthly rainfall were diagnosed with reference to observations at Waingawa near Masterton (Figure 2).

Figure 1: Log-transformed monthly rainfall totals: raw composite Blenheim series minus averages of Kelburn and Appleby. Log-transformed monthly rainfall totals from raw composite Blenheim series (Blenheim [agent 4331], Blenheim Research [agent 4310] and Blenheim Research Ews [agent 12430]), minus averages of log-transformed monthly rainfall totals at Wellington Kelburn (agent 3385) and Appleby (agent 4239), from January 1932 to November 1996 (black line). The mean difference between the Blenheim stations and the comparison stations is shown by the red line.

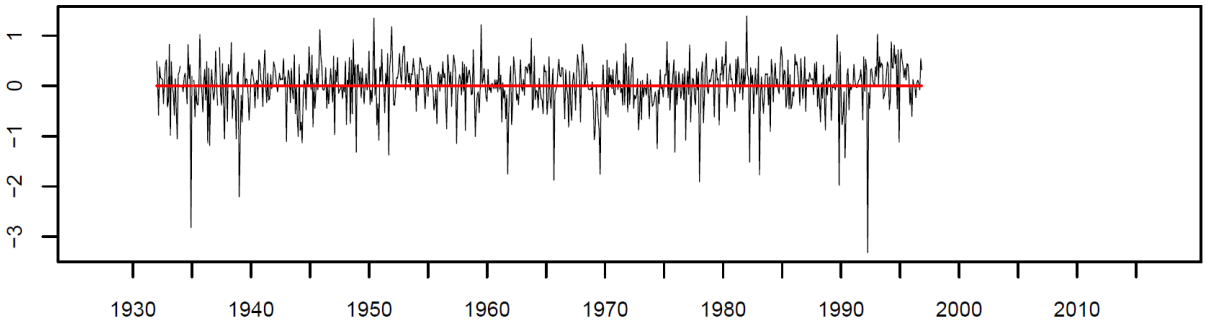
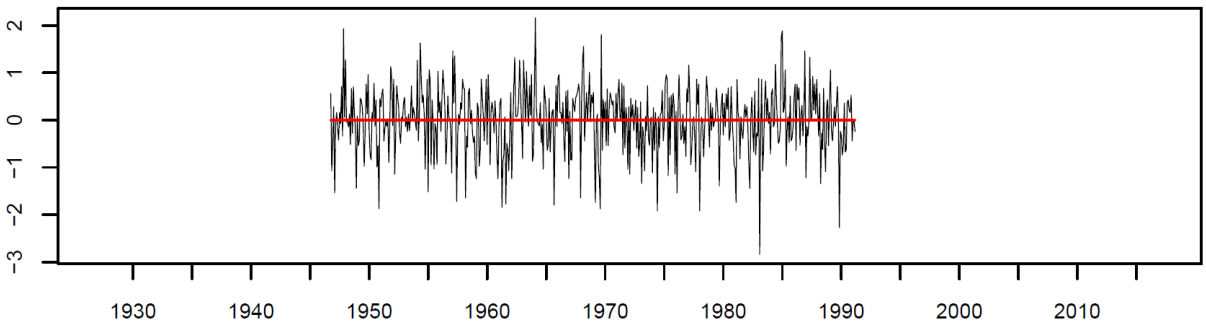


Figure 2: Log-transformed monthly rainfall totals: raw composite Blenheim series minus Waingawa. Log-transformed monthly rainfall totals from raw composite Blenheim series (Blenheim [agent 4331]], Blenheim Research [agent 4310] and Blenheim Research Ews [agent 12430]), minus log-transformed monthly rainfall totals at Waingawa (agent 2473) near Masterton, from October 1946 to March 1991 (black line). The mean difference between the Blenheim stations and Waingawa is shown by the red line.



To further analyse any potential impact of the 1985 site change, annual rainfall totals at Blenheim Sites 5 and 7 were compared to 4 neighbouring stations before and after the relocation of observations to the Marlborough Research Centre (Table 3).[6] With respect to 3 of these stations (Kelburn, Waingawa and Brancott Valley), Blenheim Site 7 was 2-5 % wetter than Site 5, while with respect to the remaining neighbouring station (Appleby), Blenheim Site 7 was 3 % drier than Site 5. None of these changes in rainfall ratios are statistically significant at the 95 % significance level.

Table 3: Changes in ratio of annual rainfall totals at Blenheim to 4 comparison stations, before and after the 1985 site change. Blenheim annual rainfall totals are from Site 5 (Blenheim, agent 4331) and Site 7 (Blenheim Research, agent 4310). Also shown are the number of years of comparison with each neighbouring station in the periods before (1980 to 1984) and after (1986 to 1995) the 1985 site change, and the statistical significance of the change in the rain ratio from Blenheim Site 5 to Site 7.

#	Neighbouring station	Agent number	Years comparison		Change in rain ratio	Statistical significance
			Before	After		
1	Wellington, Kelburn	3385	5	10	+0.05	0.185
2	Appleby	4239	5	10	-0.03	0.548
3	Waingawa	2473	5	5	+0.03	0.709
4	Brancott Valley	4325	3	8	+0.02	0.599

The evidence analysed here is deemed insufficient to diagnose a significant shift in rainfall resulting from the relocation of observations to the Marlborough Research Centre in 1985. Therefore no adjustment is here applied to the rainfall observed at the Blenheim sites to compensate for this site change.

[6] There is a 1-month overlap of rainfall totals at Blenheim (Site 5) and Blenheim Research (Site 6) in CliDB. In August 1985, Site 5 recorded 34.5 mm of rain, while Site 6 recorded 39.5 mm, which is a difference of 5 mm or +14 %. However, this is again a very short period of comparison, and no overlapping observations were found between Sites 6 and 7 in CliDB. Therefore the focus here is again on long-term comparisons with neighbouring stations.

4 References

Aguilar, E.; Auer, I.; Brunet, M.; Peterson, T.C.; Wieringa, J. (2003). WCDMP No. 53, WMD/TD No. 1186: *Guidelines on climate metadata and homogenization*. World Meteorological Organization, Geneva, Switzerland.

Fouhy, E.; Coutts, L.; McGann, R.; Collen, B.; Salinger, J. (1992). *South Pacific Historic Climate Network Climate Station Histories. Part 2: New Zealand and Offshore Islands.* NZ Meteorological Service, Wellington, ISBN 0-477-01583-2, 216p.

Salinger, M.J. (1981) *New Zealand Climate: The Instrumental Record.* PhD thesis. Victoria University of Wellington.

Wang, X.L.; Wen, Q.H.; Wu, Y. (2007) Penalized maximal *t* test for detecting undocumented mean change in climate data series. *Journal of Applied Meteorology and Climatology*, 46(6): 916-931.

Wang, X.L. (2008) Accounting for autocorrelation in detecting mean-shifts in climate data series using the penalized maximal *t* or *F* test. *Journal of Applied Meteorology and Climatology*, 47(9): 2423-2444.

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Appendix A Technical Information

Figure A-1: Monthly temperatures in raw composite Blenheim series minus averages of monthly temperatures at Kelburn (agent 3385) and East Taratahi (agent 2612) from January 1982 to August 2005. Variable names are shown in the "Var." column: monthly minimum temperature (Min.), monthly mean temperature (Mean) and monthly maximum temperature (Max.). Monthly temperature differences are shown by the black line in the plots. The mean temperature differences are shown by the red line, including mean shifts diagnosed by the penalised maximal *t* test. Also shown are the dates, magnitude (δ) and statistical significance (Sig.) of the mean shifts in temperature. A significance of 'YifD' indicates the shift is significant if the changepoint is supported by reliable metadata.

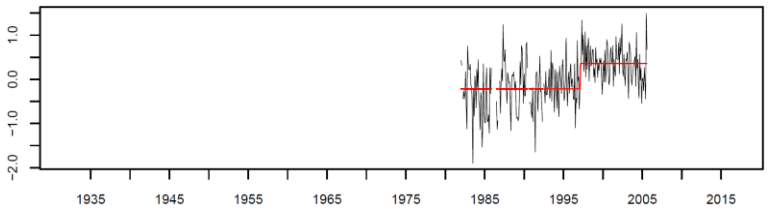
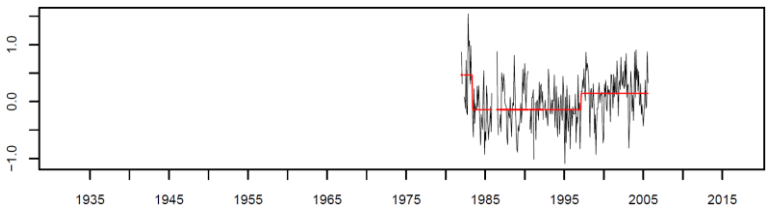
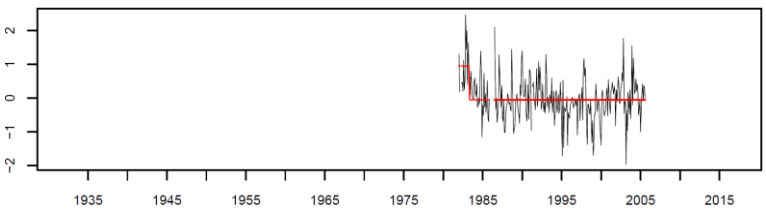
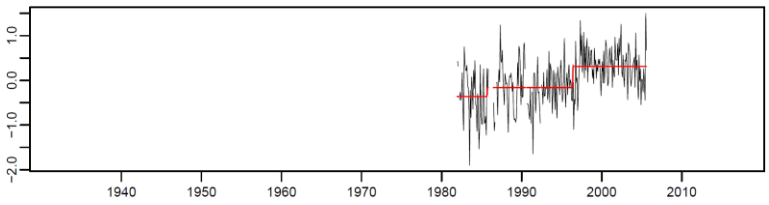
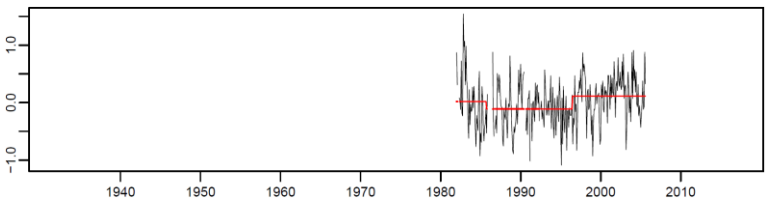
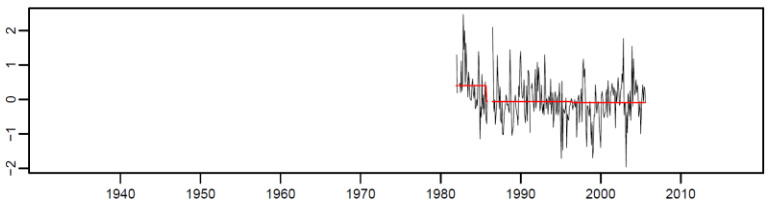
Var.	Temperature difference versus Time	Changepoints		
		Date	δ (°C)	Sig.
Min.		Detected:		
		Feb 1997	+0.57	Yes
Mean		Detected:		
		May 1983	-0.61	Yes
		Feb 1997	+0.29	Yes
Max.		Detected:		
		Apr 1983	-1.00	Yes
Min.		Prescribed:		
		Sep 1985	+0.20	YifD
		Jun 1996	+0.48	Yes
Mean		Prescribed:		
		Sep 1985	-0.13	YifD
		Jun 1996	+0.23	YifD
Max.		Prescribed:		
		Sep 1985	-0.46	YifD
		Jun 1996	-0.03	No

Figure A-2: Monthly temperatures in raw composite Blenheim series minus averages of monthly temperatures at Kelburn (agent 3385) and Appleby (agent 4239) from January 1932 to November 1996. Information presented in same format as in Figure A-1.

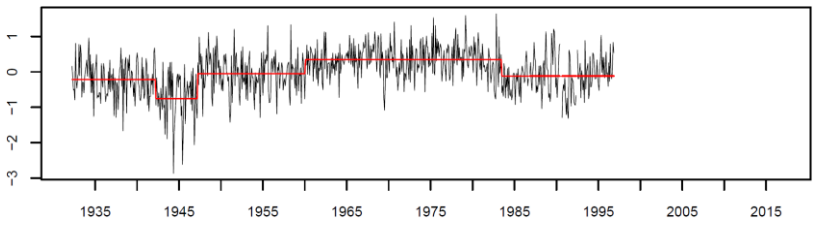
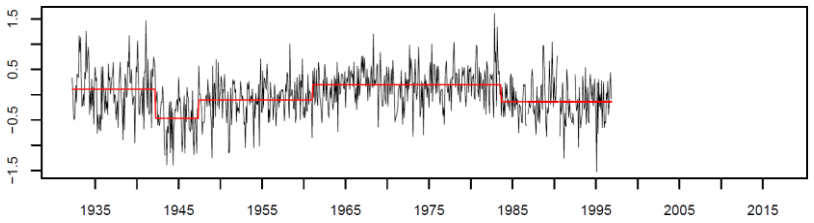
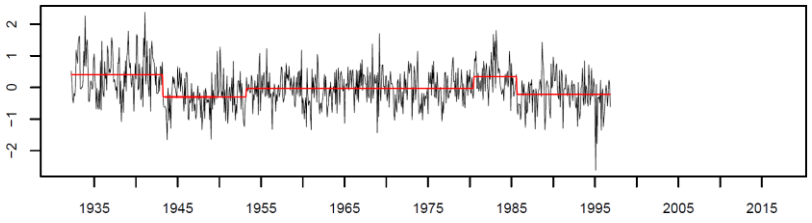
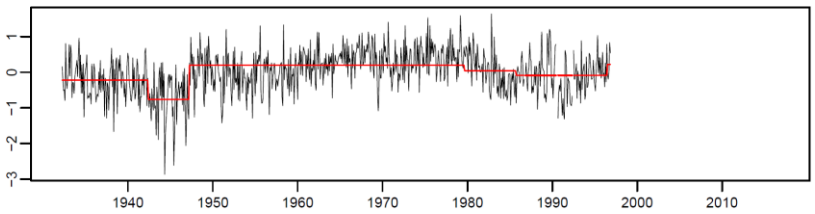
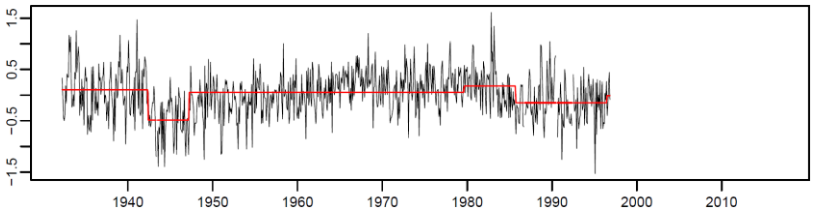
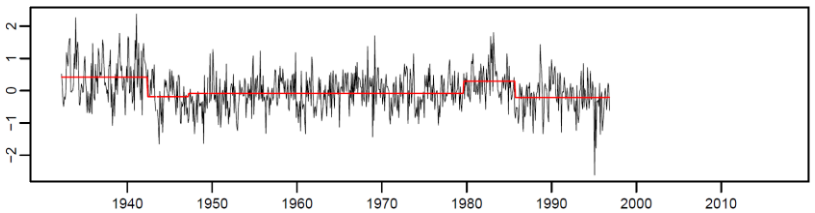
Var.	Temperature difference versus Time	Changepoints		
		Date	δ (°C)	Sig.
Min.		Detected:		
		Mar 1942	-0.54	Yes
		Mar 1947	+0.70	Yes
		Jan 1960	+0.40	Yes
		Jun 1983	-0.47	Yes
Mean		Detected:		
		Mar 1942	-0.58	Yes
		May 1947	+0.36	Yes
		Jan 1961	+0.30	Yes
		Aug 1983	-0.34	Yes
Max.		Detected:		
		Mar 1943	-0.71	Yes
		Mar 1953	+0.27	Yes
		Jun 1980	+0.37	Yes
		Aug 1985	-0.56	Yes
Min.		Prescribed:		
		May 1942	-0.54	Yes
		Mar 1947	+0.96	Yes
		Aug 1979	-0.16	YifD
		Sep 1985	-0.13	No
		Jun 1996	+0.31	No
Mean		Prescribed:		
		May 1942	-0.59	Yes
		Mar 1947	+0.54	Yes
		Aug 1979	+0.12	YifD
		Sep 1985	-0.33	Yes
		Jun 1996	+0.14	No
Max.		Prescribed:		
		May 1942	-0.60	Yes
		Mar 1947	+0.10	No
		Aug 1979	+0.38	Yes
		Sep 1985	-0.51	Yes
		Jun 1996	+0.01	No

Table A-1: Monthly mean temperature differences between Blenheim Sites 6/7 and 8 with respect to 38 automatically selected comparison stations. Positive/negative shift values indicate Blenheim Site 8 was warmer/cooler than Blenheim Site 6/7 after the site change in June 1996. Neighbour stations were automatically selected on the basis of highest correlations of first-differenced monthly anomalies with the Blenheim sites. Temperatures at the comparison stations were not checked for homogeneity, nor were their station histories examined for evidence of site changes. Missing monthly observations were not estimated and were simply omitted from the calculations.

Candidate: Blenheim 198509 raw CliDB (/-99)
Time of site change: June 1996. Period of comparison: June 1986 to May 2005.
Max. distance = NaN, min. overlap = 24 months, min. correlation = 0.700, max. ref. stations = 40.
DIST=km, MTHS=overlapping months, SHIFT=mean shift in monthly mean temperatures,
CORR=correlation of first-differenced monthly anomalies.

				Mean		Maximum		Minimum	
#	COMPARISON STATION	NETWRK/AGENT	DIST	MTHS	SHIFT	CORR	SHIFT	CORR	SHIFT	CORR
1.	Blenheim Aero Aws	G13585/ 4326	7.5	173	0.161	0.981	-0.060	0.974	0.389	0.973
2.	Grassmere Salt Work	G14711/ 4420	29.0	214	-0.359	0.943	-0.487	0.910	-0.244	0.911
3.	Castlepoint Aws	D06922/ 2592	201.0	219	1.019	0.930	1.263	0.835	0.804	0.916
4.	Wellington Aero	E14387/ 3445	74.1	209	0.235	0.923	0.217	0.837	0.261	0.868
5.	Kaikoura Aws	G23464/ 4506	103.4	167	0.376	0.918	0.509	0.869	0.229	0.878
6.	Masterton, Te Ore O	D05973/ 7578	159.3	150	0.128	0.915	-0.182	0.886	0.406	0.832
7.	Wellington, Kelburn	E14272/ 3385	72.4	224	0.166	0.909	0.012	0.783	0.332	0.891
8.	Martinborough, Huan	D15247/ 2651	130.7	153	0.003	0.903	-0.391	0.856	0.376	0.833
9.	East Taratahi Aws	D15064/ 2612	150.2	222	0.241	0.897	-0.088	0.845	0.569	0.824
10.	Kopua	D06022/ 2488	252.2	212	0.122	0.894	-0.037	0.839	0.266	0.788
11.	Culverden	H22783/ 4527	167.3	173	0.318	0.889	0.077	0.812	0.497	0.869
12.	Pelorus Sd, Crail B	G13195/ 4232	45.3	212	0.005	0.887	-0.254	0.799	0.276	0.881
13.	Waipara West	H32062/ 4794	203.6	177	0.291	0.886	0.035	0.863	0.486	0.831
14.	Christchurch Aero	H32451/ 4843	249.1	224	0.590	0.885	0.245	0.840	0.896	0.730
15.	Dannevirke	D06212/ 2534	232.1	219	0.104	0.884	0.023	0.806	0.174	0.807
16.	Akaroa,Rue Lavaud	H32893/ 4951	267.2	210	0.274	0.879	0.403	0.841	0.169	0.779
17.	Christchurch Garden	H32561/ 4858	249.8	224	0.397	0.875	0.152	0.821	0.601	0.769
18.	Mahia Aws	D97192/ 3142	431.8	165	0.121	0.875	0.222	0.735	0.007	0.878
19.	Wallaceville	E15102/ 3477	101.0	211	0.168	0.873	-0.120	0.718	0.451	0.828
20.	Pahiatua	D05484/ 7385	196.4	147	0.476	0.872	0.286	0.722	0.641	0.845
21.	Le Bons Bay Aws	H33712/ 4960	257.6	192	0.351	0.859	0.202	0.847	0.324	0.763

22. Nelson Aws	G13322/ 4271	65.7	158	0.049	0.859	-0.291	0.798	0.400	0.853
23. Wairoa, North Clyde	D97045/ 3126	404.0	152	0.235	0.855	-0.051	0.824	0.502	0.710
24. Nelson Aero	G13222/ 4241	65.3	221	-0.175	0.854	-0.274	0.797	-0.104	0.846
25. Lincoln, Broadfield	H32642/ 4882	264.9	151	0.094	0.852	0.006	0.814	0.174	0.733
26. Woodbury 2	H41025/ 7727	359.4	106	0.219	0.849	-0.029	0.829	0.459	0.764
27. Ashburton Council	H31971/ 4778	320.8	221	0.162	0.847	0.052	0.811	0.188	0.750
28. Napier Nelson Pk	D96591/ 2997	335.8	222	0.002	0.846	-0.198	0.771	0.203	0.795
29. Winchmore Ews	H31883/ 4764	309.2	224	0.269	0.845	-0.058	0.831	0.562	0.759
30. Darfield	H32412/ 4836	266.0	221	0.446	0.842	0.503	0.829	0.303	0.789
31. Palmerston North Aw	E05368/ 3243	191.9	162	0.200	0.836	0.102	0.703	0.300	0.834
32. Hicks Bay Aws	D78531/ 2692	576.5	166	0.289	0.820	0.314	0.700	0.249	0.805
33. Takaka, Kotinga 2	F02883/ 3789	119.3	214	-0.051	0.819	-0.286	0.812	0.182	0.787
34. Napier Aero Aws	D96484/ 2980	335.3	173	0.169	0.818	0.106	0.745	0.230	0.770
35. Peel Forest	H31927/ 4772	345.7	215	0.375	0.817	0.421	0.809	0.276	0.728
36. Motu Ews	B87256/ 1905	470.8	134	0.666	0.806	0.421	0.727	0.983	0.727
37. Timaru 2	H41424/ 5095	390.3	223	0.351	0.806	0.092	0.728	0.596	0.726
38. Waimana	B87103/ 1883	459.4	177	0.020	0.739	-0.044	0.712	0.105	0.718
MEAN SHIFT, ALL STATIONS				0.224		0.074		0.356	
MEDIAN SHIFT, ALL STATIONS				0.219		0.035		0.324	
MEAN OF MEDIAN(MAX) & MEDIAN(MIN)				0.179					

Table A-2: Monthly mean temperature differences between Blenheim Sites 5 and 6/7 with respect to 40 automatically selected comparison stations. Methodology same as in Table A-1.

Candidate: Blenheim 198509 raw CliDB (/-99)
Time of site change: September 1985. Period of comparison: August 1979 to August 1995.
Max. distance = NaN, min. overlap = 24 months, min. correlation = 0.700, max. ref. stations = 40.
DIST=km, MTHS=overlapping months, SHIFT=mean shift in monthly mean temperatures,
CORR=correlation of first-differenced monthly anomalies.

				Mean		Maximum		Minimum	
#	COMPARISON STATION	NETWRK/AGENT	DIST	MTHS	SHIFT	CORR	SHIFT	CORR	SHIFT	CORR
1.	Brancott Valley	G13584/ 4325	9.8	138	-0.387	0.967	-0.569	0.964	-0.155	0.931
2.	Grassmere Salt Work	G14711/ 4420	29.0	180	-0.387	0.935	-0.513	0.924	-0.274	0.861
3.	Tauherenikau	D15134/ 2623	127.1	168	-0.067	0.925	-0.222	0.862	0.086	0.801
4.	Waingawa	D05964/ 2473	150.9	133	-0.120	0.912	-0.603	0.859	0.376	0.823
5.	Ngaumu Forest	D15081/ 2614	170.0	140	-0.100	0.911	-0.389	0.847	0.206	0.791
6.	Castlepoint Light	D06921/ 2591	202.1	145	-0.251	0.901	-0.566	0.878	0.044	0.838
7.	Mohaka Forest	D97004/ 3115	376.3	118	-0.027	0.901	-0.284	0.843	0.239	0.847
8.	Porangahau 2	D06263/ 2544	265.4	175	0.277	0.887	-0.072	0.835	0.619	0.776
9.	Hanmer Forest	G22581/ 4458	144.6	177	-0.022	0.886	-0.515	0.821	0.498	0.803
10.	Waiorongomai	D15211/ 2639	103.7	168	-0.276	0.886	-0.577	0.806	0.021	0.777
11.	Makaretu Research S	D96931/ 3096	264.5	127	0.001	0.885	-0.438	0.840	0.463	0.775
12.	Totaranui 2	F03801/ 3799	110.6	105	-0.018	0.885	-0.410	0.861	0.423	0.876
13.	Normanby M.A.F.	E94526/ 3559	223.3	120	-0.196	0.884	-0.767	0.729	0.519	0.788
14.	Gwavas Forest	D96743/ 3039	288.7	103	-0.140	0.882	-0.839	0.850	0.554	0.778
15.	Esk Forest	D96272/ 2944	341.7	114	-0.168	0.882	-0.648	0.823	0.343	0.865
16.	Wellington, Kelburn	E14272/ 3385	72.4	189	-0.276	0.881	-0.503	0.780	-0.060	0.847
17.	Waipukurau Aero	D06051/ 2495	275.2	175	-0.225	0.879	-0.527	0.818	0.099	0.710
18.	Kaikoura Weather St	G23471/ 4507	103.4	142	-0.216	0.879	-0.412	0.859	-0.003	0.782
19.	Kaweka Forest	D96444/ 2970	313.9	145	-0.020	0.878	-0.611	0.798	0.609	0.828
20.	Balmoral Forest	H22871/ 4532	180.4	109	0.114	0.878	-0.436	0.858	0.639	0.783
21.	Lower Hutt,Gracefie	E14290/ 3418	86.3	117	-0.165	0.876	-0.506	0.742	0.172	0.836
22.	Kopua	D06022/ 2488	252.2	179	-0.344	0.875	-0.784	0.809	0.115	0.784
23.	Christchurch, Mt Pl	H32574/ 4871	250.0	170	-0.118	0.875	-0.097	0.863	-0.133	0.794
24.	Wellington Aero	E14387/ 3445	74.1	174	-0.299	0.872	-0.512	0.809	-0.105	0.787

25. Lincoln	H32641/ 4881	267.1	100	-0.312	0.871	-0.419	0.898	-0.178	0.744
26. Culverden	H22783/ 4527	167.3	104	-0.201	0.871	-0.799	0.810	0.441	0.845
27. Cheviot	H23822/ 4566	155.0	148	-0.176	0.869	-0.395	0.879	0.093	0.734
28. Wainuiomata Coast R	E14296/ 3424	86.8	165	-0.178	0.867	-0.438	0.730	0.041	0.778
29. Motueka, Riwaka	G12191/ 4162	94.2	184	-0.205	0.865	-0.666	0.828	0.264	0.827
30. Ashley Forest 1	H32252/ 4818	223.0	124	-0.278	0.865	-0.354	0.848	-0.186	0.806
31. Appleby	G13211/ 4239	75.5	189	-0.349	0.864	-0.491	0.805	-0.205	0.839
32. Mt Bruce Res	D05765/ 2414	166.5	137	-0.209	0.864	-0.264	0.746	-0.131	0.775
33. East Taratahi Aws	D15064/ 2612	150.2	151	-0.018	0.863	-0.342	0.810	0.297	0.769
34. Pelorus Sd, Crail B	G13195/ 4232	45.3	146	-0.236	0.863	-0.837	0.790	0.302	0.805
35. Dannevirke	D06212/ 2534	232.1	186	-0.032	0.860	-0.377	0.759	0.319	0.775
36. Rangiora Nzfs	H32352/ 4827	230.1	189	-0.206	0.858	-0.296	0.836	-0.076	0.729
37. Christchurch Garden	H32561/ 4858	249.8	187	-0.239	0.857	-0.254	0.823	-0.170	0.742
38. Nelson Aero	G13222/ 4241	65.3	186	-0.311	0.857	-0.469	0.819	-0.127	0.837
39. Hastings Aws	D96680/ 3017	320.2	91	-0.343	0.855	-0.823	0.833	0.201	0.752
40. Christchurch Aero	H32451/ 4843	249.1	189	-0.280	0.854	-0.307	0.829	-0.228	0.724
MEAN SHIFT, ALL STATIONS				-0.175		-0.483		0.149	
MEDIAN SHIFT, ALL STATIONS				-0.201		-0.469		0.115	
MEAN OF MEDIAN(MAX) & MEDIAN(MIN)				-0.177					

Table A-3: Monthly mean temperature differences between Blenheim Sites 4 and 5 with respect to 40 automatically selected comparison stations. Methodology same as in Table A-1.

Candidate: Blenheim 198509 raw CliDB (/-99)
Time of site change: August 1979. Period of comparison: August 1969 to August 1985.
Max. distance = NaN, min. overlap = 24 months, min. correlation = 0.700, max. ref. stations = 40.
DIST=km, MTHS=overlapping months, SHIFT=mean shift in monthly mean temperatures,
CORR=correlation of first-differenced monthly anomalies.

				Mean		Maximum		Minimum	
#	COMPARISON STATION	NETWRK/AGENT	DIST	MTHS	SHIFT	CORR	SHIFT	CORR	SHIFT	CORR
1.	Blenheim Aero	G13581/ 4322	6.9	192	-0.148	0.988	0.288	0.972	-0.591	0.984
2.	Vernon Lagoon	G14501/ 4411	7.0	174	-0.036	0.985	0.079	0.969	-0.155	0.982
3.	Blenheim,Wither Hil	G13595/ 4333	3.6	167	0.025	0.978	0.220	0.967	-0.187	0.966
4.	Grassmere Salt Work	G14711/ 4420	29.0	186	-0.227	0.956	-0.121	0.924	-0.341	0.917
5.	Cape Palliser	D15631/ 2689	112.2	151	-0.020	0.947	0.254	0.925	-0.265	0.886
6.	Waihopai Power Stn	G13651/ 4344	35.9	164	0.135	0.942	0.339	0.877	-0.039	0.930
7.	Tauherenikau	D15134/ 2623	127.1	191	-0.024	0.932	0.193	0.866	-0.263	0.868
8.	Waingawa	D05964/ 2473	150.9	192	-0.067	0.928	0.326	0.862	-0.471	0.880
9.	Gladstone, Arahura	D15163/ 2635	146.3	156	0.179	0.927	0.421	0.865	-0.063	0.881
10.	Ngaumu Forest	D15081/ 2614	170.0	185	-0.260	0.924	0.076	0.848	-0.596	0.841
11.	Lower Hutt,Taita	E14192/ 3366	92.1	159	0.021	0.923	0.252	0.782	-0.211	0.905
12.	Kopua	D06022/ 2488	252.2	190	-0.093	0.919	0.306	0.816	-0.522	0.875
13.	Lower Hutt,Gracefie	E14290/ 3418	86.3	191	-0.030	0.917	0.327	0.784	-0.410	0.880
14.	Wellington Aero	E14387/ 3445	74.1	193	-0.197	0.914	0.127	0.865	-0.548	0.864
15.	Mt Bruce Res	D05765/ 2414	166.5	175	-0.226	0.913	-0.273	0.769	-0.242	0.855
16.	Kaweka Forest	D96444/ 2970	313.9	192	-0.077	0.913	0.131	0.814	-0.317	0.892
17.	Gwavas Forest	D96743/ 3039	288.7	187	-0.181	0.913	0.017	0.840	-0.348	0.836
18.	Esk Forest	D96272/ 2944	341.7	183	-0.061	0.912	0.290	0.840	-0.488	0.895
19.	Dannevirke	D06212/ 2534	232.1	191	0.039	0.912	0.370	0.757	-0.310	0.871
20.	Cape Campbell	G14721/ 4423	36.2	183	-0.413	0.910	-0.214	0.880	-0.605	0.859
21.	Waiorongomai	D15211/ 2639	103.7	193	-0.060	0.908	0.345	0.804	-0.490	0.859
22.	Waiau, Clarence St	H23603/ 4554	147.9	111	-0.268	0.908	-0.137	0.901	-0.393	0.843
23.	Lower Hutt,Avalon	E14195/ 3369	89.9	183	0.004	0.905	0.418	0.738	-0.471	0.883
24.	Wellington, Kelburn	E14272/ 3385	72.4	193	-0.022	0.904	0.363	0.817	-0.407	0.898

25. Castlepoint Light	D06921/ 2591	202.1	156	-0.011	0.904	0.329	0.858	-0.342	0.890
26. Hanmer Forest	G22581/ 4458	144.6	190	-0.079	0.903	0.203	0.860	-0.398	0.881
27. Mohaka Forest	D97004/ 3115	376.3	183	-0.097	0.901	0.120	0.798	-0.351	0.878
28. Wainuiomata Coast R	E14296/ 3424	86.8	185	0.048	0.899	0.404	0.749	-0.333	0.865
29. Motueka, Riwaka	G12191/ 4162	94.2	193	0.134	0.899	0.430	0.803	-0.177	0.897
30. Woodville,Ballantra	D05383/ 2375	206.7	122	0.202	0.896	0.615	0.704	0.306	0.791
31. Wallaceville	E15102/ 3477	101.0	188	0.051	0.894	0.375	0.720	-0.245	0.853
32. Napier Nelson Pk	D96591/ 2997	335.8	188	-0.125	0.893	0.193	0.825	-0.461	0.853
33. Appleby	G13211/ 4239	75.5	193	0.075	0.892	0.354	0.765	-0.227	0.895
34. Kaikoura Weather St	G23471/ 4507	103.4	193	-0.376	0.891	-0.038	0.894	-0.746	0.834
35. Rai Valley	G13251/ 4250	44.1	179	-0.044	0.891	0.379	0.759	-0.504	0.895
36. Makaretu Research S	D96931/ 3096	264.5	184	-0.018	0.890	0.218	0.824	-0.287	0.825
37. Nelson Aero	G13222/ 4241	65.3	193	0.156	0.887	0.306	0.772	-0.015	0.896
38. Balmoral Forest	H22871/ 4532	180.4	186	-0.344	0.887	0.190	0.865	-0.864	0.830
39. Waikaremoana Onepot	D87811/ 2832	404.1	172	0.126	0.887	0.396	0.784	-0.140	0.895
40. Waipukurau Aero	D06051/ 2495	275.2	187	-0.068	0.884	0.222	0.801	-0.366	0.814
MEAN SHIFT, ALL STATIONS				-0.059		0.227		-0.347	
MEDIAN SHIFT, ALL STATIONS				-0.036		0.288		-0.342	
MEAN OF MEDIAN(MAX) & MEDIAN(MIN)				-0.027					