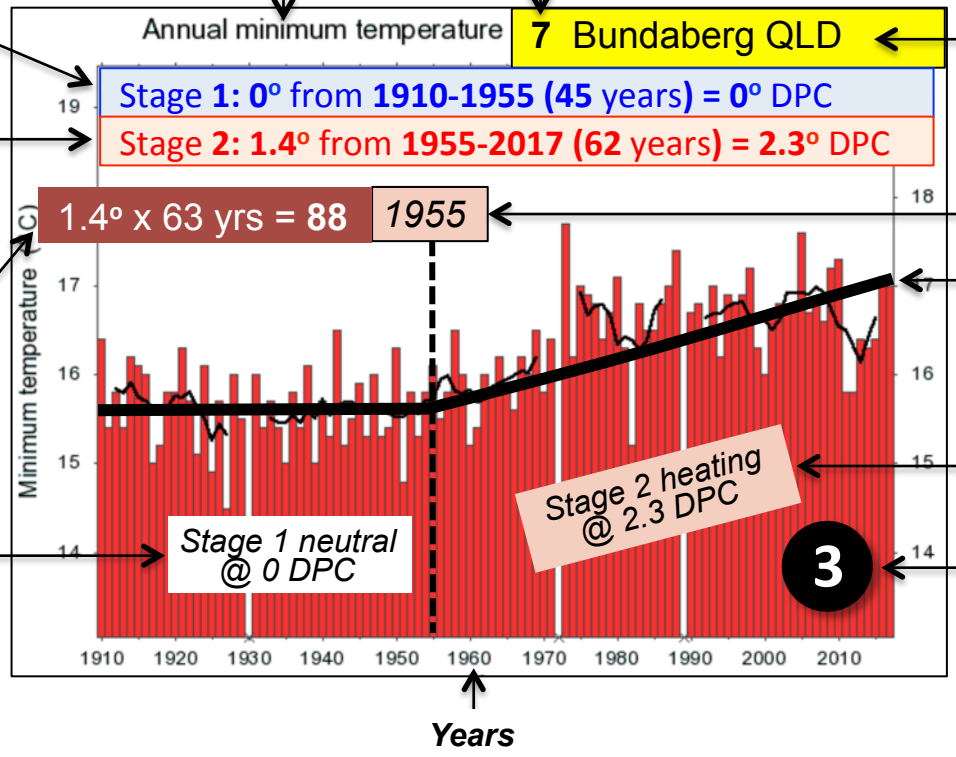
Laing Submission

APPENDIX 1
Analysis of BOM dataset: 109 stations

http://www.bom.gov.au/climate/change/index.shtml#tabs=Tracker&tracker=site-networks

Key to heating graphs



Stage 1 heating parameters: *ΔT, heating interval, heating years = heating rate*

Stage 2 heating parameters: *ΔT, heating interval, heating years = heating rate*

ΔHeat parameters: *ΔT x Heating period ΔY = ΔH NB ΔH ends at 2018; enddate may differ from data enddate used to calculate heating rate*

Stage 1 Heating rate

BOM weather station *predominantly ACORN-SAT database*

Stage 2 Startdate

Heating curve*, based on 2 linear stages*

Stage 2 Heating rate

Quality Index *includes fit of heating curve, Startdate*

Climate heating parameters

Temperature increase or decrease	***ΔT***	*degrees C*
Heating interval	***ΔY*** *= Ye - Ys*	*years (from startdate - to enddate)*
Heating years	***ΔY***	*years*
Heating rate	***R*** *= (ΔTx 100) / ΔY*	*degrees per century (DPC)*
Climate heating	***ΔH*** *= ΔT x ΔY*	*degree years*
Startdate	***Ys***	*date (year)*
Enddate - end of data (used in R)	*Yer*	*date (year)*
Enddate - selected date 2018 (used in ΔH)	*Yeh*	*date (year)*

These parameters apply to each heating stage 1 and 2. Where necessary the stage is indicated via a subscript 1 or 2.

Bold parameters are climate parameters; plain parameters are arbitrary metadata

Bureau of Meteorology: Description of data

http://www.bom.gov.au/climate/change/hqsites/about-hq-site-data.shtml

Background

Several observational datasets have been developed to identify, monitor and attribute variations and changes in the Australian climate. These datasets have been produced using a variety of quality control and homogenisation techniques to ensure they are comparable through time and free of spurious non-climate influences which might otherwise mask real trends.

Discontinuities (ie erroneous shifts) in climate data through time may be caused by changes in the location or exposure of the observation site, instrumentation type or observation practices. For example, prior to 1910 temperature measurements were often taken using non-standard temperature screens which gave different values to those taken in modern Stevenson Screens. For this reason temperature observations before this period are not currently included in Bureau datasets used for monitoring climate change.

Homogenisation of data allows discontinuities stemming from non-climate influences to be removed from the data before long-term changes are investigated. Procedures to identify non-climatic changes in historical climate data generally involve a combination of:

- investigating historical information (metadata) about the observations,
- using statistical tests to compare records from nearby locations, and
- using comparison data recorded simultaneously at old and new locations, or with old and new instrument types.

The Australian Climate Observations Reference Network – Surface Air Temperature (ACORN-SAT), monthly pan evaporation and monthly cloud amount datasets have been temporally homogenised. Rainfall data has not been homogenised in either the monthly or daily datasets; stations suspected of being affected by an inhomogeneity or data quality problem during their record were excluded from the dataset leaving a network composed of only the best and most reliable stations.

Scientific papers describing the homogenisation process have been published for each applicable dataset. This information and the datasets are available below.

Daily temperature: Data (ACORN-SAT versions 1 and 2) | Information and individual station data

These datasets underlie operational monitoring of Australia's changing climate.

Content of the site networks application

The site networks application provides access to homogeneous historical climate data for Australian observing sites. Climate variables available include temperature, rainfall, pan evaporation and cloud amount, at timescales ranging from daily data through to annual averages.

Climate data are provided in both graphical and numerical formats for individual station sites. Graphs can be viewed as either mean/absolute data or as anomalies from the standard.

Basic supporting information (metadata) about each site is given to help you choose the most appropriate location.

Bureau of Meteorology: Description of data

Site data temporal averaging methods

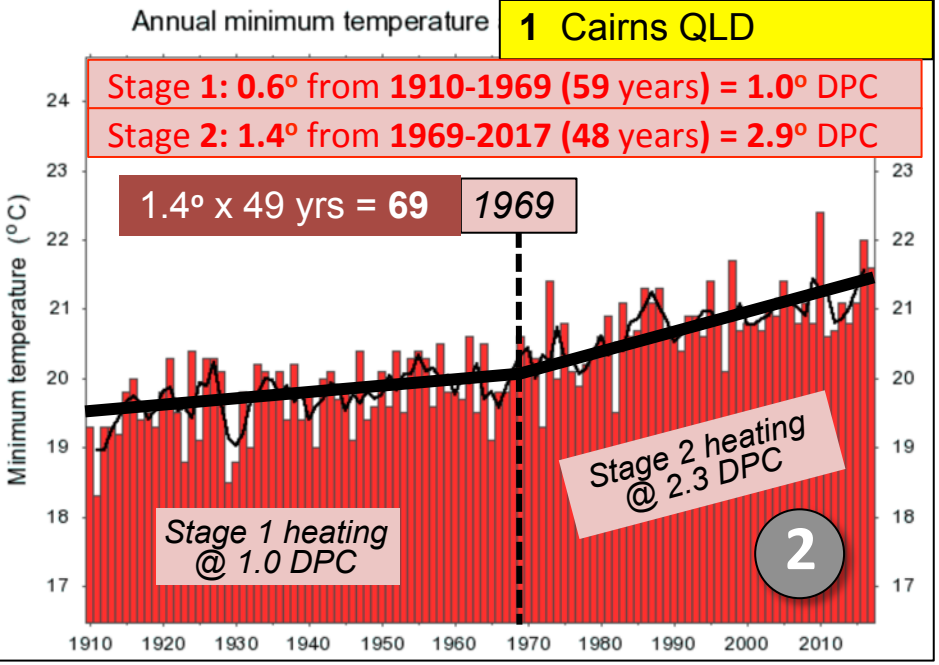
Temperature

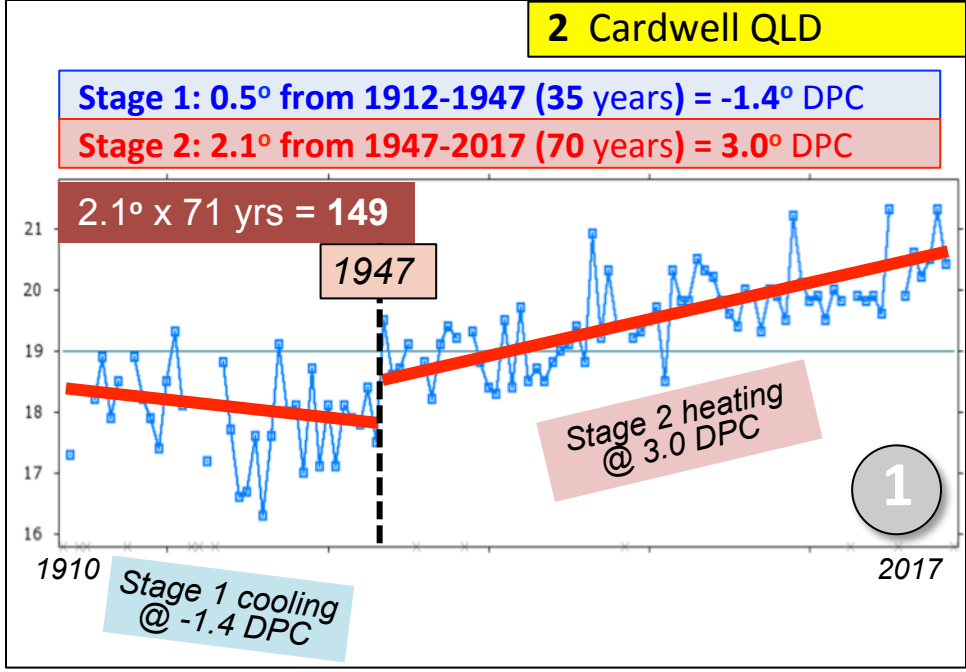
For maximum and minimum temperatures, monthly values are calculated from the average of the daily temperature data from the ACORN-SAT dataset. There should be no more than 15 days missing in any month for a monthly value to be reported. Annual (and seasonal) values are calculated from the simple average over the applicable months. If there are insufficient daily data that results in a missing month, then the annual value (and applicable seasonal value) for that year (and season) will also be marked as missing.

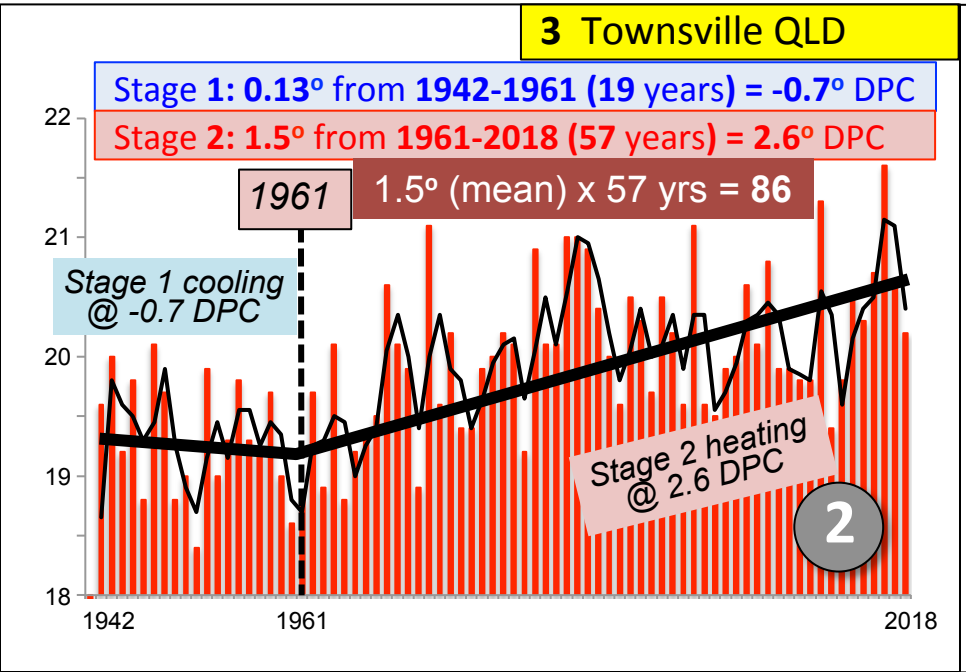
For mean temperature, the average of the maximum and minimum temperatures is used for the appropriate time period; e.g. the mean monthly temperature for a given month is (monthly maximum + monthly minimum)/2. Therefore the annual mean temperature for a given year is the average of the annual maximum and annual minimum temperatures. A similar calculation is used for seasonal, monthly and daily mean temperatures.

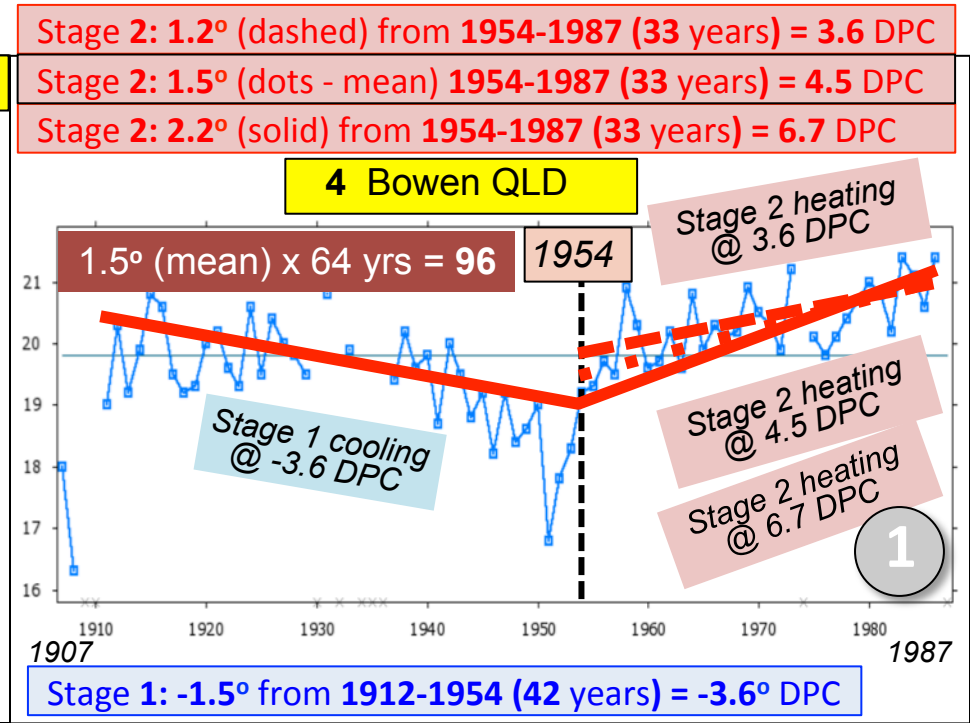
It is possible that a station with more than 15 days with missing daily mean temperatures in a month could still report a monthly mean temperature value. This could occur if each of maximum and minimum temperature are missing on 15 days or fewer, but there are more than 15 days on which at least one of the two is missing.

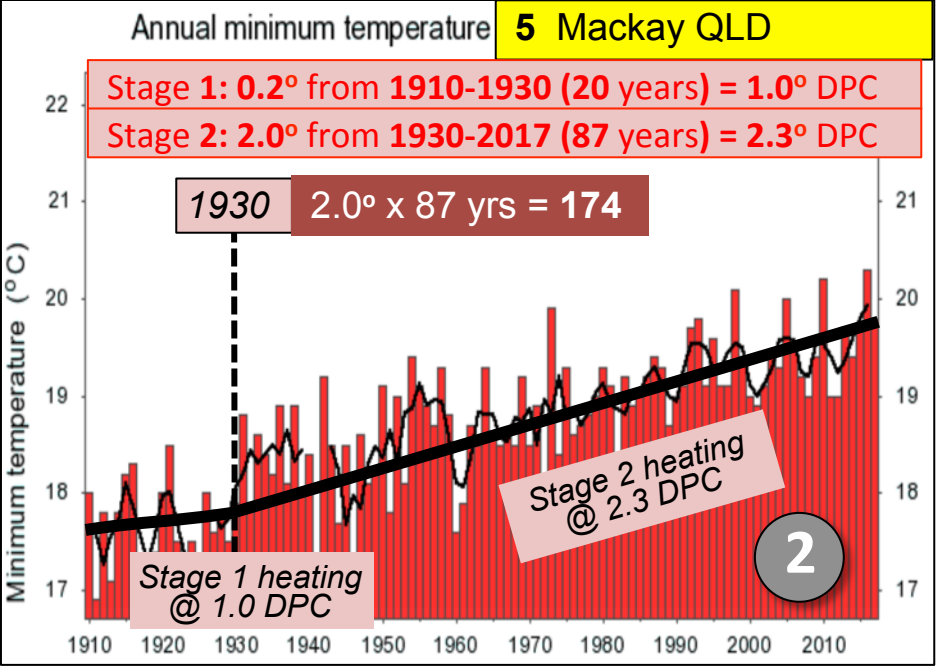
The anomaly data are calculated with respect to a 30-year climate normal (1961–1990) for the appropriate month, season or annual period. The daily anomaly data are calculated with respect to the corresponding monthly normal (e.g. each day in January is referenced to the January monthly average). The climate normal for a given month is the average of all individual monthly values for that month over the 1961–1990 reference period. The annual climate normal is the average of the 12 monthly climate normals. The seasonal climate normal is the average of the three applicable monthly climate normals.

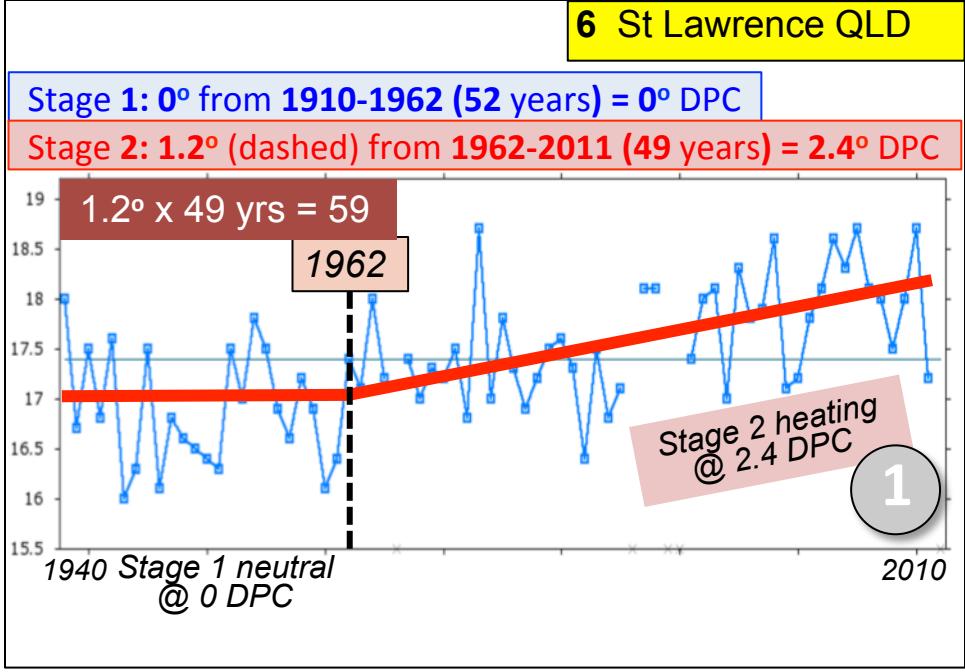

Annual minimum temperature
1 Cairns QLD
Stage 1: 0.6° from 1910-1969 (59 years) = 1.0° DPC
Stage 2: 1.4° from 1969-2017 (48 years) = 2.9° DPC
1.4° x 49 yrs = 69
1969
Minimum temperature (°C)
Stage 2 heating @ 2.3 DPC
Stage 1 heating @ 1.0 DPC
2
1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010

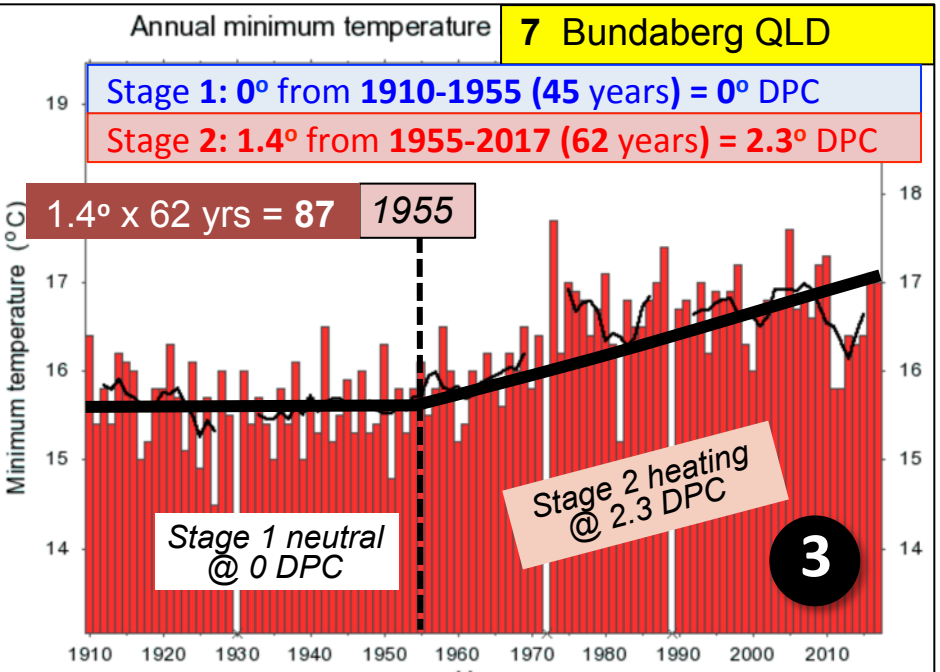

2 Cardwell QLD
Stage 1: 0.5° from 1912-1947 (35 years) = -1.4° DPC
Stage 2: 2.1° from 1947-2017 (70 years) = 3.0° DPC
2.1° x 71 yrs = 149
1947
Stage 2 heating @ 3.0 DPC
1
1910
Stage 1 cooling @ -1.4 DPC
2017

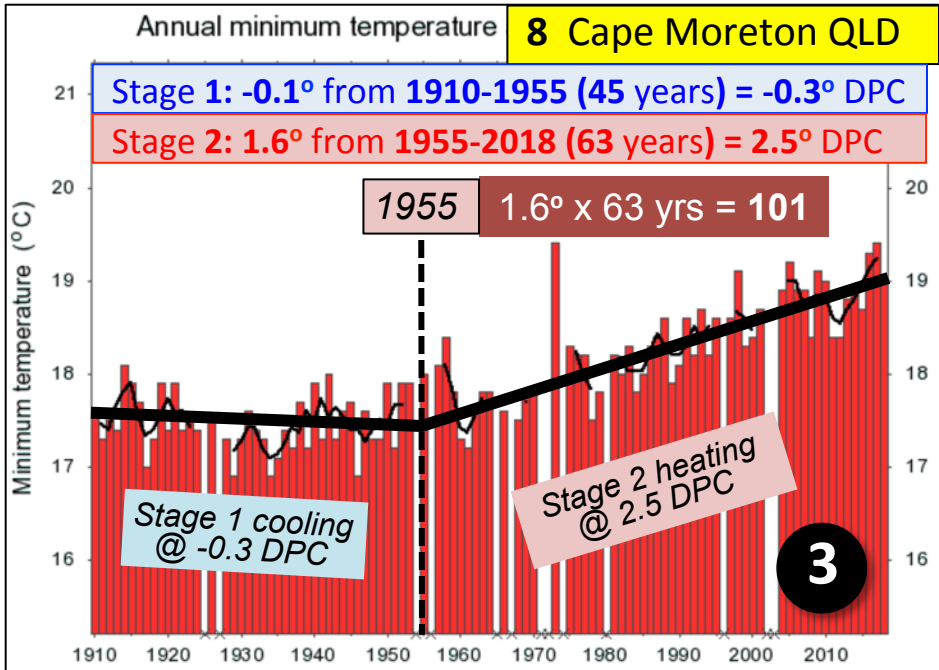

3 Townsville QLD
Stage 1: 0.13° from 1942-1961 (19 years) = -0.7° DPC
Stage 2: 1.5° from 1961-2018 (57 years) = 2.6° DPC
1961
1.5° (mean) x 57 yrs = 86
Stage 1 cooling @ -0.7 DPC
Stage 2 heating @ 2.6 DPC
2
1942
1961
2018

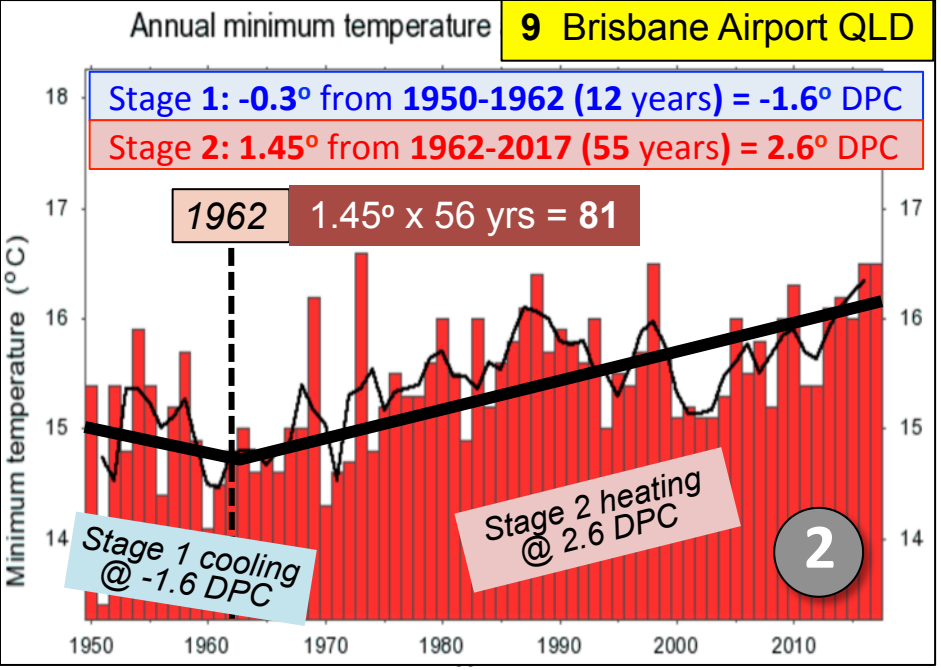

Stage 2: 1.2° (dashed) from 1954-1987 (33 years) = 3.6 DPC
Stage 2: 1.5° (dots - mean) 1954-1987 (33 years) = 4.5 DPC
Stage 2: 2.2° (solid) from 1954-1987 (33 years) = 6.7 DPC
4 Bowen QLD
1.5° (mean) x 64 yrs = 96
1954
Stage 2 heating @ 3.6 DPC
Stage 1 cooling @ -3.6 DPC
Stage 2 heating @ 4.5 DPC
Stage 2 heating @ 6.7 DPC
1
1907
1987
Stage 1: -1.5° from 1912-1954 (42 years) = -3.6° DPC

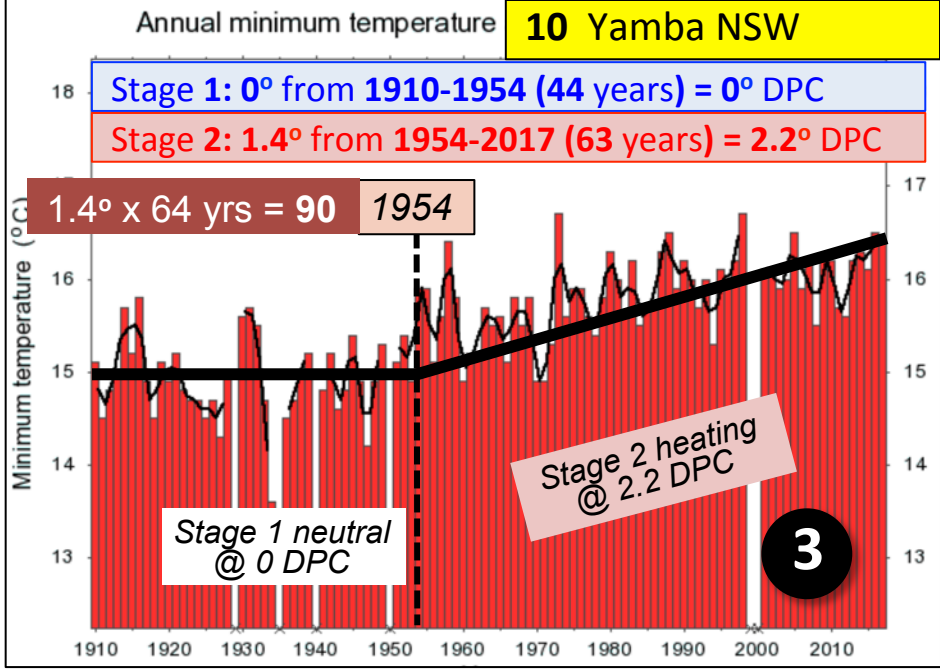

Annual minimum temperature
5 Mackay QLD
Stage 1: 0.2° from 1910-1930 (20 years) = 1.0° DPC
Stage 2: 2.0° from 1930-2017 (87 years) = 2.3° DPC
1930
2.0° x 87 yrs = 174
Minimum temperature (°C)
Stage 2 heating @ 2.3 DPC
Stage 1 heating @ 1.0 DPC
2

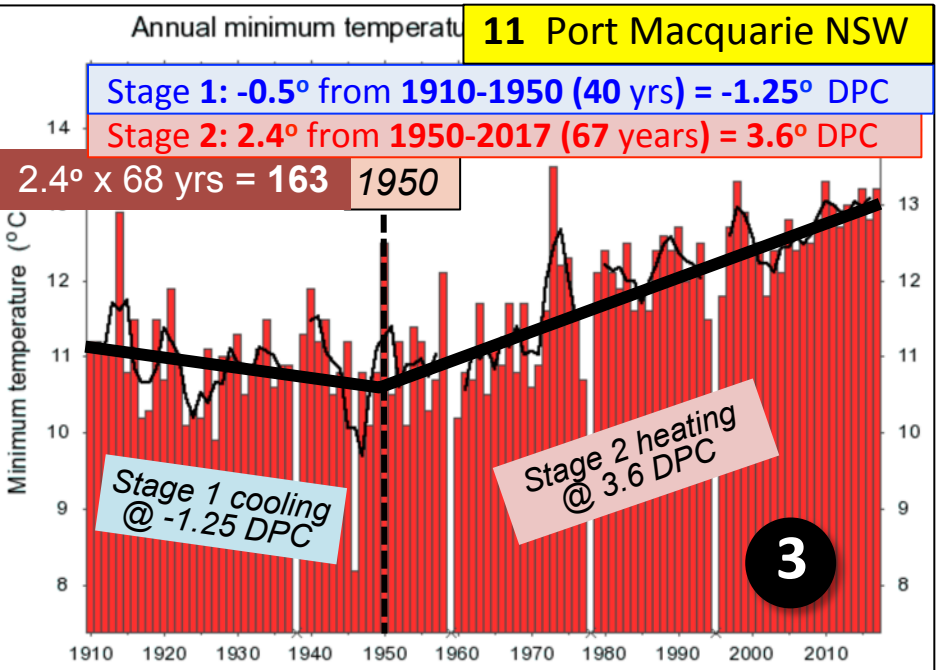

6 St Lawrence QLD
Stage 1: 0° from 1910-1962 (52 years) = 0° DPC
Stage 2: 1.2° (dashed) from 1962-2011 (49 years) = 2.4° DPC
1.2° x 49 yrs = 59
1962
Stage 2 heating @ 2.4 DPC
1
1940 Stage 1 neutral @ 0 DPC
2010

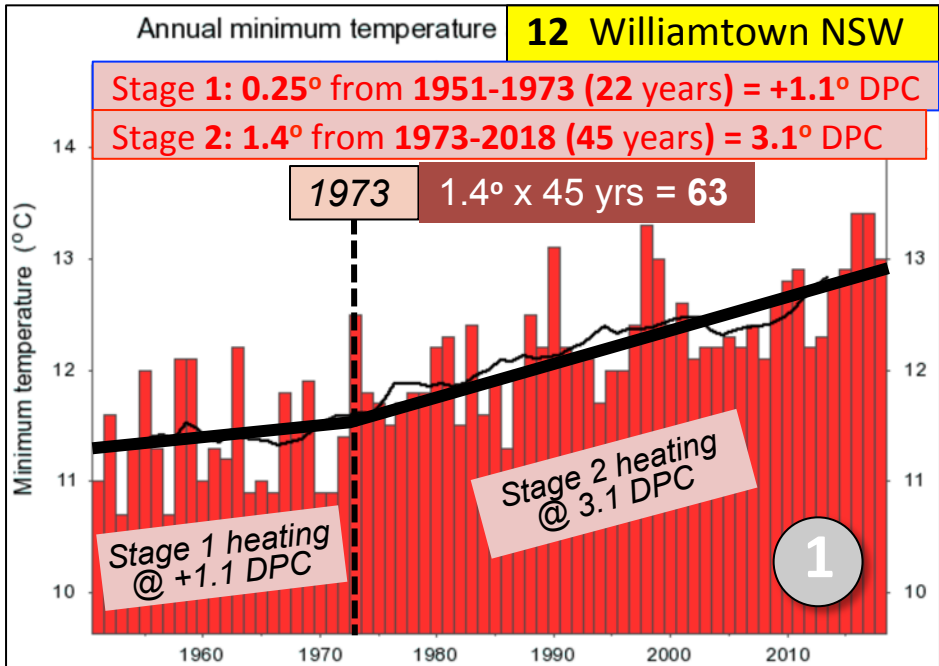

Annual minimum temperature
7 Bundaberg QLD
Stage 1: 0° from 1910-1955 (45 years) = 0° DPC
Stage 2: 1.4° from 1955-2017 (62 years) = 2.3° DPC
1.4° x 62 yrs = 87
1955
Minimum temperature (°C)
Stage 1 neutral @ 0 DPC
Stage 2 heating @ 2.3 DPC
3

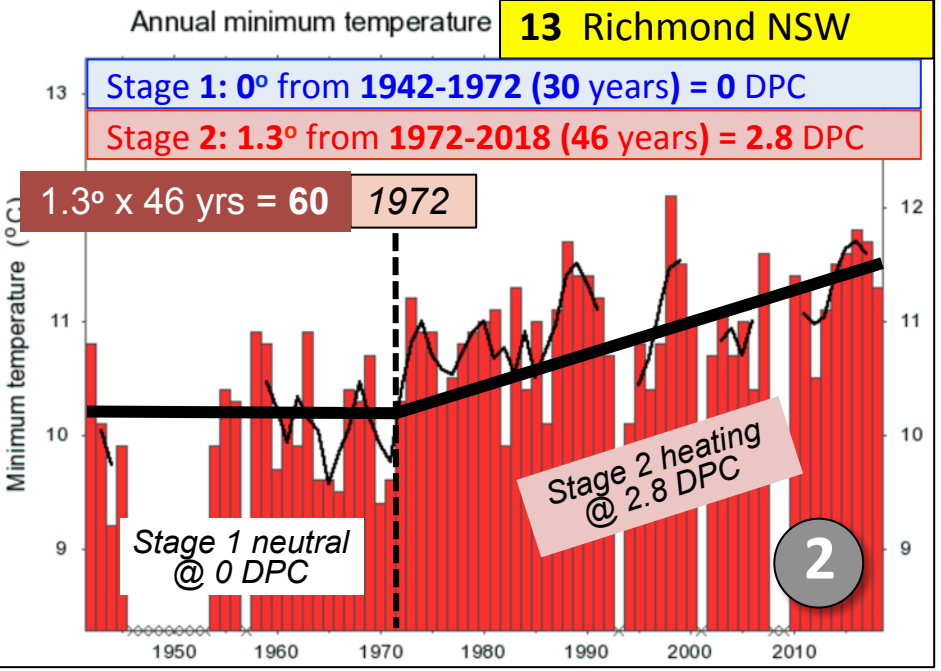

Annual minimum temperature
8 Cape Moreton QLD
Stage 1: -0.1° from 1910-1955 (45 years) = -0.3° DPC
Stage 2: 1.6° from 1955-2018 (63 years) = 2.5° DPC
1955
1.6° x 63 yrs = 101
Minimum temperature (°C)
Stage 1 cooling @ -0.3 DPC
Stage 2 heating @ 2.5 DPC
3

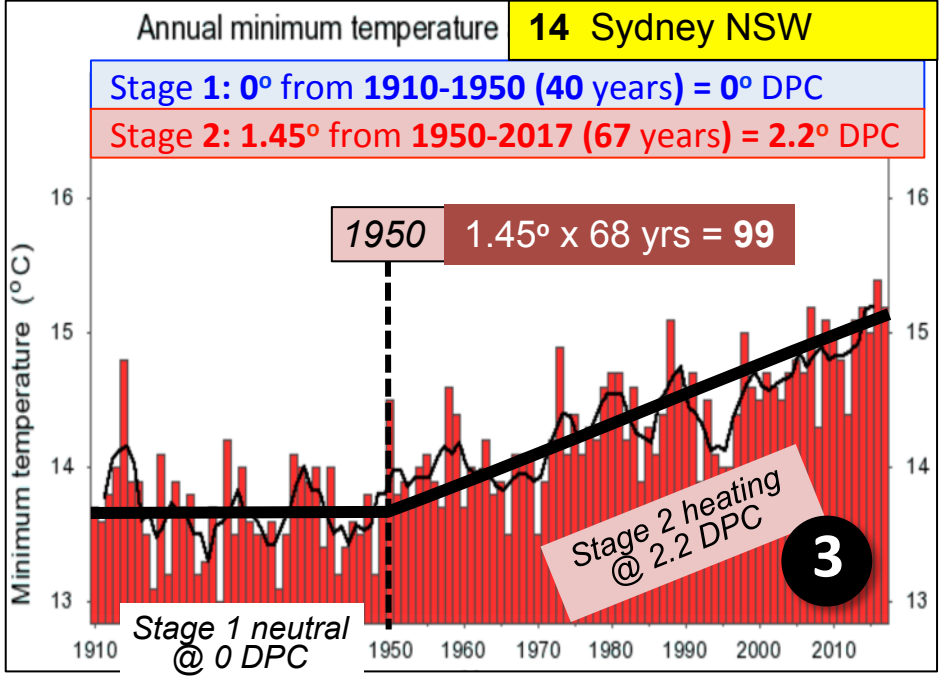

Annual minimum temperature
9 Brisbane Airport QLD
Stage 1: -0.3° from 1950-1962 (12 years) = -1.6° DPC
Stage 2: 1.45° from 1962-2017 (55 years) = 2.6° DPC
1962
1.45° x 56 yrs = 81
Stage 1 cooling @ -1.6 DPC
Stage 2 heating @ 2.6 DPC
2
Minimum temperature (°C)

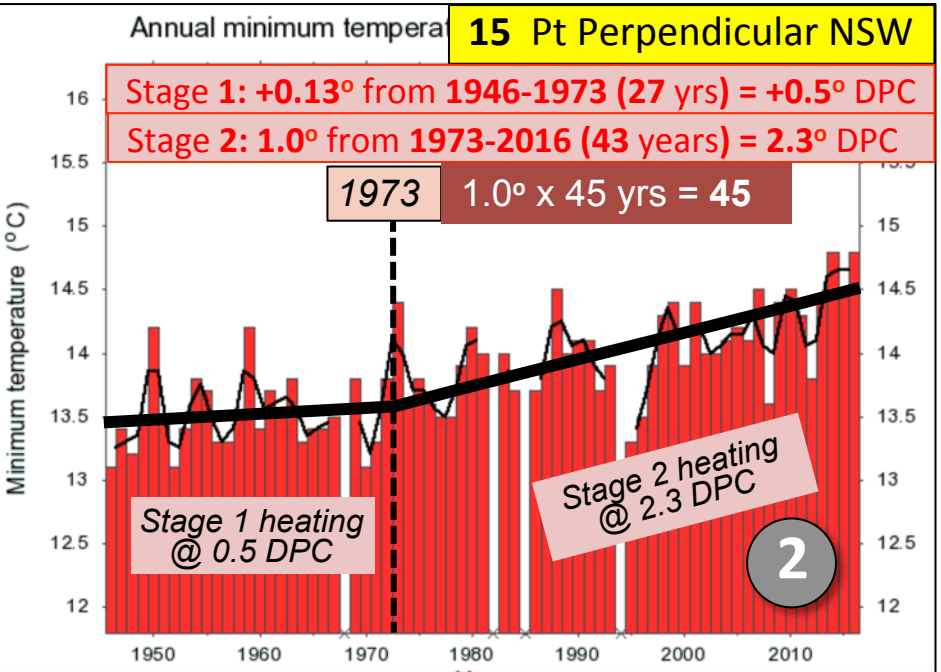

Annual minimum temperature
10 Yamba NSW
Stage 1: 0° from 1910-1954 (44 years) = 0° DPC
Stage 2: 1.4° from 1954-2017 (63 years) = 2.2° DPC
1.4° x 64 yrs = 90
1954
Stage 1 neutral @ 0 DPC
Stage 2 heating @ 2.2 DPC
3
Minimum temperature (°C)

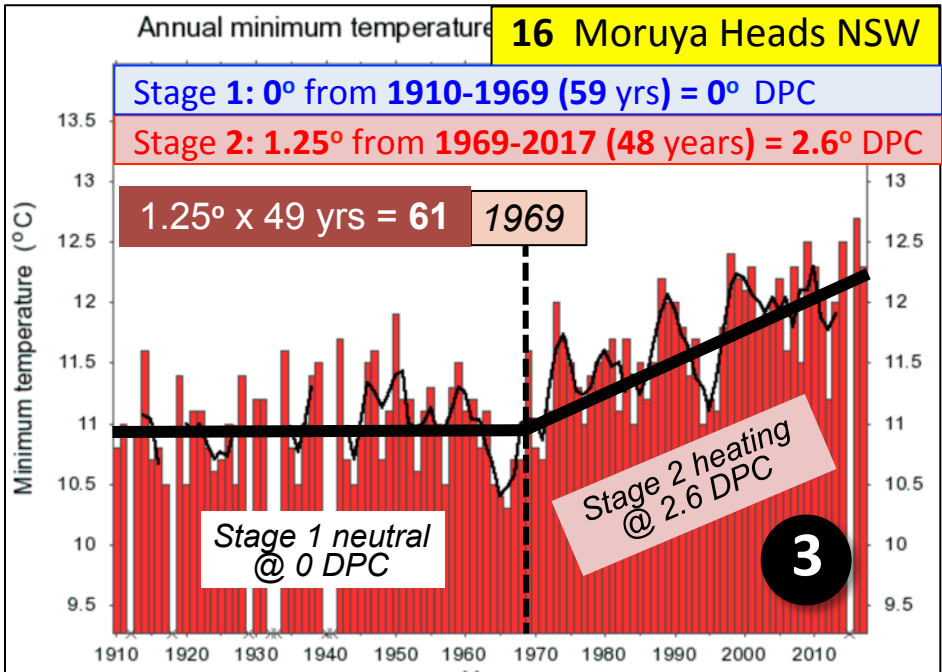

Annual minimum temperatu
11 Port Macquarie NSW
Stage 1: -0.5° from 1910-1950 (40 yrs) = -1.25° DPC
Stage 2: 2.4° from 1950-2017 (67 years) = 3.6° DPC
2.4° x 68 yrs = 163
1950
Stage 1 cooling @ -1.25 DPC
Stage 2 heating @ 3.6 DPC
3
Minimum temperature (°C)

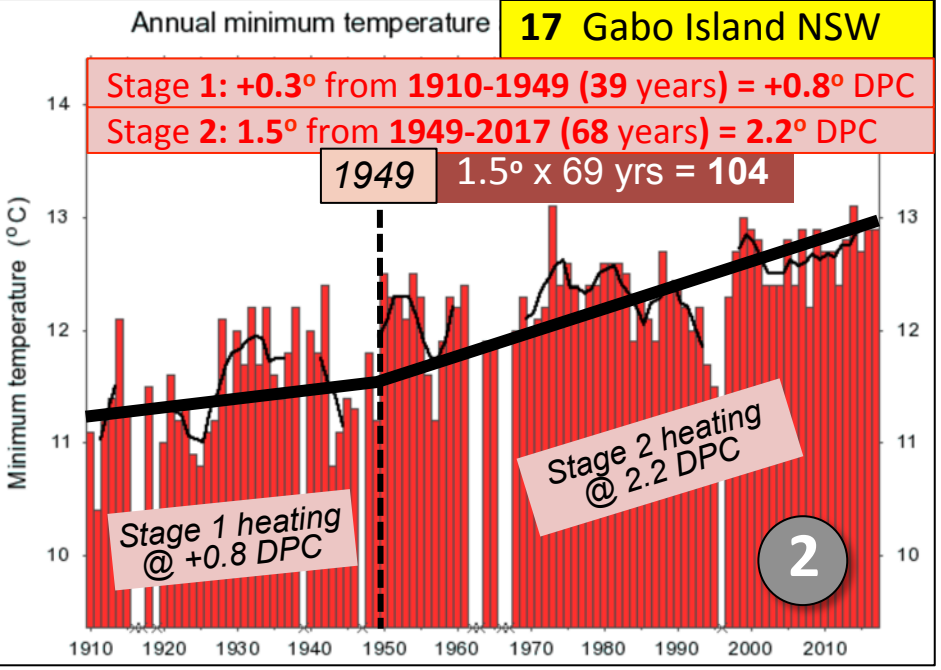

Annual minimum temperature
12 Williamtown NSW
Stage 1: 0.25° from 1951-1973 (22 years) = +1.1° DPC
Stage 2: 1.4° from 1973-2018 (45 years) = 3.1° DPC
1973
1.4° x 45 yrs = 63
Stage 1 heating @ +1.1 DPC
Stage 2 heating @ 3.1 DPC
1
Minimum temperature (°C)

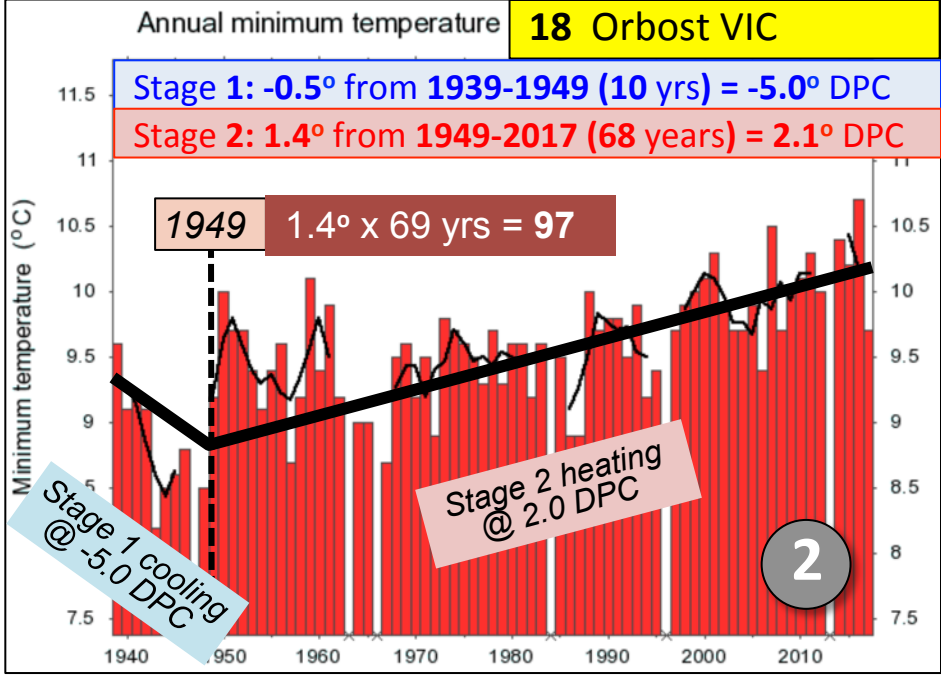

Annual minimum temperature
13 Richmond NSW
Stage 1: 0° from 1942-1972 (30 years) = 0 DPC
Stage 2: 1.3° from 1972-2018 (46 years) = 2.8 DPC
1.3° x 46 yrs = 60
1972
Minimum temperature (°C)
Stage 1 neutral @ 0 DPC
Stage 2 heating @ 2.8 DPC
2
1950 1960 1970 1980 1990 2000 2010

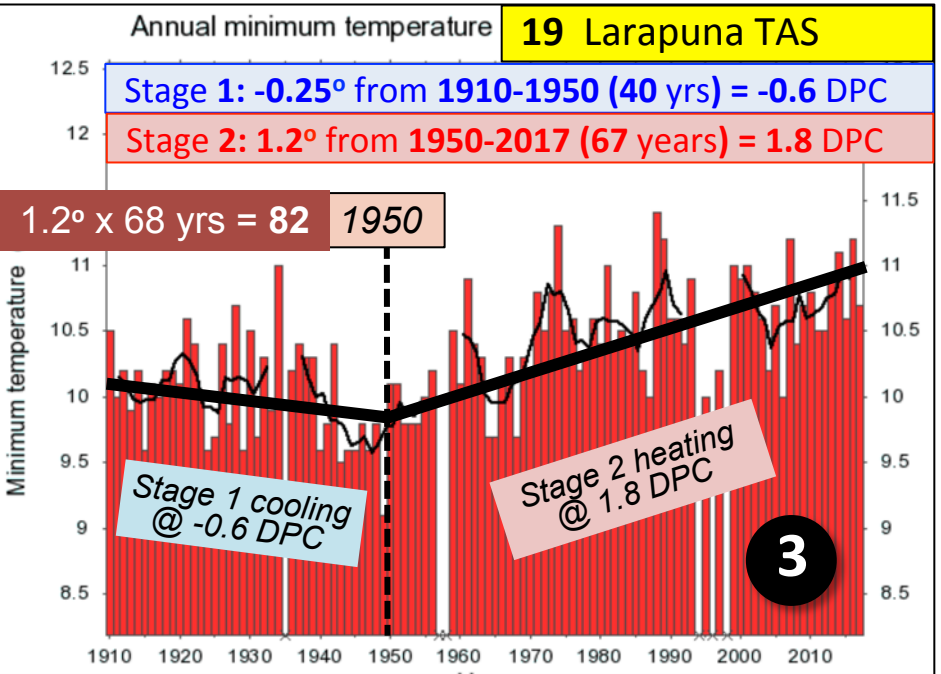

Annual minimum temperature
14 Sydney NSW
Stage 1: 0° from 1910-1950 (40 years) = 0° DPC
Stage 2: 1.45° from 1950-2017 (67 years) = 2.2° DPC
1950
1.45° x 68 yrs = 99
Minimum temperature (°C)
Stage 1 neutral @ 0 DPC
Stage 2 heating @ 2.2 DPC
3
1910 1950 1960 1970 1980 1990 2000 2010

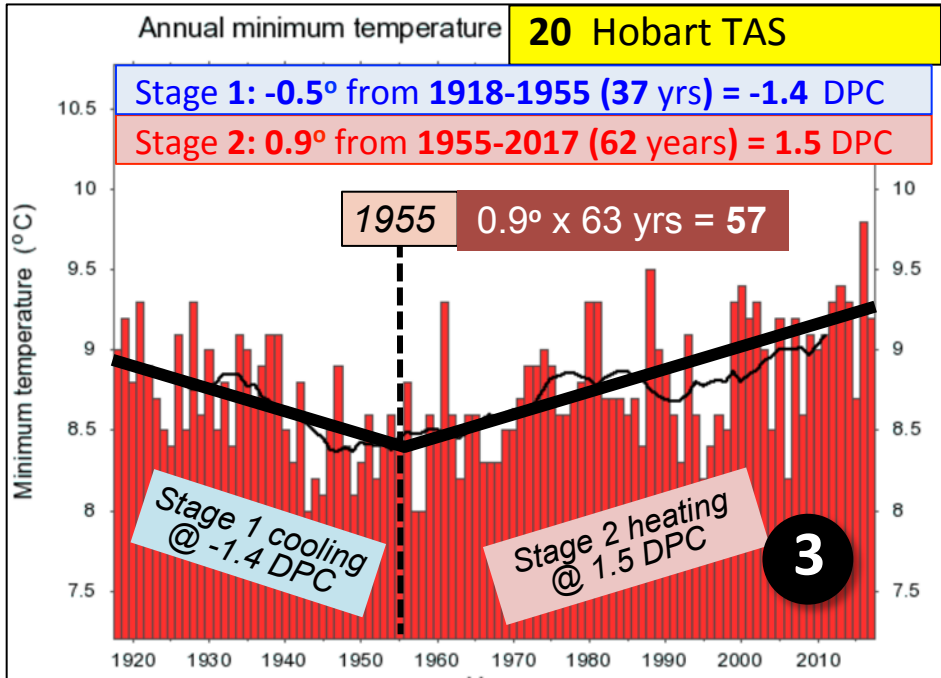

Annual minimum temperat
15 Pt Perpendicular NSW
Stage 1: +0.13° from 1946-1973 (27 yrs) = +0.5° DPC
Stage 2: 1.0° from 1973-2016 (43 years) = 2.3° DPC
1973
1.0° x 45 yrs = 45
Minimum temperature (°C)
Stage 1 heating @ 0.5 DPC
Stage 2 heating @ 2.3 DPC
2
1950 1960 1970 1980 1990 2000 2010

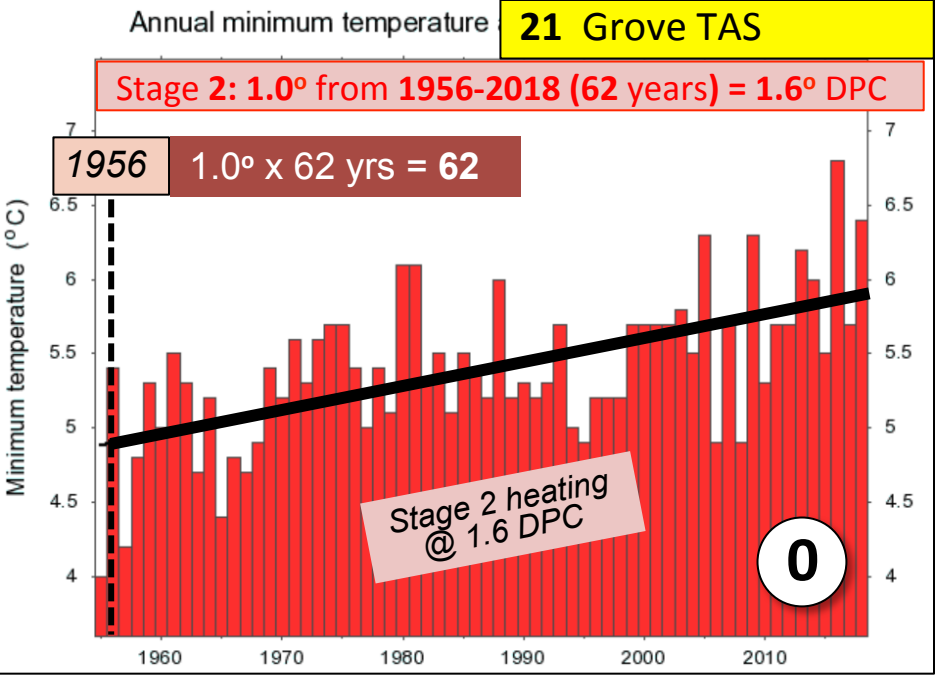

Annual minimum temperature
16 Moruya Heads NSW
Stage 1: 0° from 1910-1969 (59 yrs) = 0° DPC
Stage 2: 1.25° from 1969-2017 (48 years) = 2.6° DPC
1.25° x 49 yrs = 61
1969
Minimum temperature (°C)
Stage 1 neutral @ 0 DPC
Stage 2 heating @ 2.6 DPC
3
1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010

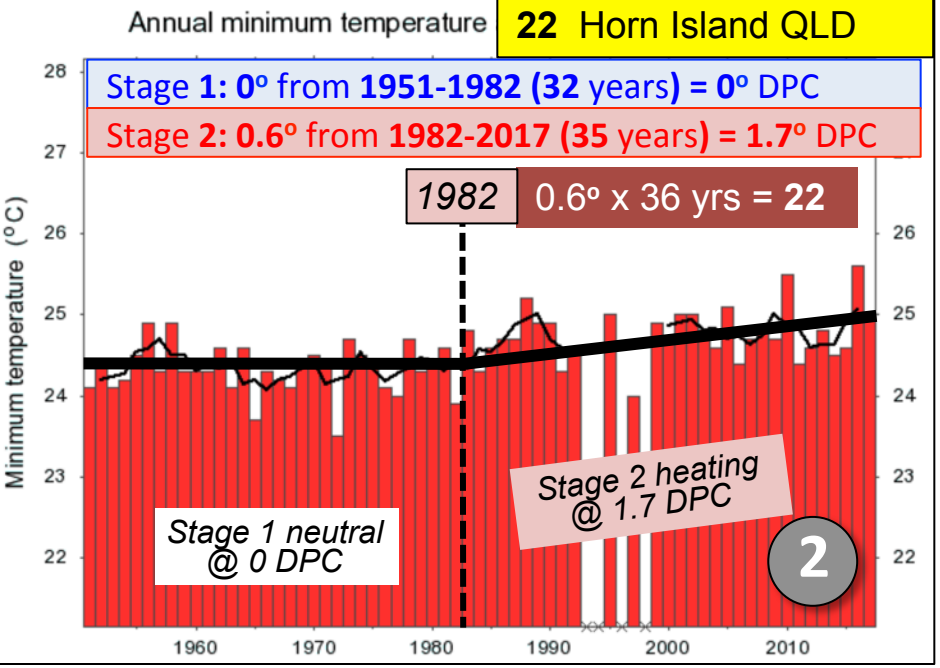

Annual minimum temperature
17 Gabo Island NSW
Stage 1: +0.3° from 1910-1949 (39 years) = +0.8° DPC
Stage 2: 1.5° from 1949-2017 (68 years) = 2.2° DPC
1949
1.5° x 69 yrs = 104
Minimum temperature (°C)
Stage 1 heating @ +0.8 DPC
Stage 2 heating @ 2.2 DPC
2

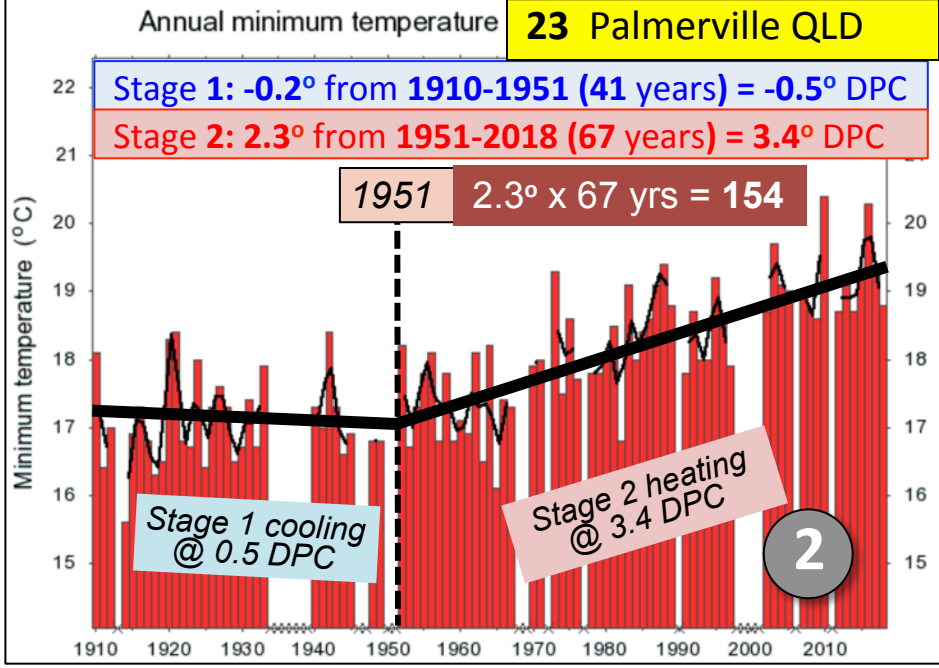

Annual minimum temperature
18 Orbost VIC
Stage 1: -0.5° from 1939-1949 (10 yrs) = -5.0° DPC
Stage 2: 1.4° from 1949-2017 (68 years) = 2.1° DPC
1949
1.4° x 69 yrs = 97
Minimum temperature (°C)
Stage 1 cooling @ -5.0 DPC
Stage 2 heating @ 2.0 DPC
2

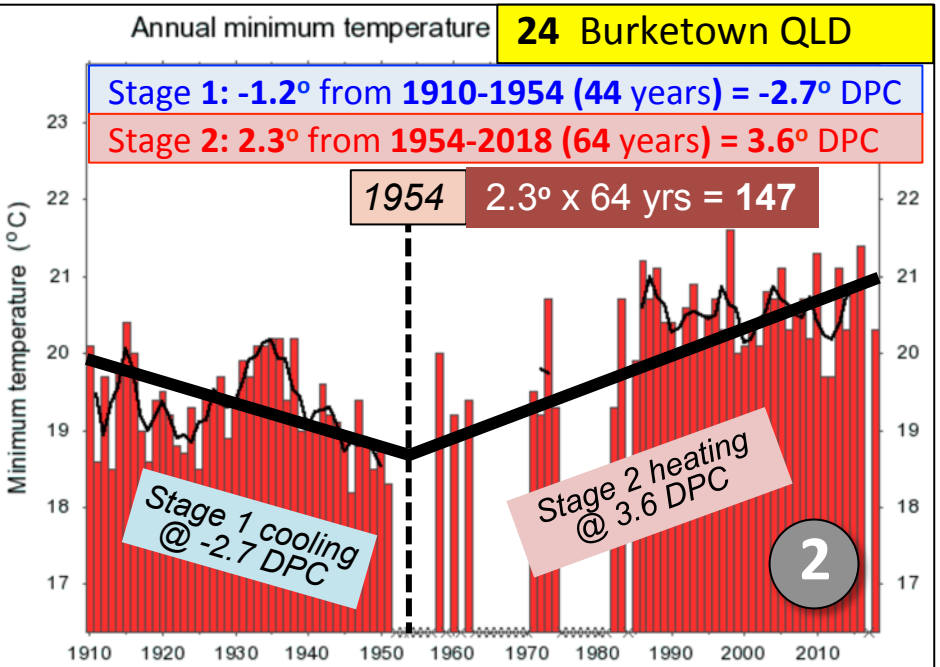

Annual minimum temperature
19 Larapuna TAS
Stage 1: -0.25° from 1910-1950 (40 yrs) = -0.6 DPC
Stage 2: 1.2° from 1950-2017 (67 years) = 1.8 DPC
1.2° x 68 yrs = 82
1950
Minimum temperature
Stage 1 cooling @ -0.6 DPC
Stage 2 heating @ 1.8 DPC
3

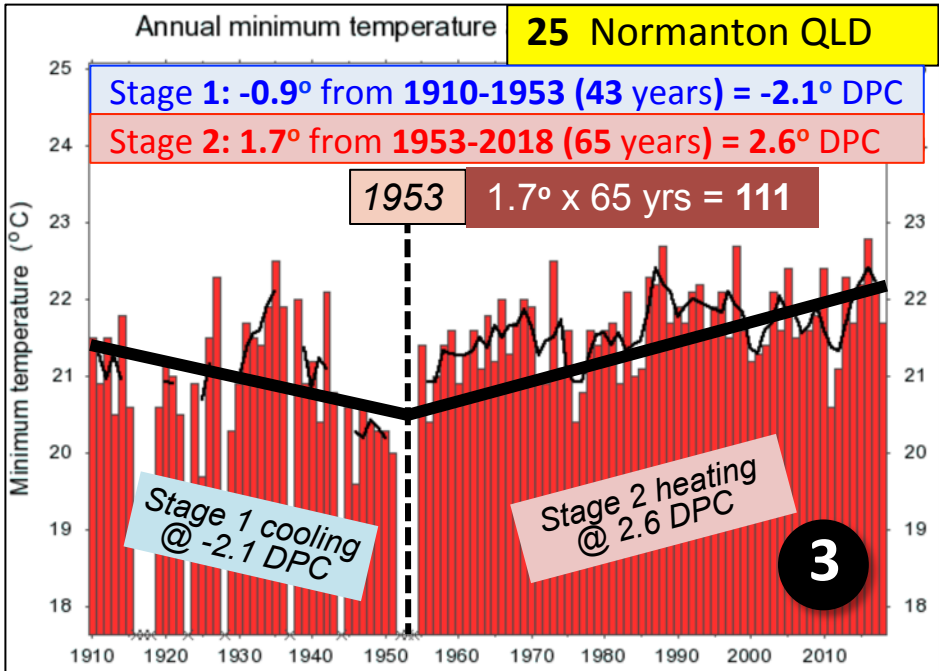

Annual minimum temperature
20 Hobart TAS
Stage 1: -0.5° from 1918-1955 (37 yrs) = -1.4 DPC
Stage 2: 0.9° from 1955-2017 (62 years) = 1.5 DPC
1955
0.9° x 63 yrs = 57
Minimum temperature (°C)
Stage 1 cooling @ -1.4 DPC
Stage 2 heating @ 1.5 DPC
3

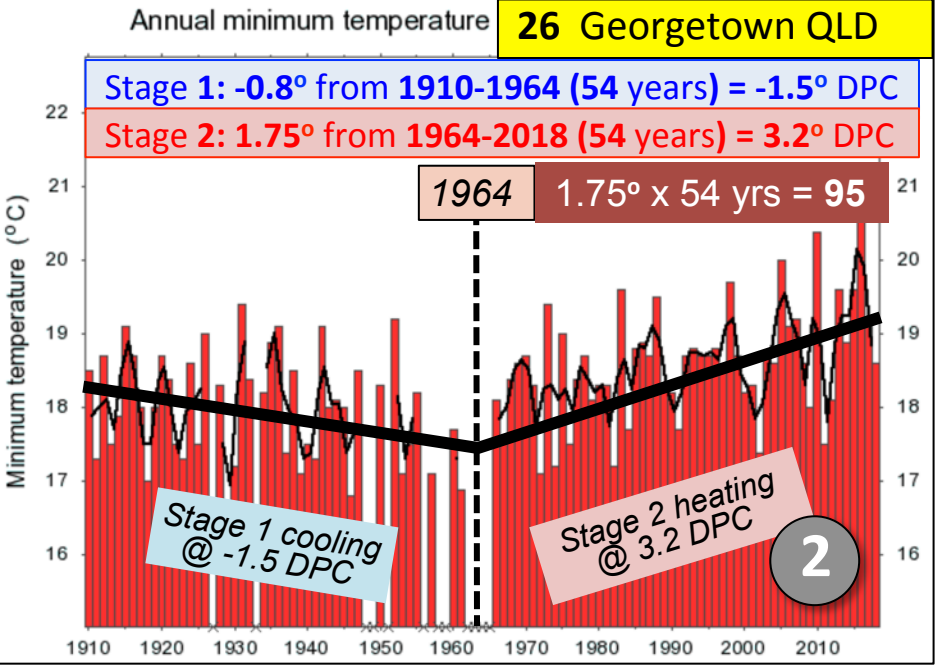

Annual minimum temperature
21 Grove TAS
Stage 2: 1.0° from 1956-2018 (62 years) = 1.6° DPC
1956
1.0° x 62 yrs = 62
Minimum temperature (°C)
7
6.5
6
5.5
5
4.5
4
1960
1970
1980
1990
2000
2010
Stage 2 heating @ 1.6 DPC
0

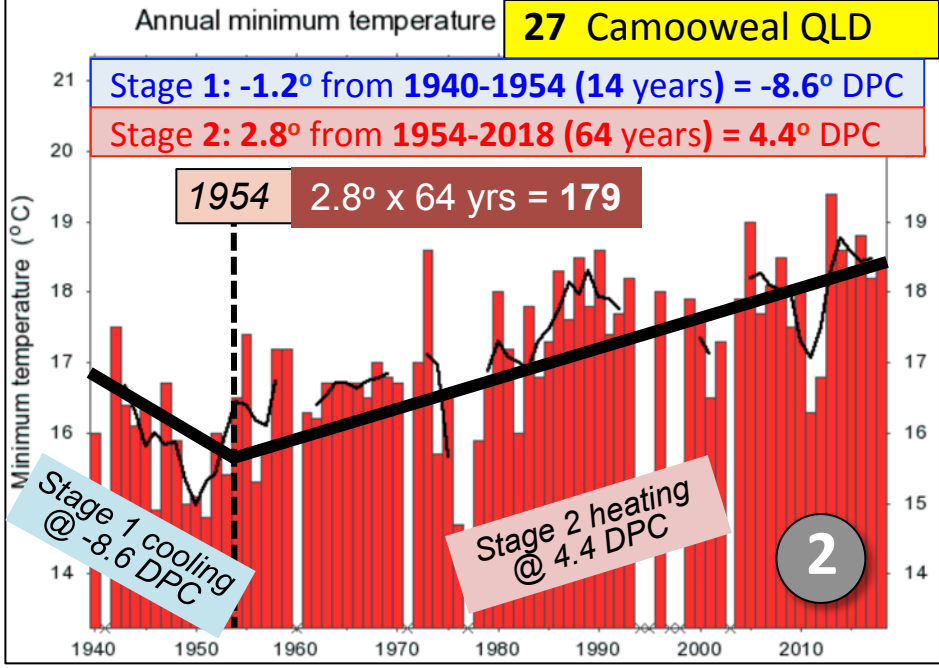

Annual minimum temperature
22 Horn Island QLD
Stage 1: 0° from 1951-1982 (32 years) = 0° DPC
Stage 2: 0.6° from 1982-2017 (35 years) = 1.7° DPC
1982
0.6° x 36 yrs = 22
Stage 1 neutral @ 0 DPC
Stage 2 heating @ 1.7 DPC
2
Minimum temperature (°C)

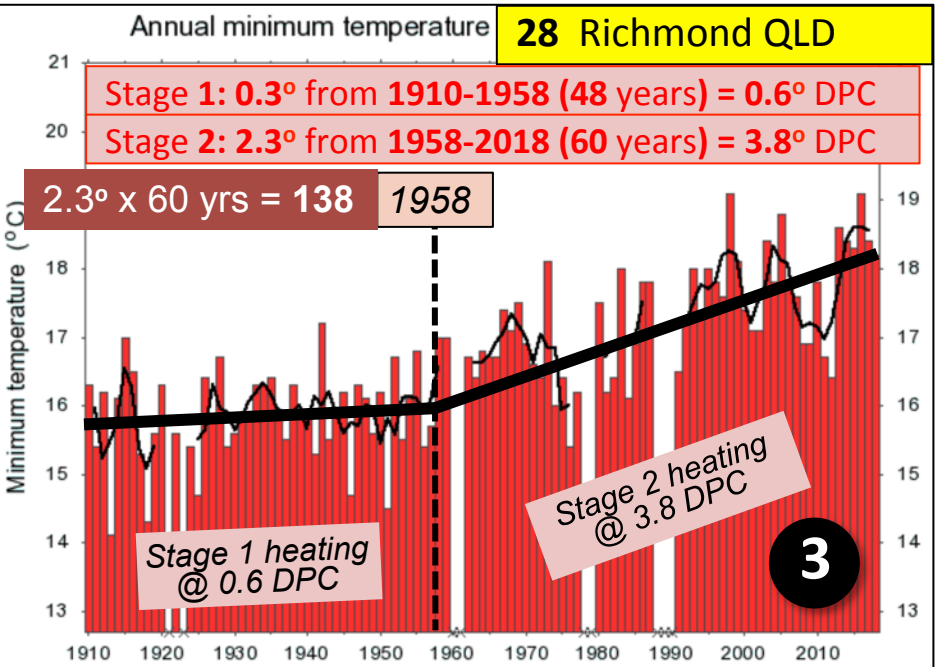

Annual minimum temperature
23 Palmerville QLD
Stage 1: -0.2° from 1910-1951 (41 years) = -0.5° DPC
Stage 2: 2.3° from 1951-2018 (67 years) = 3.4° DPC
1951
2.3° x 67 yrs = 154
Stage 1 cooling @ 0.5 DPC
Stage 2 heating @ 3.4 DPC
2
Minimum temperature (°C)

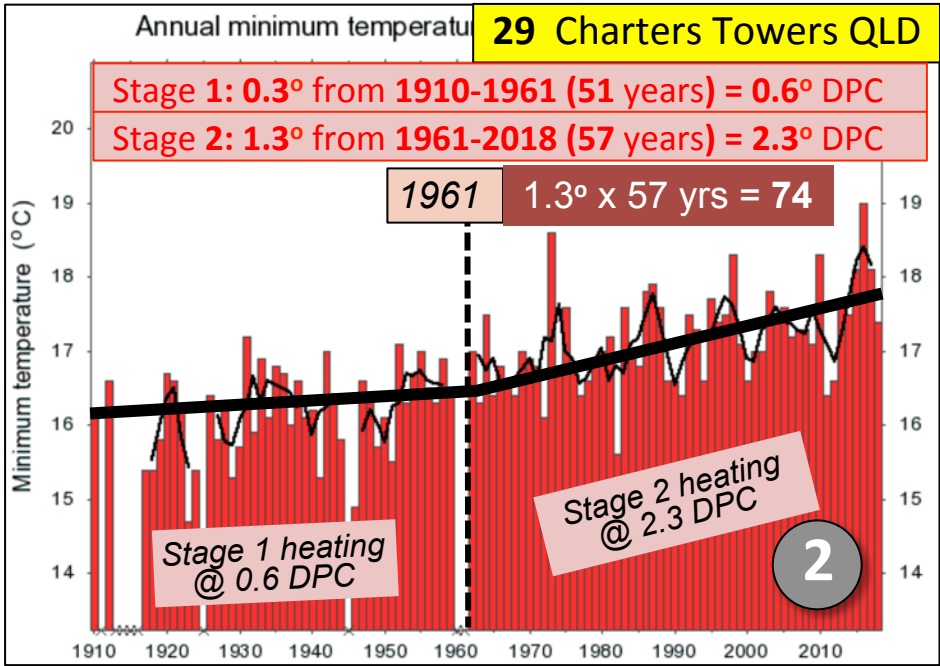

Annual minimum temperature
24 Burketown QLD
Stage 1: -1.2° from 1910-1954 (44 years) = -2.7° DPC
Stage 2: 2.3° from 1954-2018 (64 years) = 3.6° DPC
1954
2.3° x 64 yrs = 147
Stage 1 cooling @ -2.7 DPC
Stage 2 heating @ 3.6 DPC
2
Minimum temperature (°C)

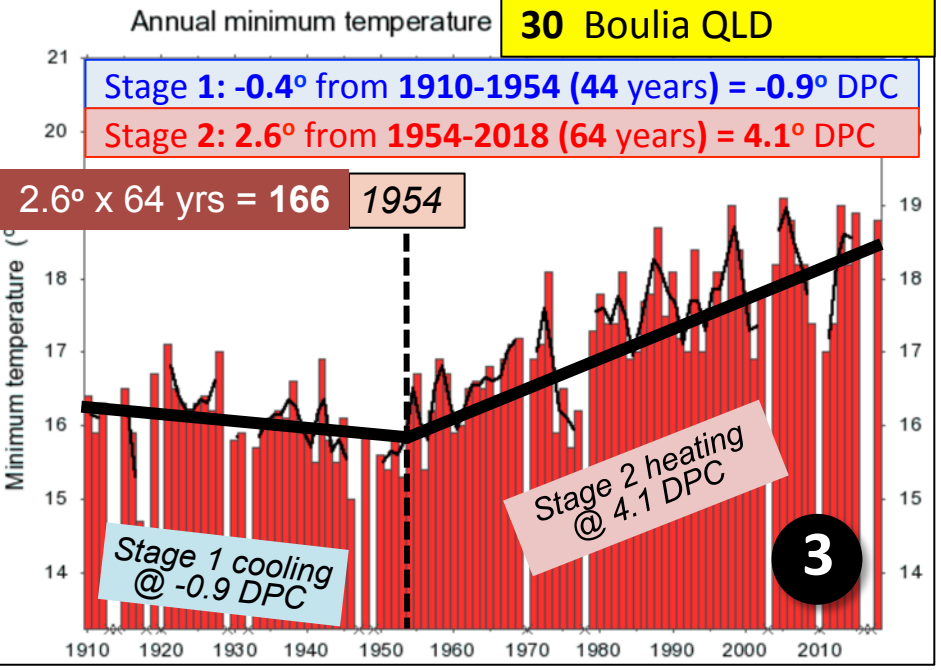

Annual minimum temperature
25 Normanton QLD
Stage 1: -0.9° from 1910-1953 (43 years) = -2.1° DPC
Stage 2: 1.7° from 1953-2018 (65 years) = 2.6° DPC
1953
1.7° x 65 yrs = 111
Stage 1 cooling @ -2.1 DPC
Stage 2 heating @ 2.6 DPC
3
Minimum temperature (°C)

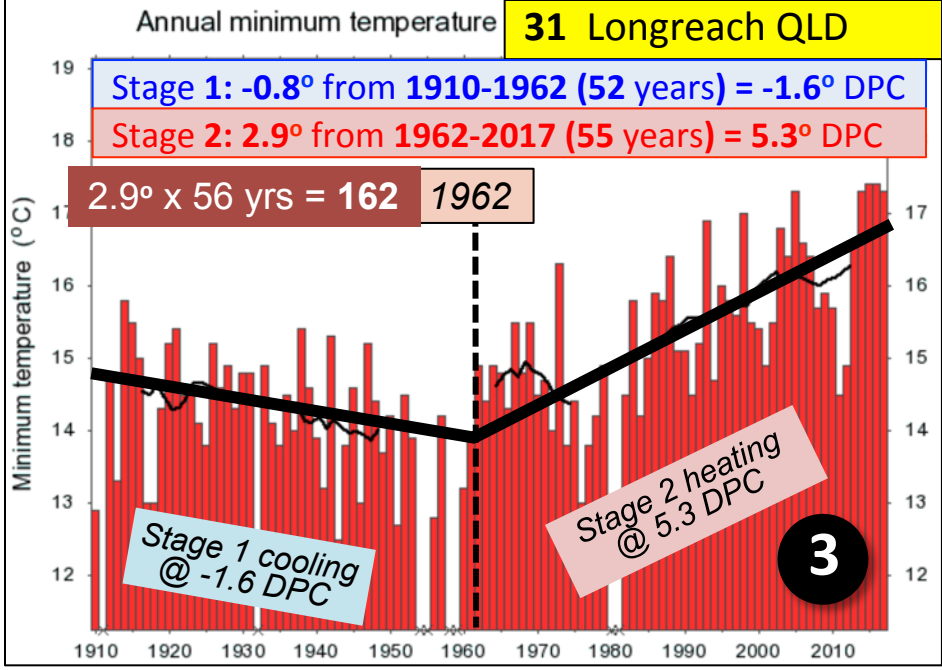

Annual minimum temperature
26 Georgetown QLD
Stage 1: -0.8° from 1910-1964 (54 years) = -1.5° DPC
Stage 2: 1.75° from 1964-2018 (54 years) = 3.2° DPC
1964
1.75° x 54 yrs = 95
Minimum temperature (°C)
Stage 1 cooling @ -1.5 DPC
Stage 2 heating @ 3.2 DPC
2

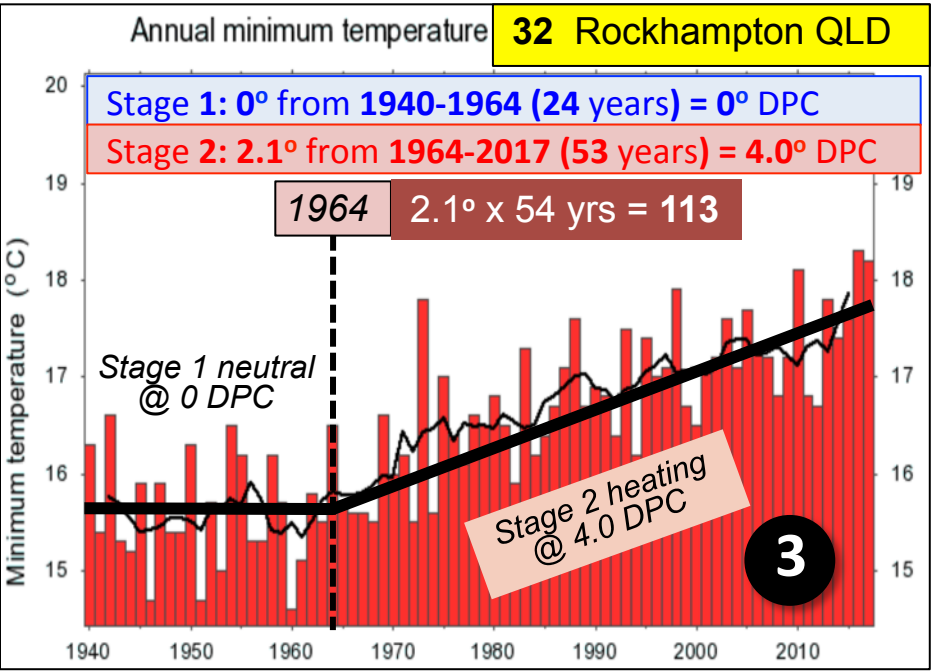

Annual minimum temperature
27 Camooweal QLD
Stage 1: -1.2° from 1940-1954 (14 years) = -8.6° DPC
Stage 2: 2.8° from 1954-2018 (64 years) = 4.4° DPC
1954
2.8° x 64 yrs = 179
Minimum temperature (°C)
Stage 1 cooling @ -8.6 DPC
Stage 2 heating @ 4.4 DPC
2

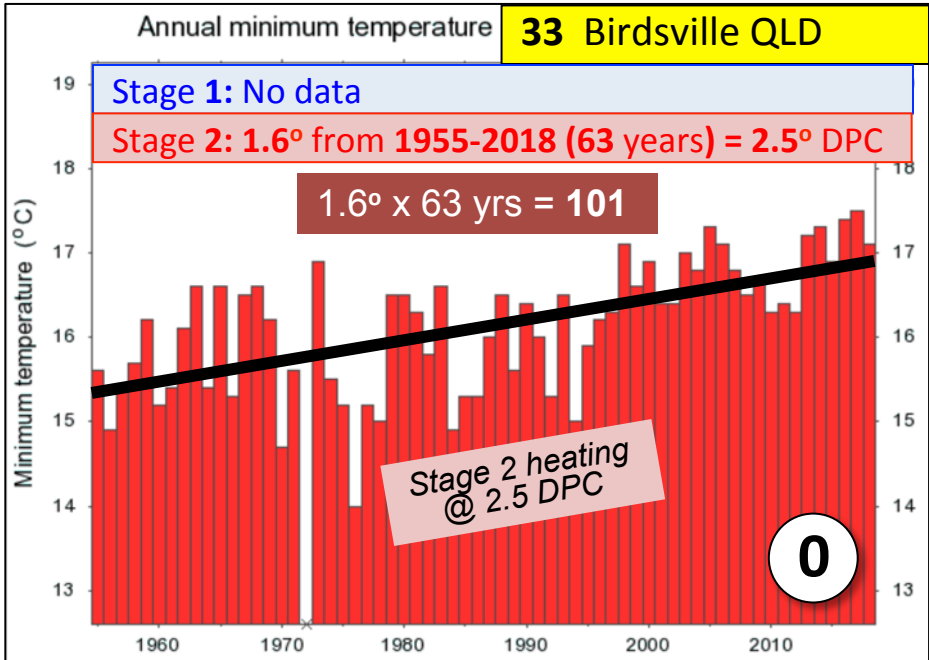

Annual minimum temperature
28 Richmond QLD
Stage 1: 0.3° from 1910-1958 (48 years) = 0.6° DPC
Stage 2: 2.3° from 1958-2018 (60 years) = 3.8° DPC
2.3° x 60 yrs = 138
1958
Minimum temperature (°C)
Stage 1 heating @ 0.6 DPC
Stage 2 heating @ 3.8 DPC
3

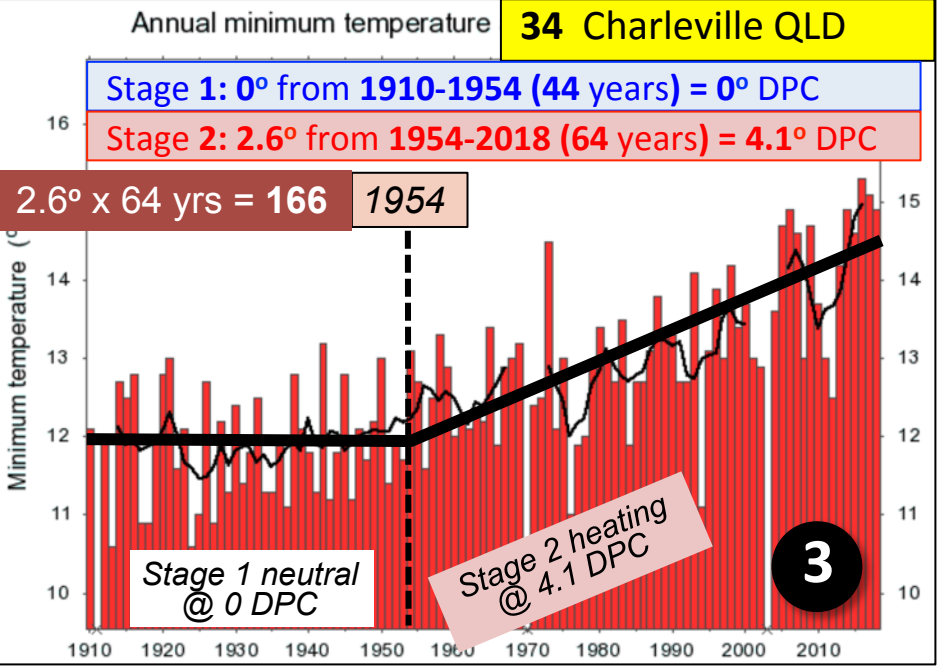

Annual minimum temperatu
29 Charters Towers QLD
Stage 1: 0.3° from 1910-1961 (51 years) = 0.6° DPC
Stage 2: 1.3° from 1961-2018 (57 years) = 2.3° DPC
1961
1.3° x 57 yrs = 74
Minimum temperature (°C)
Stage 1 heating @ 0.6 DPC
Stage 2 heating @ 2.3 DPC
2

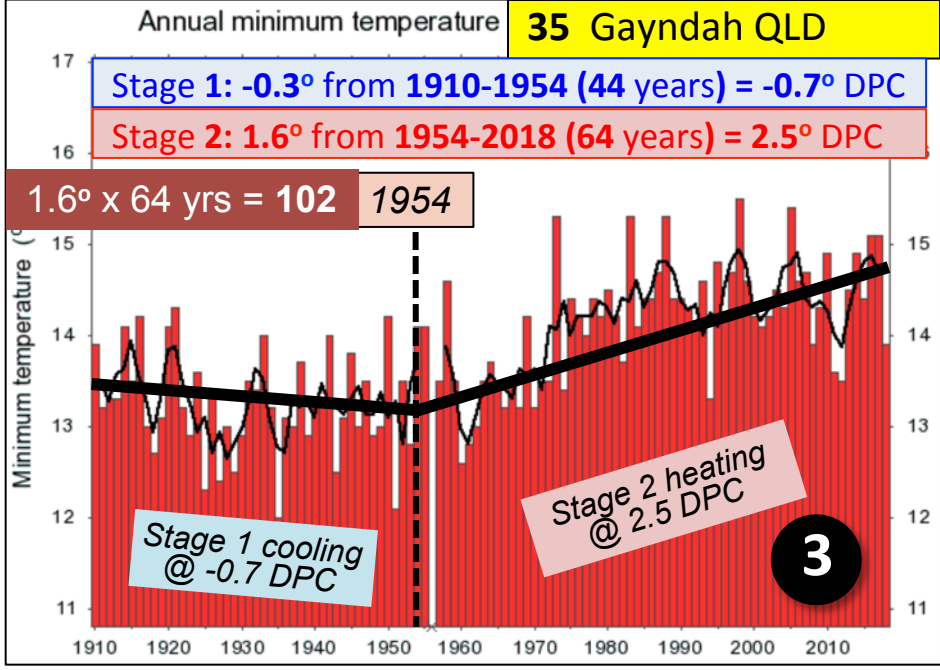

Annual minimum temperature
30 Boulia QLD
Stage 1: -0.4° from 1910-1954 (44 years) = -0.9° DPC
Stage 2: 2.6° from 1954-2018 (64 years) = 4.1° DPC
2.6° x 64 yrs = 166
1954
Minimum temperature (°C)
Stage 1 cooling @ -0.9 DPC
Stage 2 heating @ 4.1 DPC
3

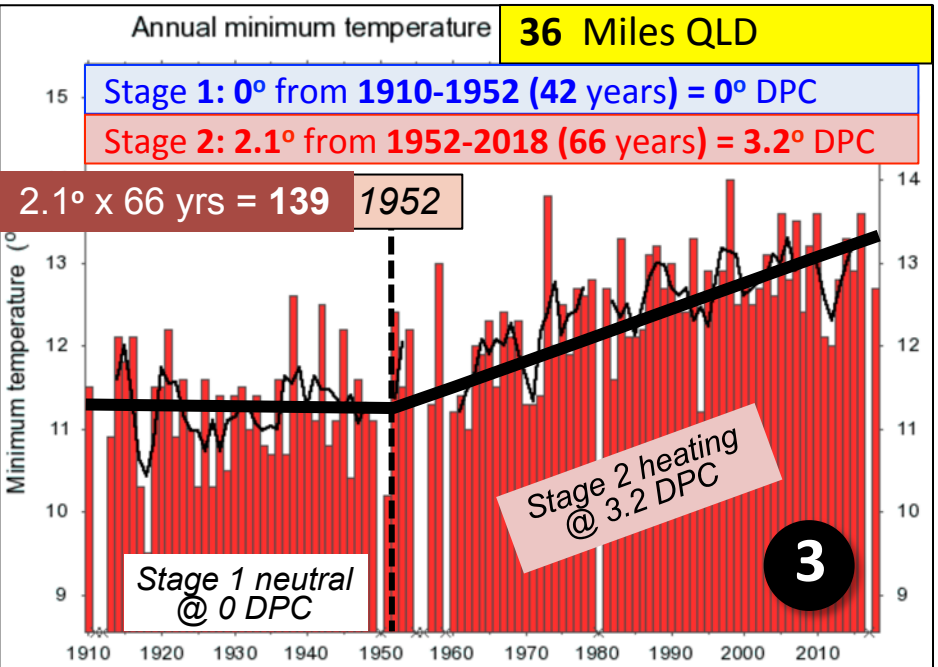

Annual minimum temperature
31 Longreach QLD
Stage 1: -0.8° from 1910-1962 (52 years) = -1.6° DPC
Stage 2: 2.9° from 1962-2017 (55 years) = 5.3° DPC
2.9° x 56 yrs = 162
1962
Minimum temperature (°C)
Stage 1 cooling @ -1.6 DPC
Stage 2 heating @ 5.3 DPC
3

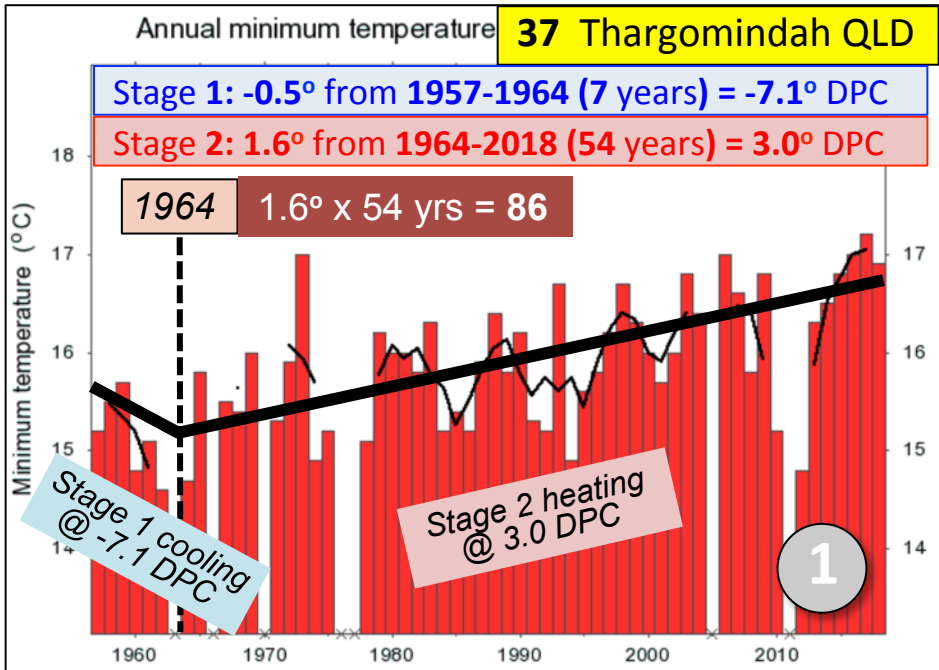

Annual minimum temperature
32 Rockhampton QLD
Stage 1: 0° from 1940-1964 (24 years) = 0° DPC
Stage 2: 2.1° from 1964-2017 (53 years) = 4.0° DPC
1964
2.1° x 54 yrs = 113
Minimum temperature (°C)
Stage 1 neutral @ 0 DPC
Stage 2 heating @ 4.0 DPC
3

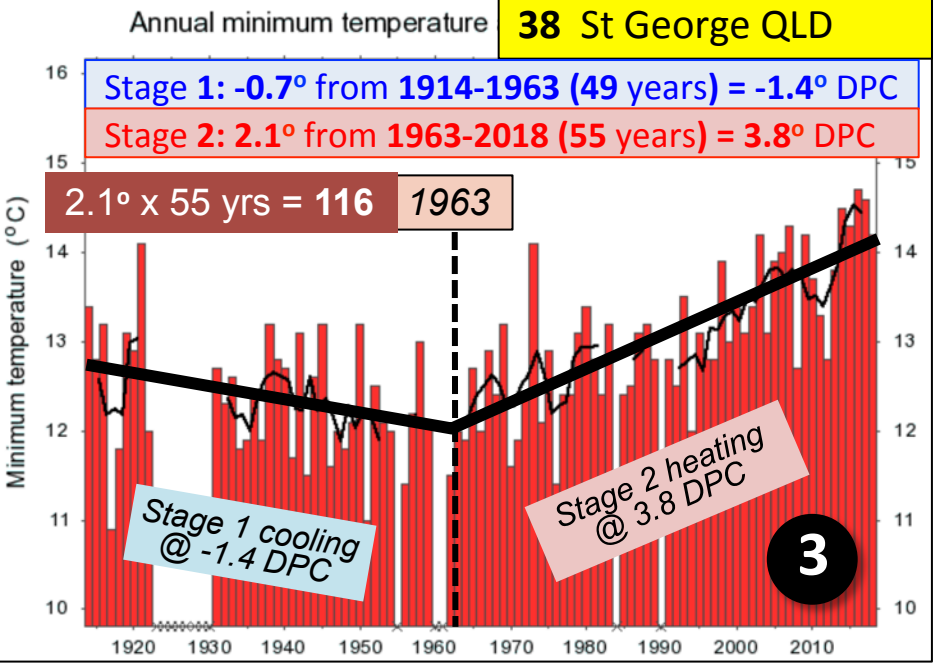

Annual minimum temperature
33 Birdsville QLD
Stage 1: No data
Stage 2: 1.6° from 1955-2018 (63 years) = 2.5° DPC
1.6° x 63 yrs = 101
Minimum temperature (°C)
Stage 2 heating @ 2.5 DPC
0

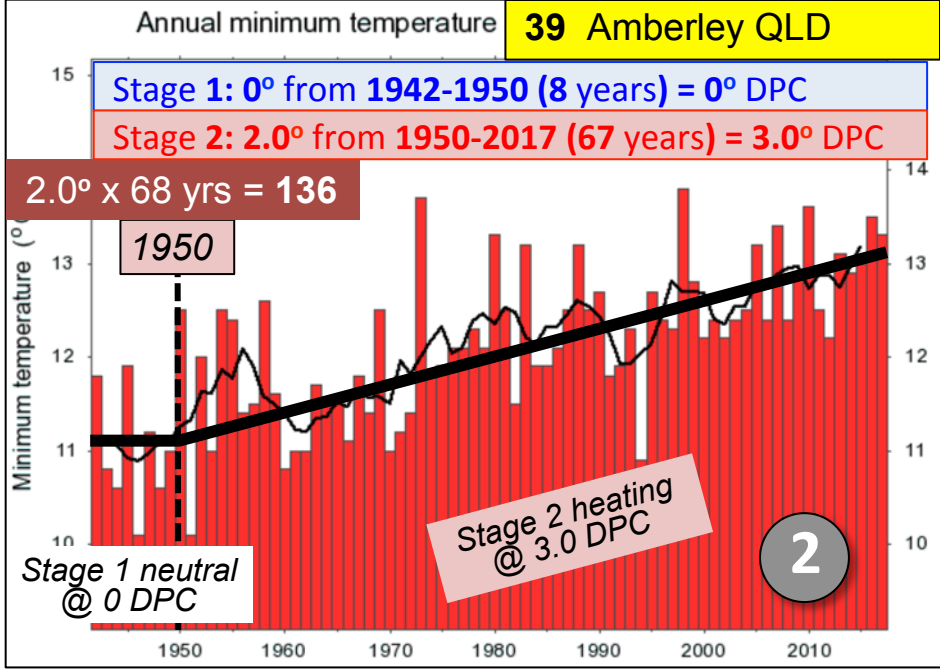

Annual minimum temperature
34 Charleville QLD
Stage 1: 0° from 1910-1954 (44 years) = 0° DPC
Stage 2: 2.6° from 1954-2018 (64 years) = 4.1° DPC
2.6° x 64 yrs = 166
1954
Minimum temperature (°C)
Stage 1 neutral @ 0 DPC
Stage 2 heating @ 4.1 DPC
3

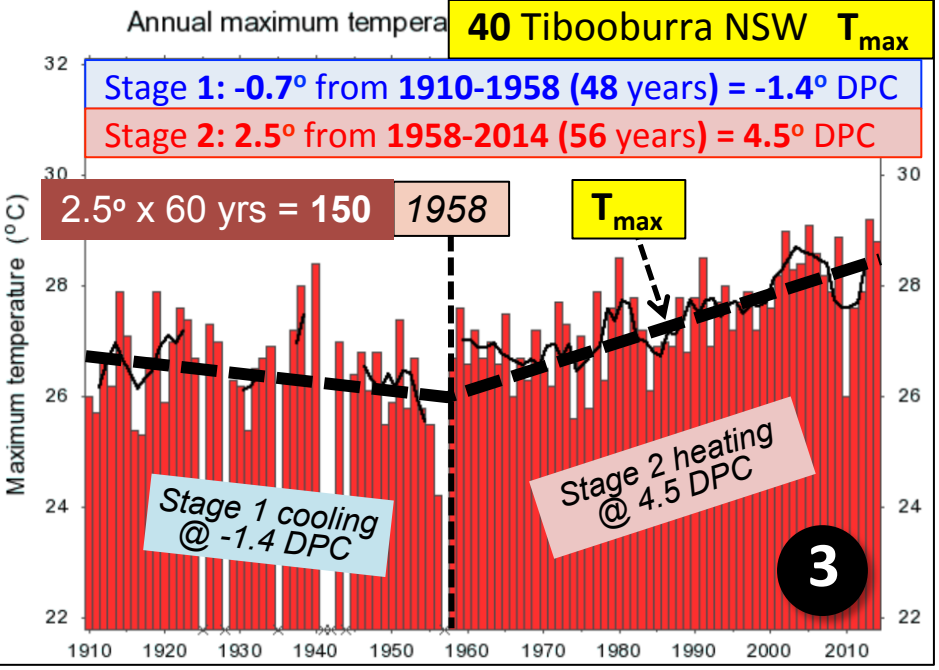

Annual minimum temperature
35 Gayndah QLD
Stage 1: -0.3° from 1910-1954 (44 years) = -0.7° DPC
Stage 2: 1.6° from 1954-2018 (64 years) = 2.5° DPC
1.6° x 64 yrs = 102
1954
Minimum temperature (°C)
Stage 1 cooling @ -0.7 DPC
Stage 2 heating @ 2.5 DPC
3

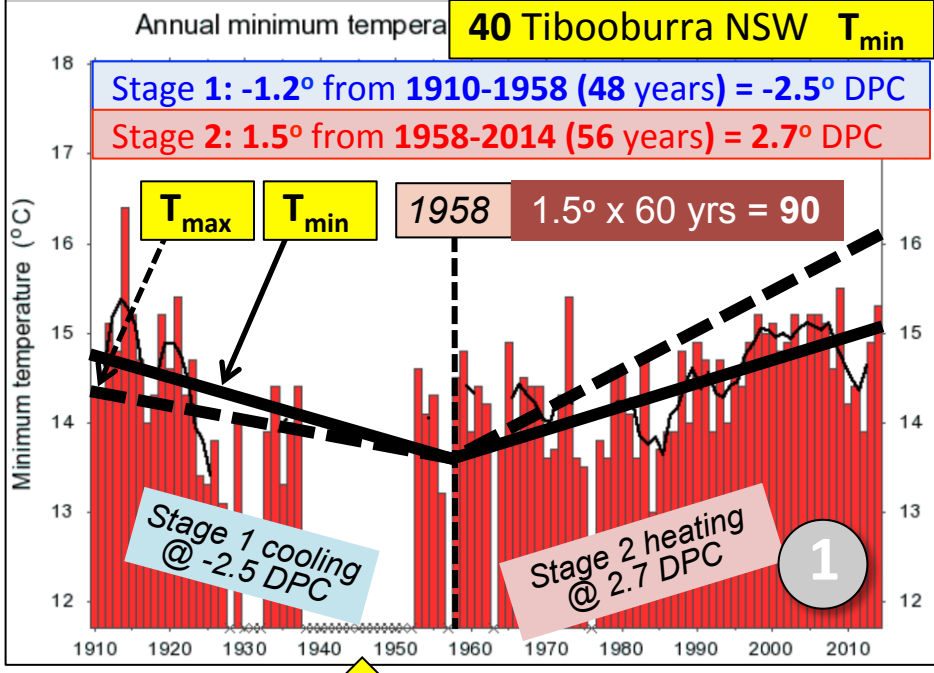

Annual minimum temperature
36 Miles QLD
Stage 1: 0° from 1910-1952 (42 years) = 0° DPC
Stage 2: 2.1° from 1952-2018 (66 years) = 3.2° DPC
2.1° x 66 yrs = 139
1952
Minimum temperature (°C)
Stage 1 neutral @ 0 DPC
Stage 2 heating @ 3.2 DPC
3


Annual minimum temperature
37 Thargomindah QLD
Stage 1: -0.5° from 1957-1964 (7 years) = -7.1° DPC
Stage 2: 1.6° from 1964-2018 (54 years) = 3.0° DPC
1964
1.6° x 54 yrs = 86
Minimum temperature (°C)
Stage 1 cooling @ -7.1 DPC
Stage 2 heating @ 3.0 DPC
1


Annual minimum temperature
38 St George QLD
Stage 1: -0.7° from 1914-1963 (49 years) = -1.4° DPC
Stage 2: 2.1° from 1963-2018 (55 years) = 3.8° DPC
2.1° x 55 yrs = 116
1963
Minimum temperature (°C)
Stage 1 cooling @ -1.4 DPC
Stage 2 heating @ 3.8 DPC
3

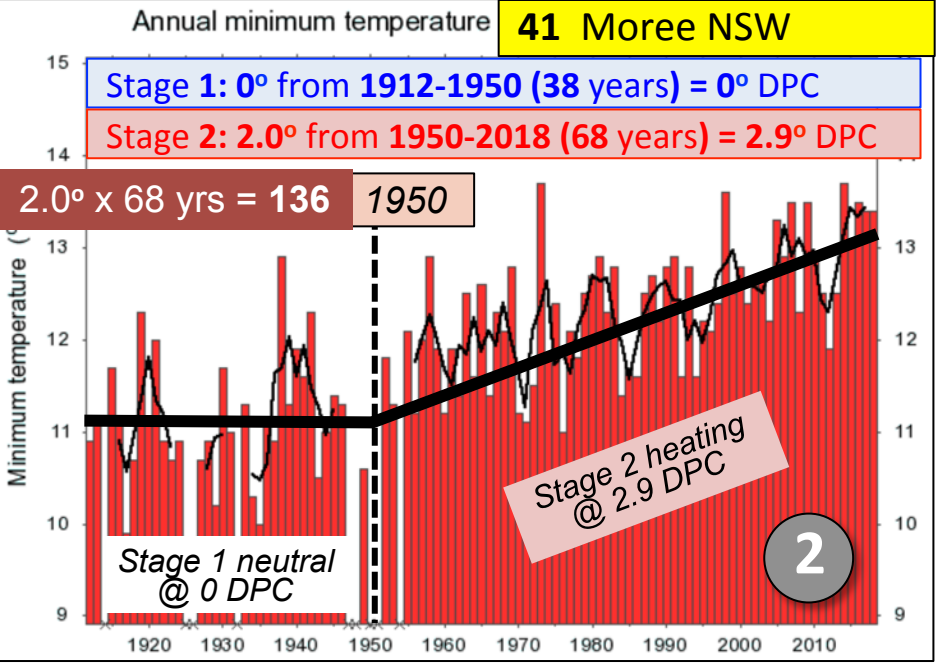

Annual minimum temperature
39 Amberley QLD
Stage 1: 0° from 1942-1950 (8 years) = 0° DPC
Stage 2: 2.0° from 1950-2017 (67 years) = 3.0° DPC
2.0° x 68 yrs = 136
1950
Minimum temperature (°C)
Stage 1 neutral @ 0 DPC
Stage 2 heating @ 3.0 DPC
2

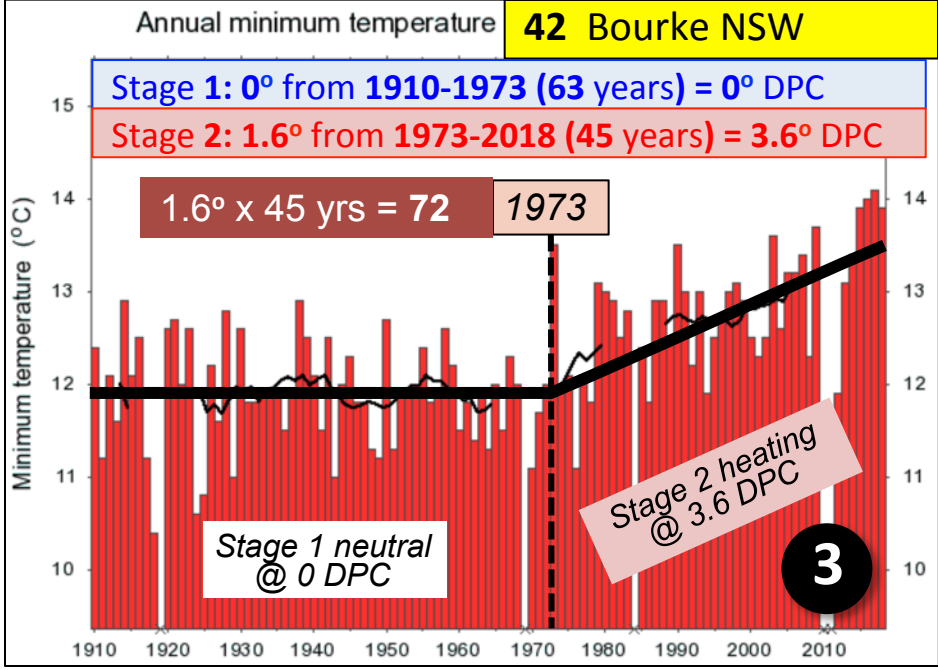


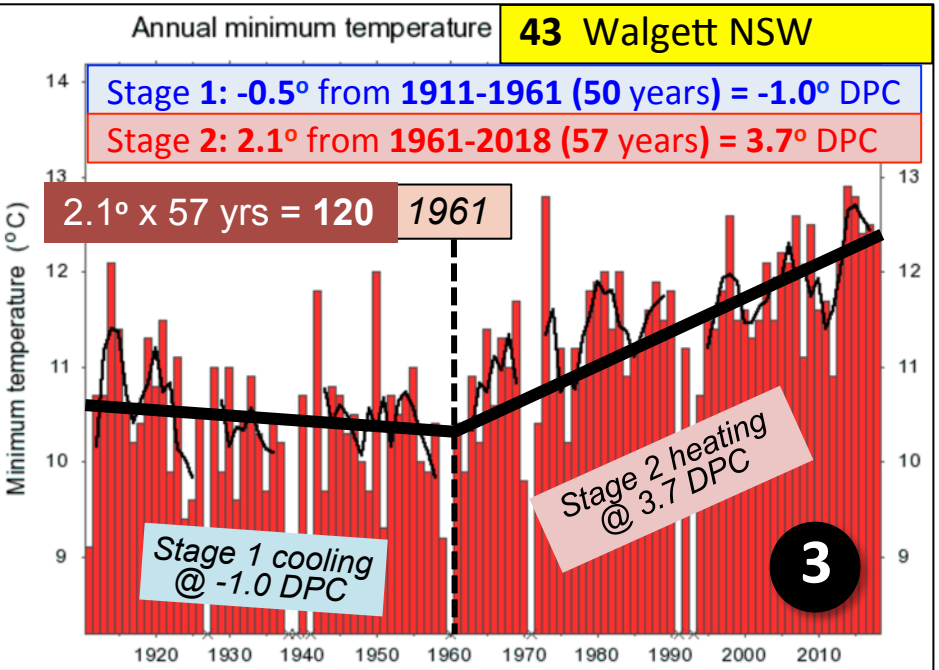


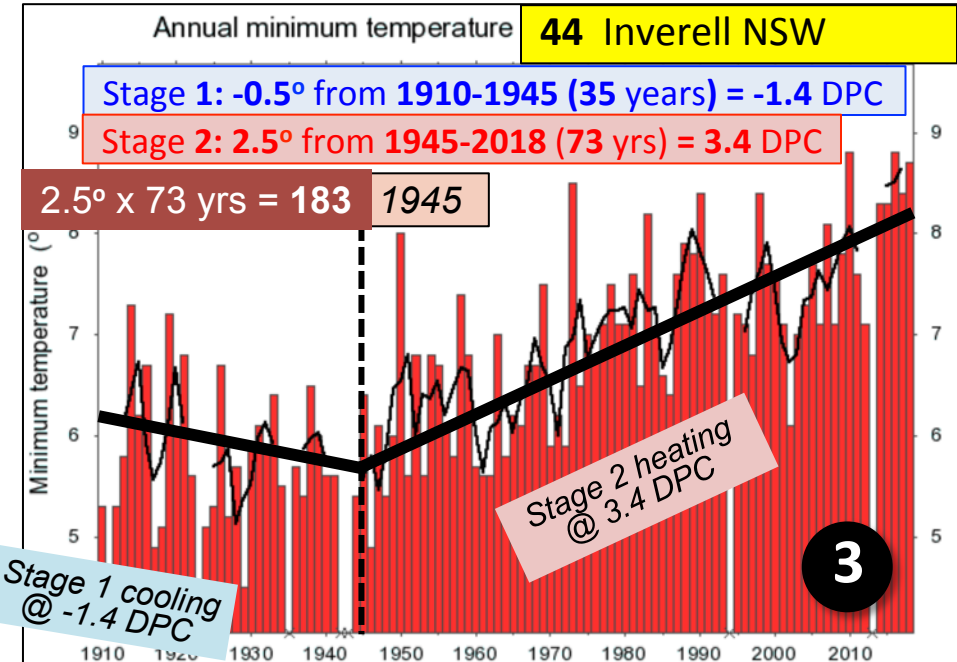
The Tibooburra records are more complete for Tmax than Tmin (Tmin is missing 15 continuous years between 1938 & 1952). Tmax (Figure on L) provides a clear heating curve for Stages 1 and 2 (dashed), a clear startdate for climate heating at 1958, and clear Stage 2 Tmax heating rate of 4.5 DPC.
For Tmin (Figure on R) the reliable 1958 startdate from L Figure provides a viable Stage 2 heating line for Tmin (solid), and a Stage 2 Tmin heating rate of 2.7 DPC.

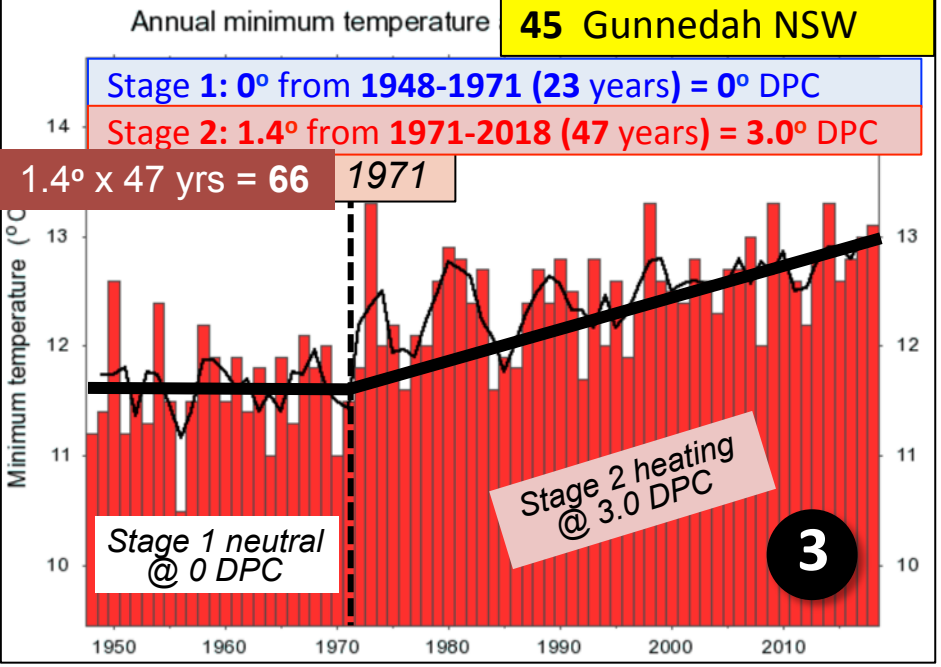
Selected values:
Stage 1 Cooling rate = **-2.5** DPC
Stage 2 Heating rate = **2.7** DPC
Startdate = **1958**
ΔH = **90**
QI = **2**

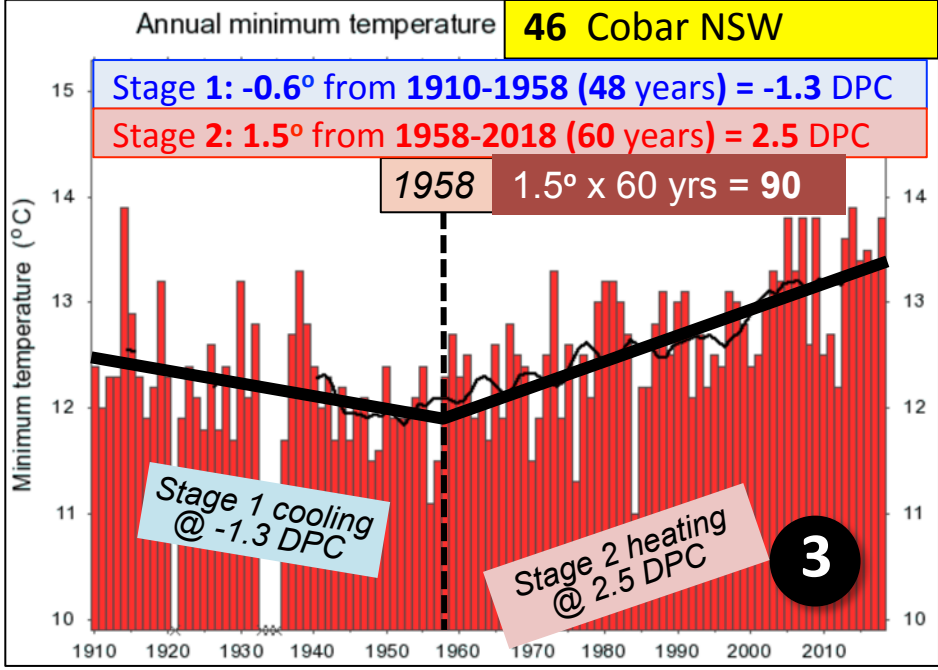

Annual minimum temperature
41 Moree NSW
Stage 1: 0° from 1912-1950 (38 years) = 0° DPC
Stage 2: 2.0° from 1950-2018 (68 years) = 2.9° DPC
2.0° x 68 yrs = 136
1950
Stage 2 heating @ 2.9 DPC
Stage 1 neutral @ 0 DPC
2
Minimum temperature (°C)

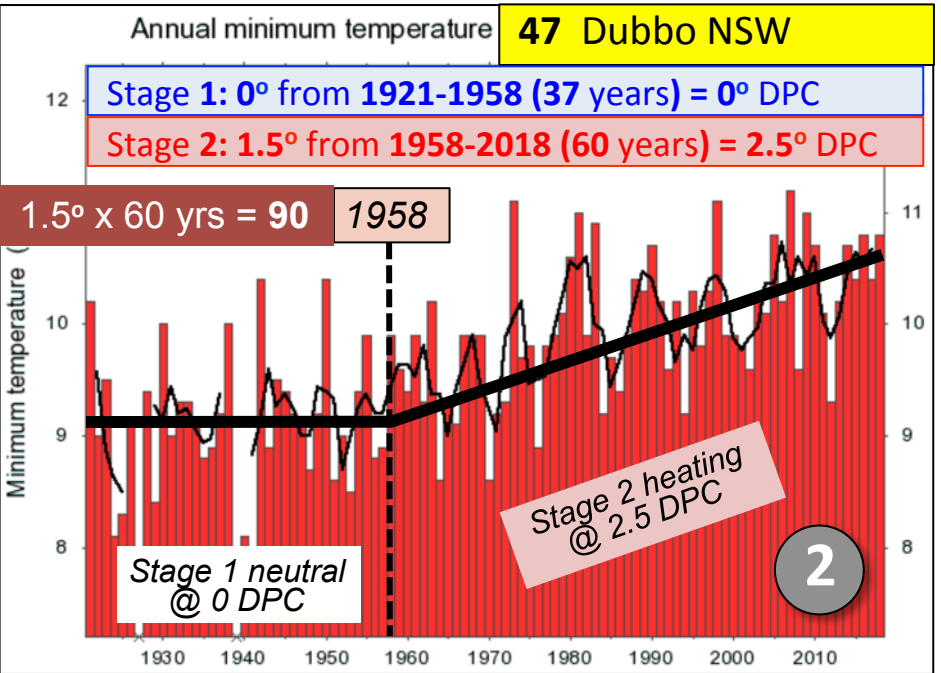

Annual minimum temperature
42 Bourke NSW
Stage 1: 0° from 1910-1973 (63 years) = 0° DPC
Stage 2: 1.6° from 1973-2018 (45 years) = 3.6° DPC
1.6° x 45 yrs = 72
1973
Stage 2 heating @ 3.6 DPC
Stage 1 neutral @ 0 DPC
3
Minimum temperature (°C)

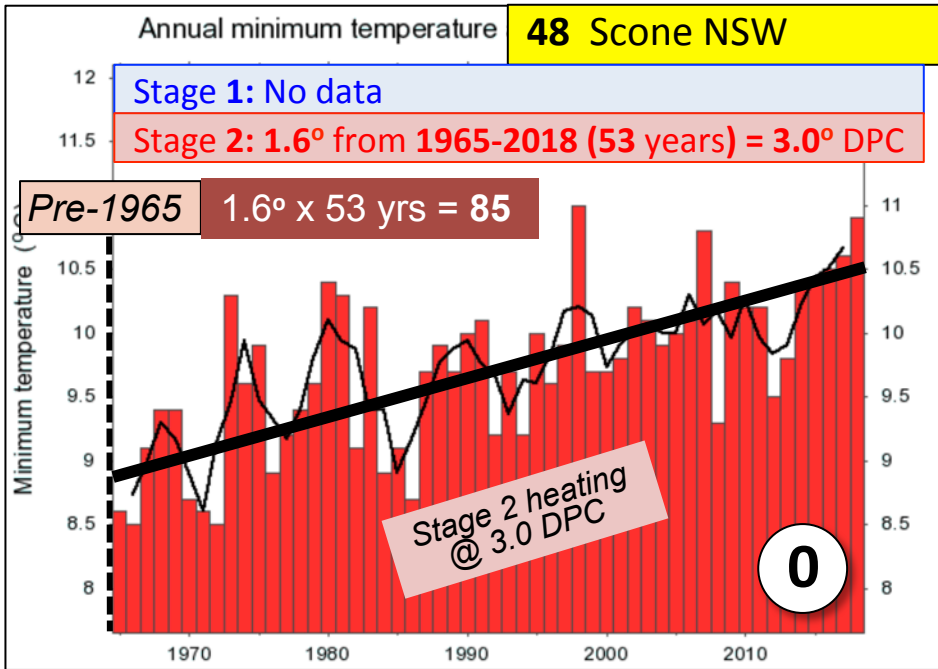

Annual minimum temperature
43 Walgett NSW
Stage 1: -0.5° from 1911-1961 (50 years) = -1.0° DPC
Stage 2: 2.1° from 1961-2018 (57 years) = 3.7° DPC
2.1° x 57 yrs = 120
1961
Stage 2 heating @ 3.7 DPC
Stage 1 cooling @ -1.0 DPC
3
Minimum temperature (°C)

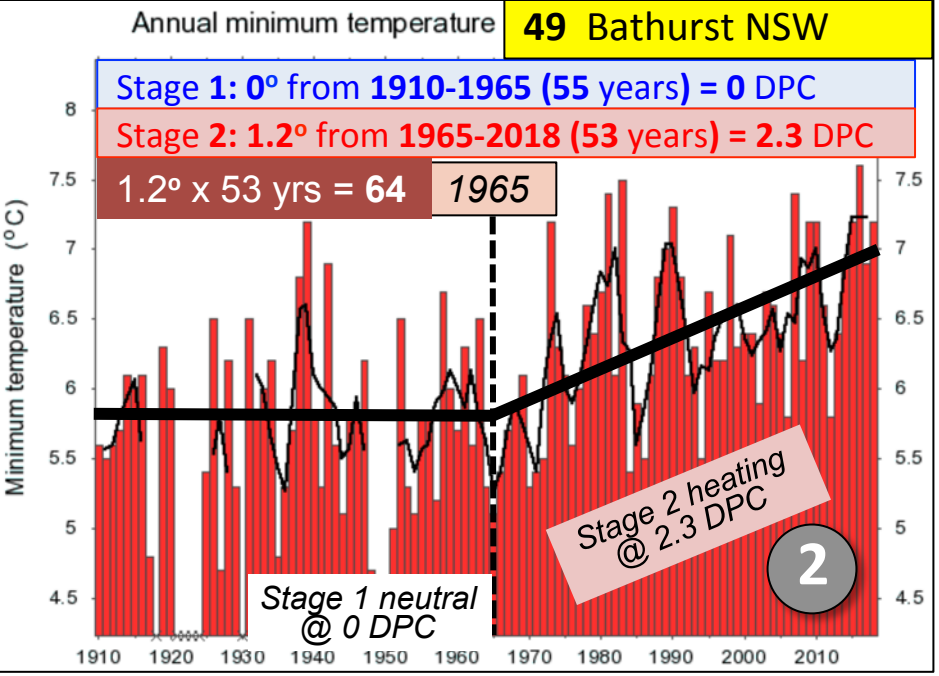

Annual minimum temperature
44 Inverell NSW
Stage 1: -0.5° from 1910-1945 (35 years) = -1.4 DPC
Stage 2: 2.5° from 1945-2018 (73 yrs) = 3.4 DPC
2.5° x 73 yrs = 183
1945
Stage 2 heating @ 3.4 DPC
Stage 1 cooling @ -1.4 DPC
3
Minimum temperature (°C)

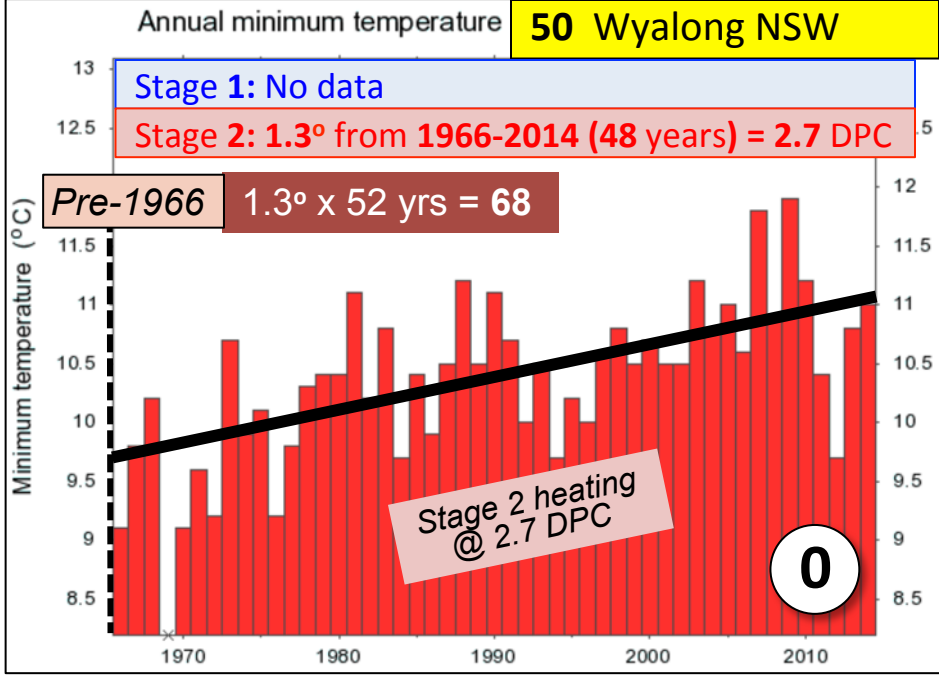

Annual minimum temperature
45 Gunnedah NSW
Stage 1: 0° from 1948-1971 (23 years) = 0° DPC
Stage 2: 1.4° from 1971-2018 (47 years) = 3.0° DPC
1.4° x 47 yrs = 66
1971
Minimum temperature (°C)
Stage 1 neutral @ 0 DPC
Stage 2 heating @ 3.0 DPC
3

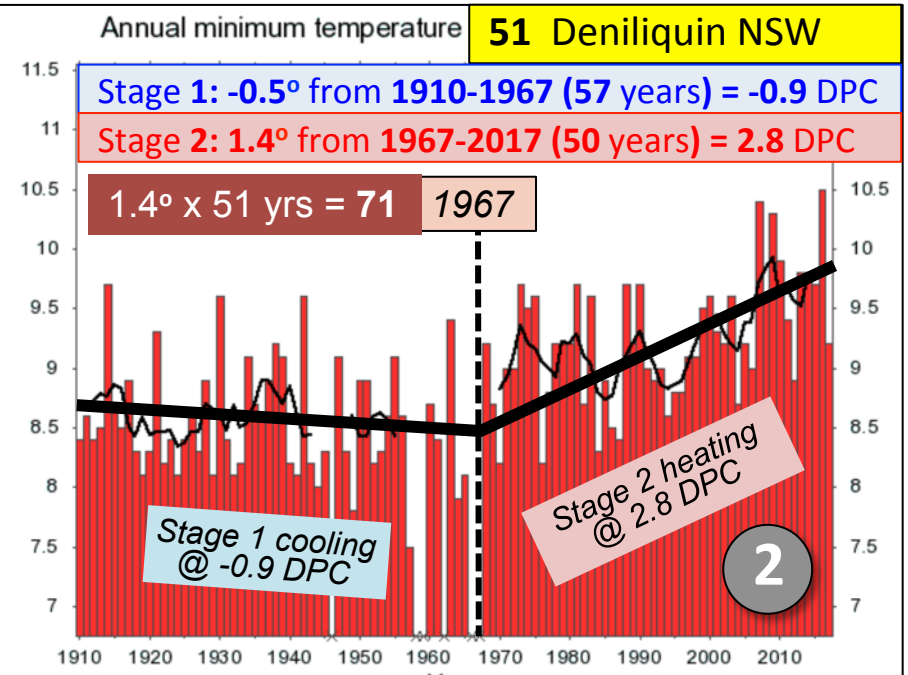

Annual minimum temperature
46 Cobar NSW
Stage 1: -0.6° from 1910-1958 (48 years) = -1.3 DPC
Stage 2: 1.5° from 1958-2018 (60 years) = 2.5 DPC
1958
1.5° x 60 yrs = 90
Minimum temperature (°C)
Stage 1 cooling @ -1.3 DPC
Stage 2 heating @ 2.5 DPC
3

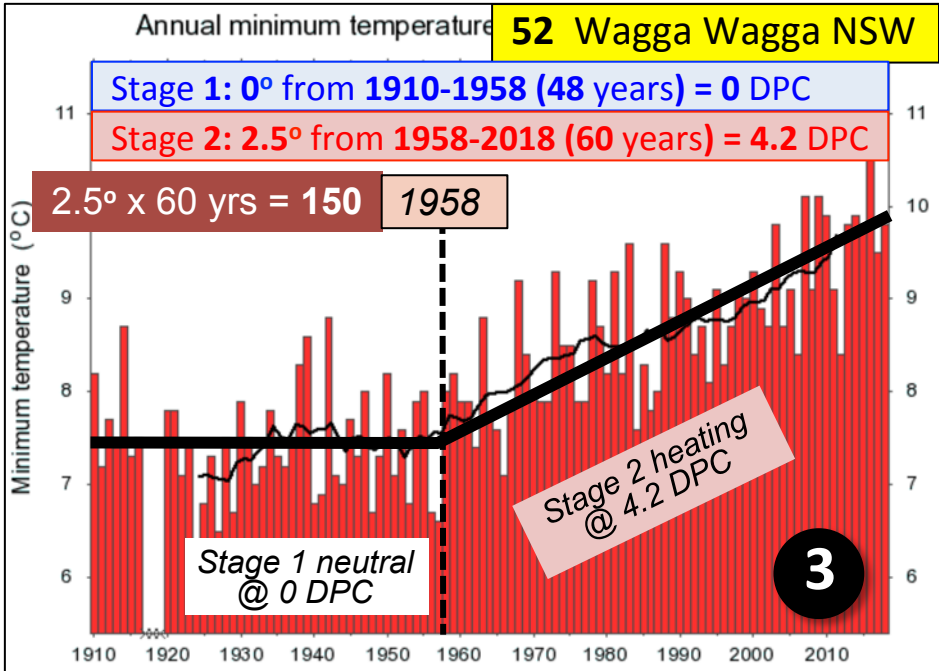

Annual minimum temperature
47 Dubbo NSW
Stage 1: 0° from 1921-1958 (37 years) = 0° DPC
Stage 2: 1.5° from 1958-2018 (60 years) = 2.5° DPC
1.5° x 60 yrs = 90
1958
Minimum temperature
Stage 1 neutral @ 0 DPC
Stage 2 heating @ 2.5 DPC
2

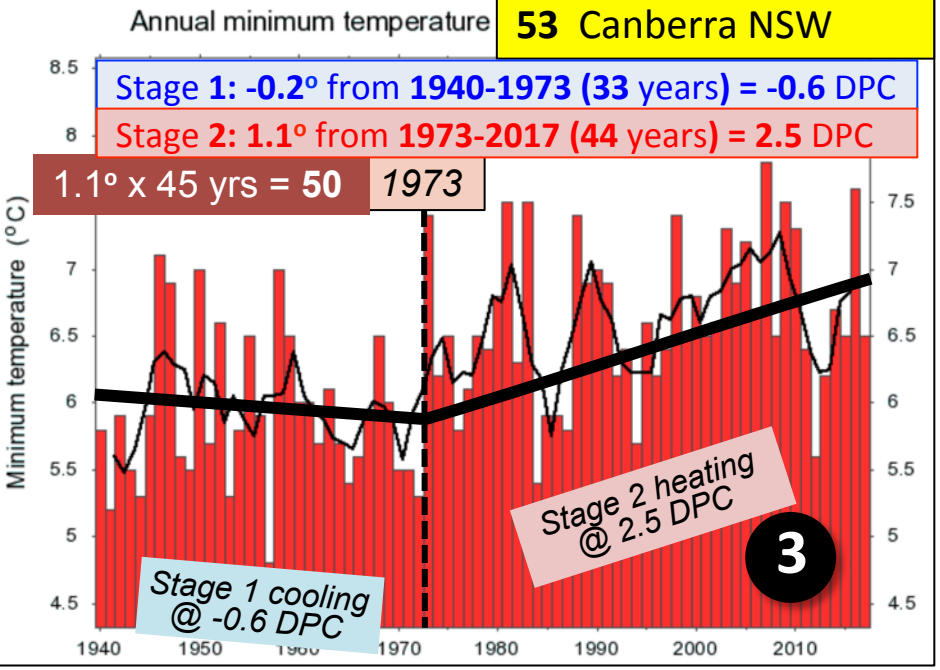

Annual minimum temperature
48 Scone NSW
Stage 1: No data
Stage 2: 1.6° from 1965-2018 (53 years) = 3.0° DPC
Pre-1965
1.6° x 53 yrs = 85
Minimum temperature
Stage 2 heating @ 3.0 DPC
0

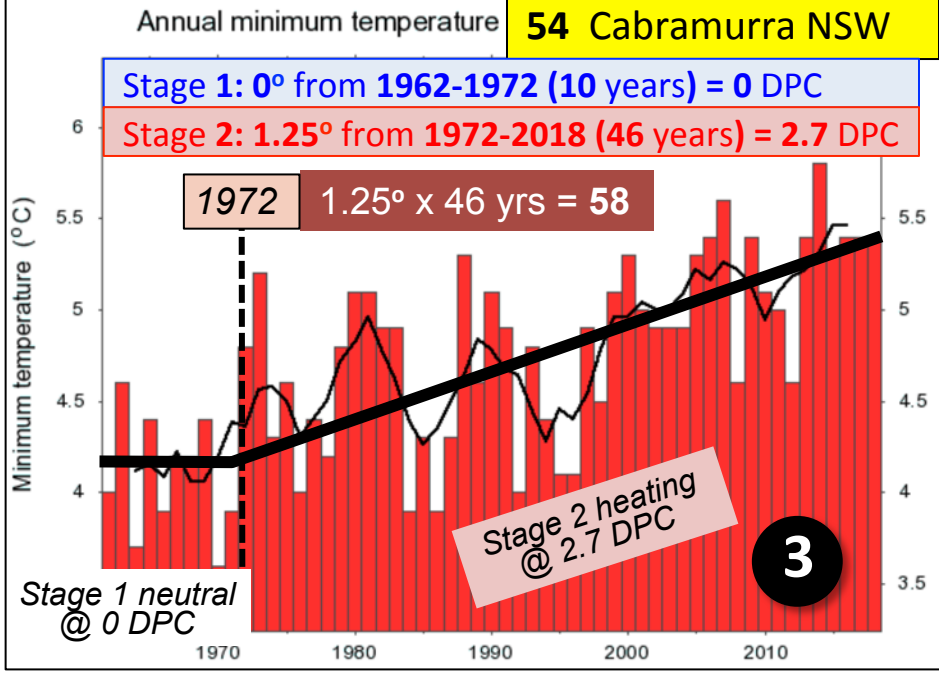

Annual minimum temperature
49 Bathurst NSW
Stage 1: 0° from 1910-1965 (55 years) = 0 DPC
Stage 2: 1.2° from 1965-2018 (53 years) = 2.3 DPC
1.2° x 53 yrs = 64
1965
Minimum temperature (°C)
Stage 2 heating @ 2.3 DPC
Stage 1 neutral @ 0 DPC
2

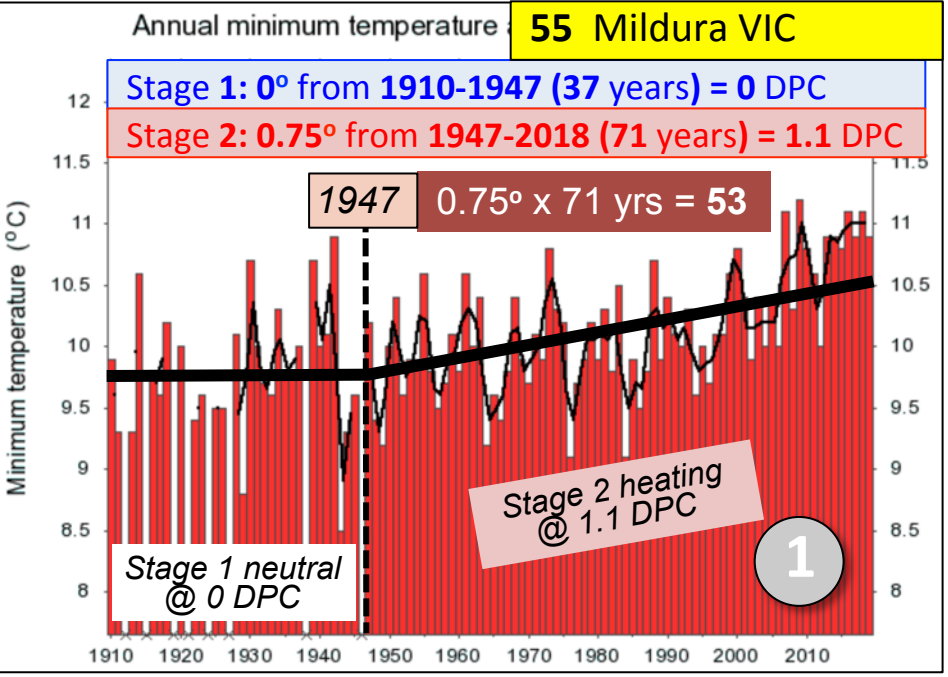

Annual minimum temperature
50 Wyalong NSW
Stage 1: No data
Stage 2: 1.3° from 1966-2014 (48 years) = 2.7 DPC
Pre-1966
1.3° x 52 yrs = 68
Minimum temperature (°C)
Stage 2 heating @ 2.7 DPC
0

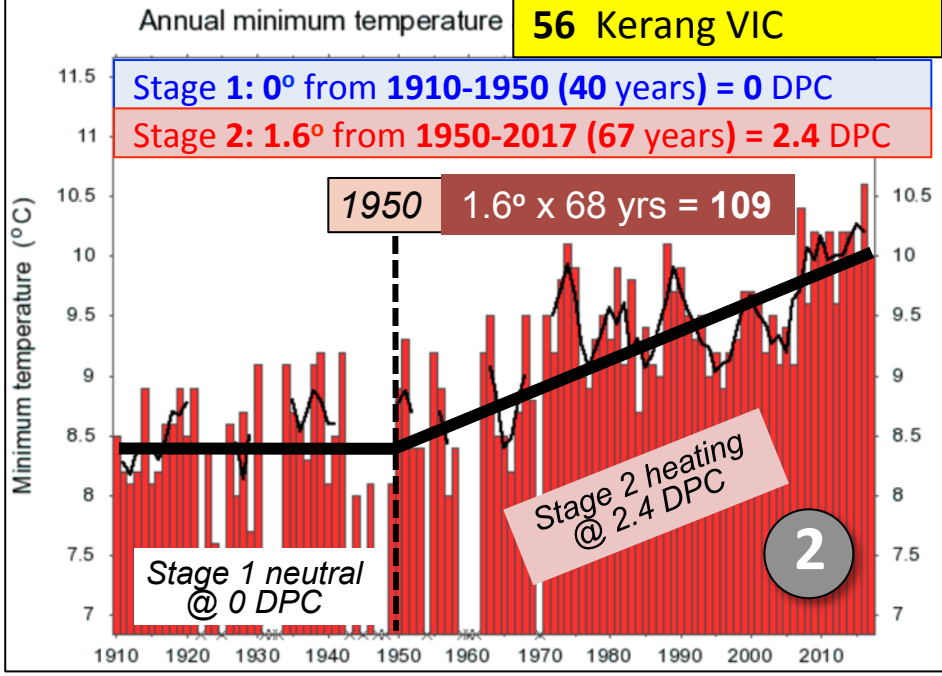

Annual minimum temperature
51 Deniliquin NSW
Stage 1: -0.5° from 1910-1967 (57 years) = -0.9 DPC
Stage 2: 1.4° from 1967-2017 (50 years) = 2.8 DPC
1.4° x 51 yrs = 71
1967
Stage 1 cooling @ -0.9 DPC
Stage 2 heating @ 2.8 DPC
2

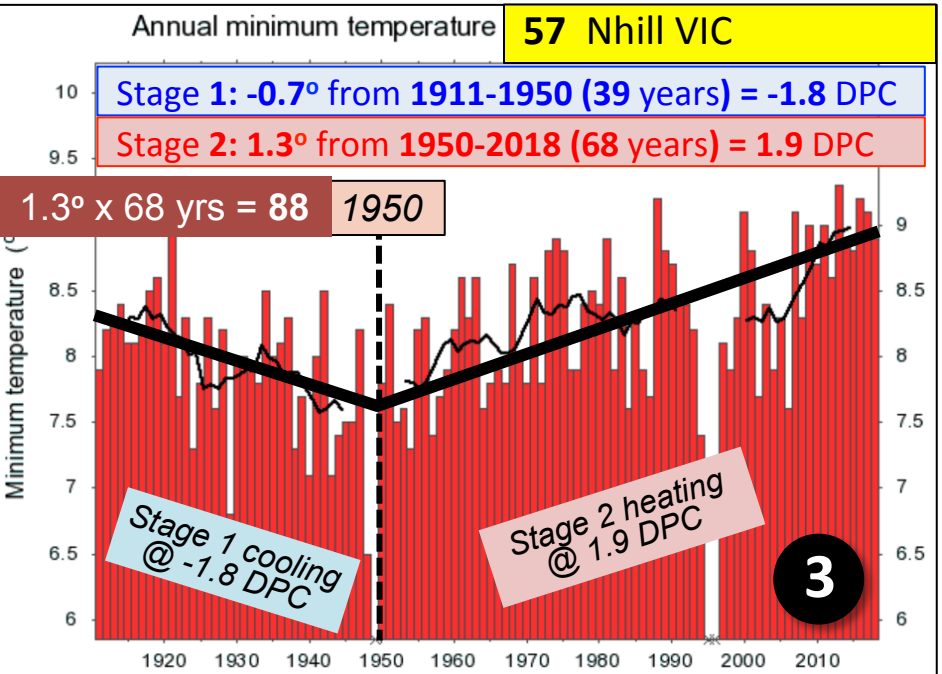

Annual minimum temperature
52 Wagga Wagga NSW
Stage 1: 0° from 1910-1958 (48 years) = 0 DPC
Stage 2: 2.5° from 1958-2018 (60 years) = 4.2 DPC
2.5° x 60 yrs = 150
1958
Minimum temperature (°C)
Stage 1 neutral @ 0 DPC
Stage 2 heating @ 4.2 DPC
3

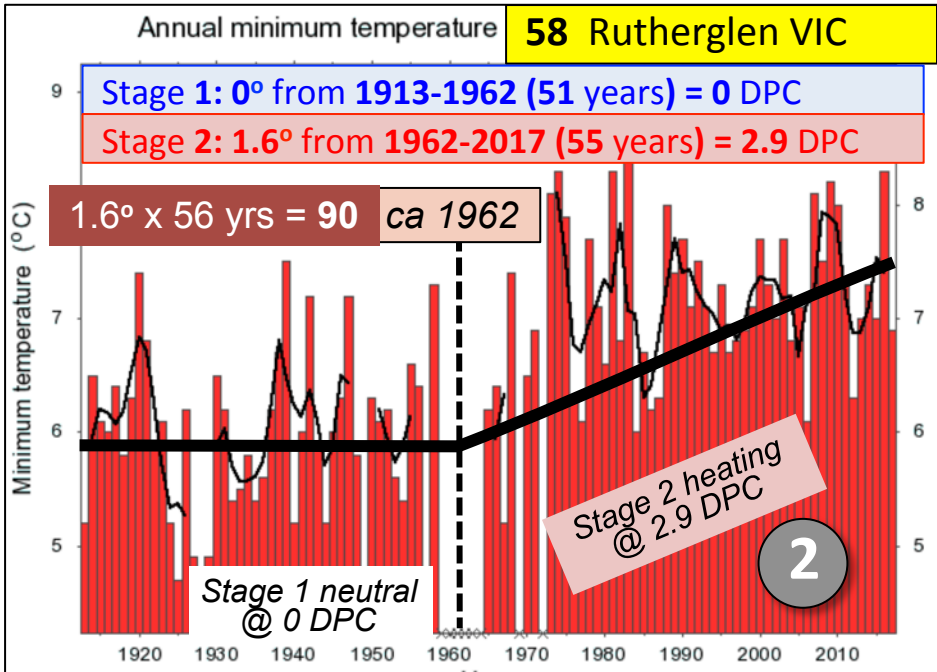

Annual minimum temperature
53 Canberra NSW
Stage 1: -0.2° from 1940-1973 (33 years) = -0.6 DPC
Stage 2: 1.1° from 1973-2017 (44 years) = 2.5 DPC
1.1° x 45 yrs = 50
1973
Minimum temperature (°C)
Stage 2 heating @ 2.5 DPC
Stage 1 cooling @ -0.6 DPC
3
8.5
8
7.5
7
6.5
6
5.5
5
4.5
1940
1950
1970
1980
1990
2000
2010

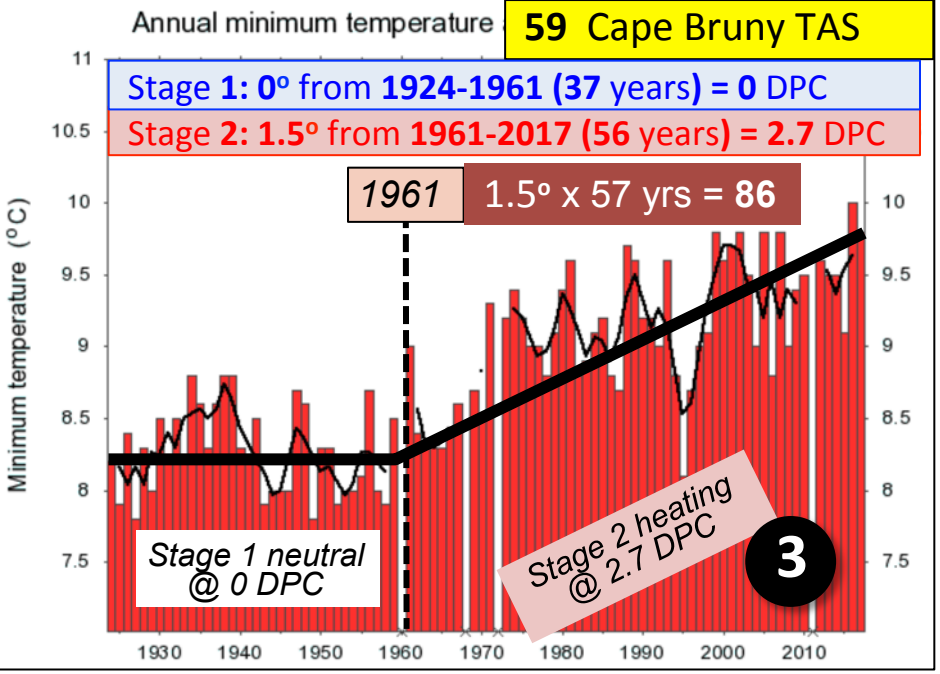

Annual minimum temperature
54 Cabramurra NSW
Stage 1: 0° from 1962-1972 (10 years) = 0 DPC
Stage 2: 1.25° from 1972-2018 (46 years) = 2.7 DPC
1972
1.25° x 46 yrs = 58
Minimum temperature (°C)
Stage 2 heating @ 2.7 DPC
Stage 1 neutral @ 0 DPC
3
6
5.5
5
4.5
4
3.5
1970
1980
1990
2000
2010

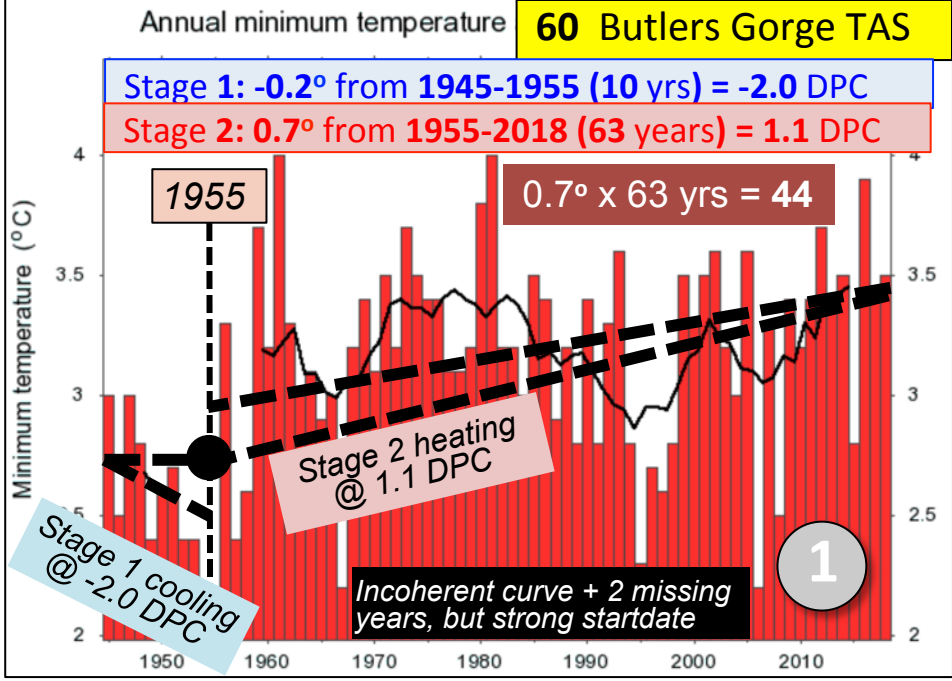

Annual minimum temperature
55 Mildura VIC
Stage 1: 0° from 1910-1947 (37 years) = 0 DPC
Stage 2: 0.75° from 1947-2018 (71 years) = 1.1 DPC
1947
0.75° x 71 yrs = 53
Stage 2 heating @ 1.1 DPC
Stage 1 neutral @ 0 DPC
1
Minimum temperature (°C)

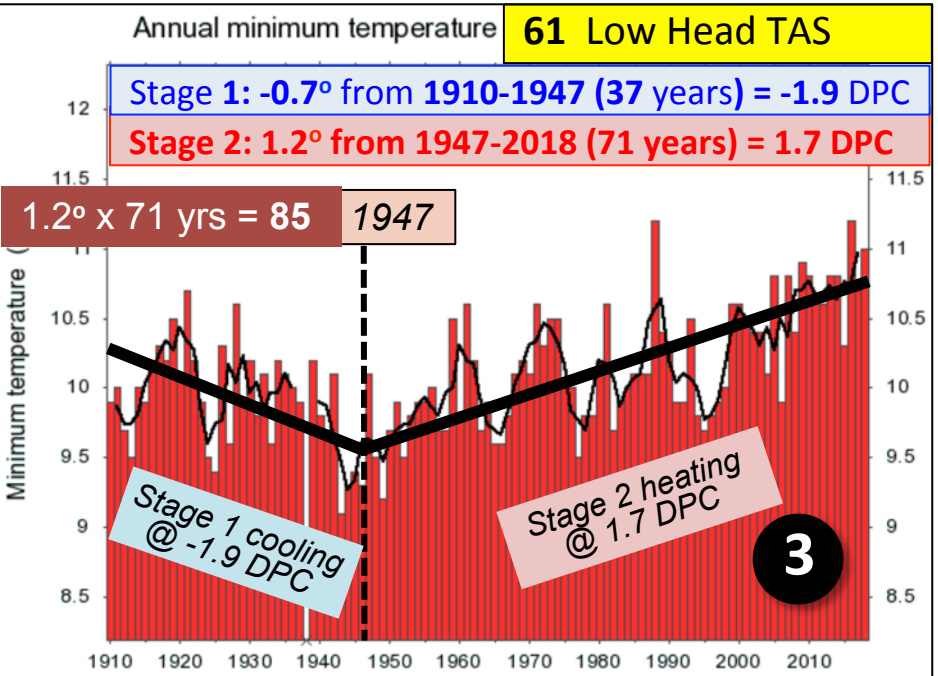

Annual minimum temperature
56 Kerang VIC
Stage 1: 0° from 1910-1950 (40 years) = 0 DPC
Stage 2: 1.6° from 1950-2017 (67 years) = 2.4 DPC
1950
1.6° x 68 yrs = 109
Stage 2 heating @ 2.4 DPC
Stage 1 neutral @ 0 DPC
2
Minimum temperature (°C)

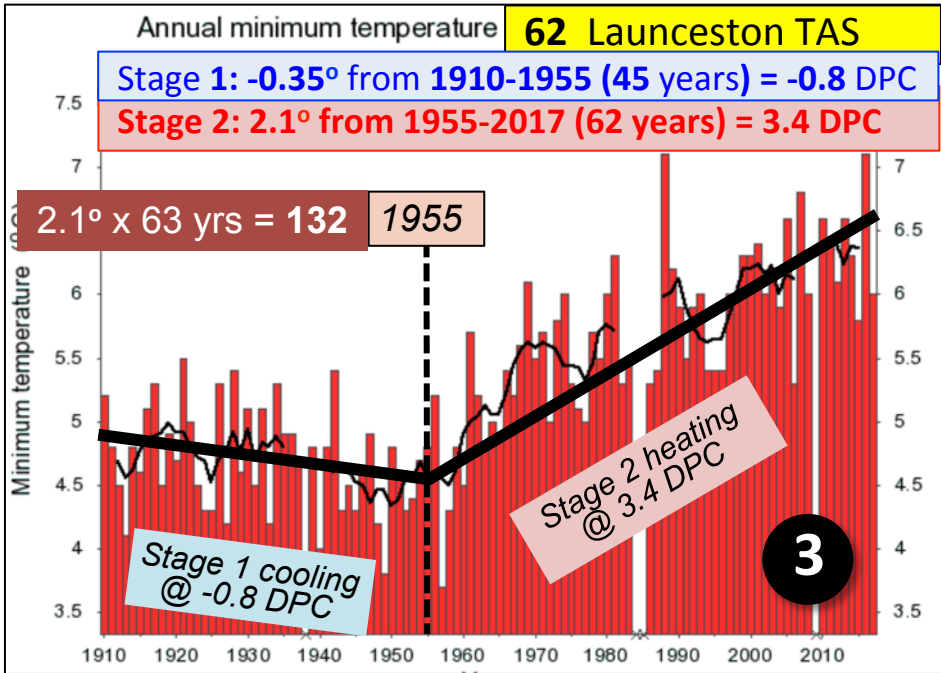

Annual minimum temperature
57 Nhill VIC
Stage 1: -0.7° from 1911-1950 (39 years) = -1.8 DPC
Stage 2: 1.3° from 1950-2018 (68 years) = 1.9 DPC
1.3° x 68 yrs = 88
1950
Stage 1 cooling @ -1.8 DPC
Stage 2 heating @ 1.9 DPC
3
Minimum temperature

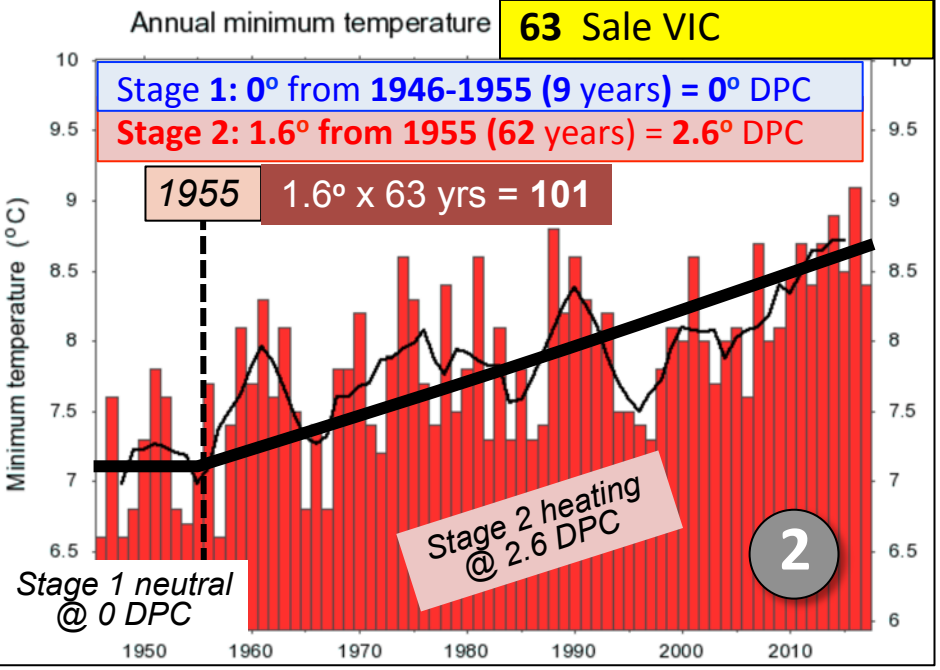

Annual minimum temperature
58 Rutherglen VIC
Stage 1: 0° from 1913-1962 (51 years) = 0 DPC
Stage 2: 1.6° from 1962-2017 (55 years) = 2.9 DPC
1.6° x 56 yrs = 90
ca 1962
Stage 2 heating @ 2.9 DPC
Stage 1 neutral @ 0 DPC
2
Minimum temperature (°C)

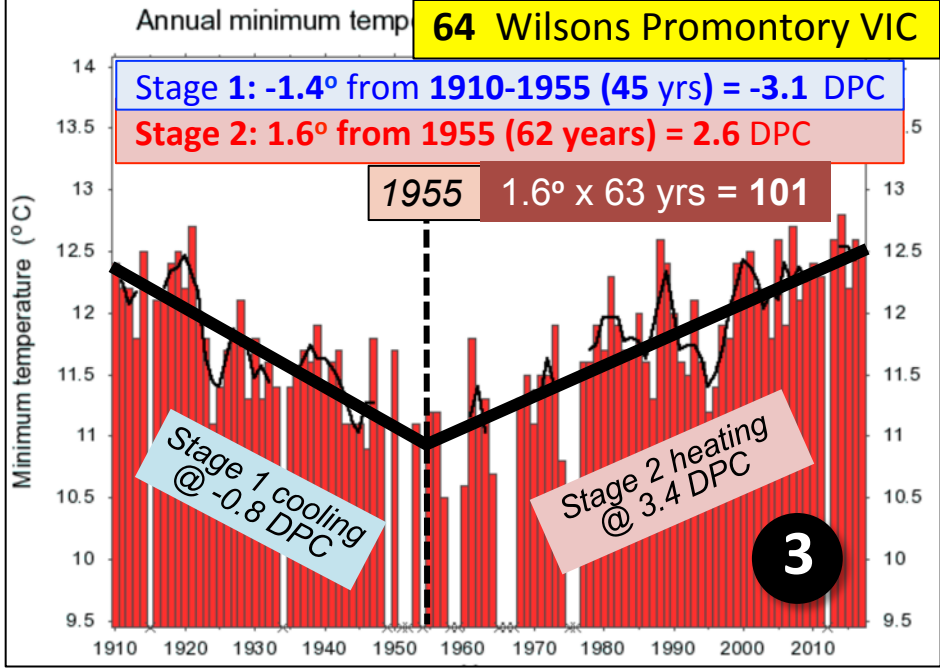

Annual minimum temperature
59 Cape Bruny TAS
Stage 1: 0° from 1924-1961 (37 years) = 0 DPC
Stage 2: 1.5° from 1961-2017 (56 years) = 2.7 DPC
1961
1.5° x 57 yrs = 86
Minimum temperature (°C)
Stage 1 neutral @ 0 DPC
Stage 2 heating @ 2.7 DPC
3

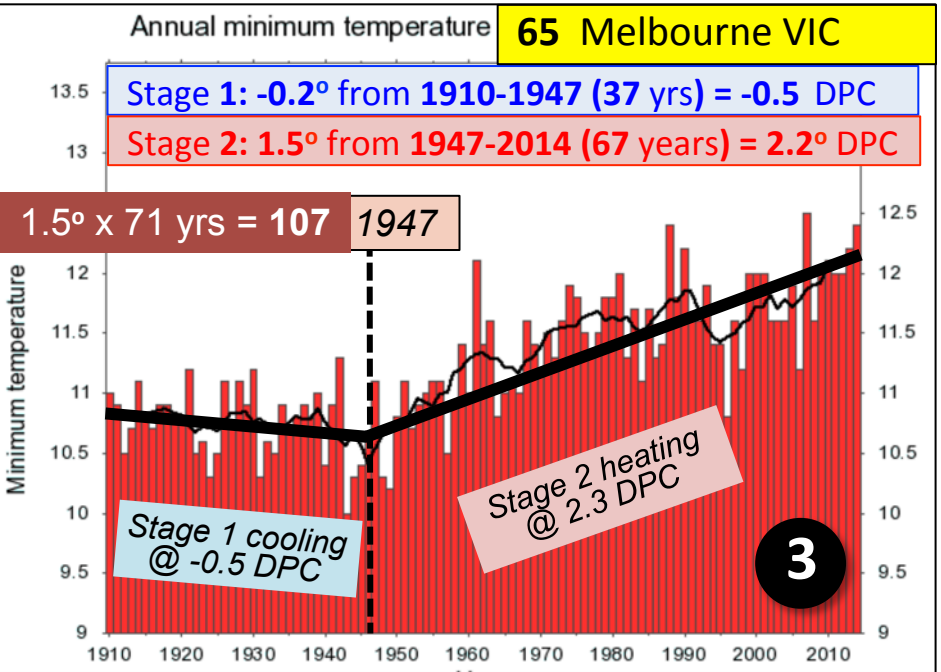

Annual minimum temperature
60 Butlers Gorge TAS
Stage 1: -0.2° from 1945-1955 (10 yrs) = -2.0 DPC
Stage 2: 0.7° from 1955-2018 (63 years) = 1.1 DPC
1955
0.7° x 63 yrs = 44
Minimum temperature (°C)
Stage 2 heating @ 1.1 DPC
Stage 1 cooling @ -2.0 DPC
Incoherent curve + 2 missing years, but strong startdate
1

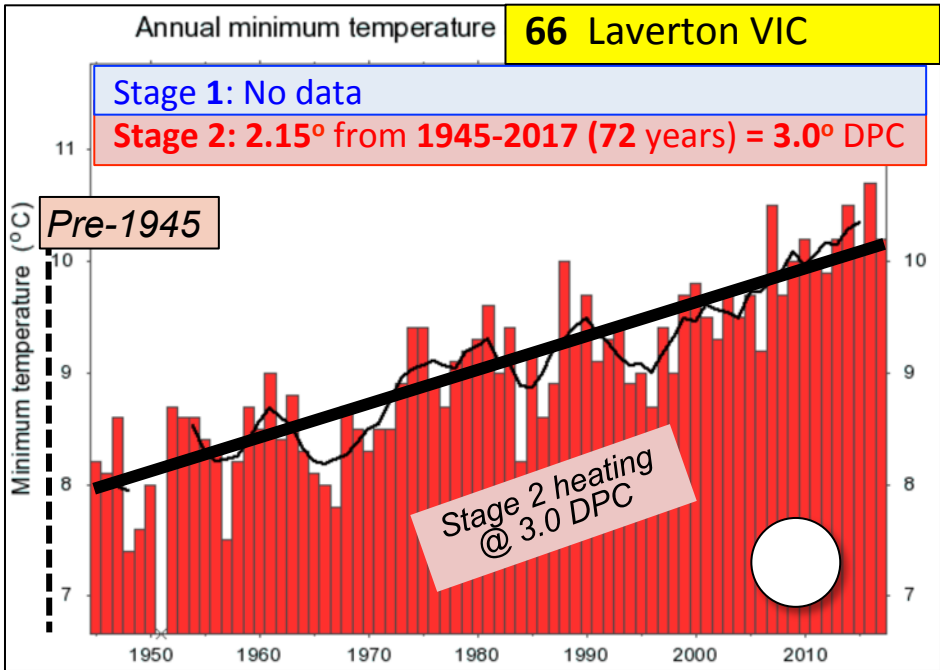

Annual minimum temperature
61 Low Head TAS
Stage 1: -0.7° from 1910-1947 (37 years) = -1.9 DPC
Stage 2: 1.2° from 1947-2018 (71 years) = 1.7 DPC
1.2° x 71 yrs = 85
1947
Minimum temperature
Stage 1 cooling @ -1.9 DPC
Stage 2 heating @ 1.7 DPC
3

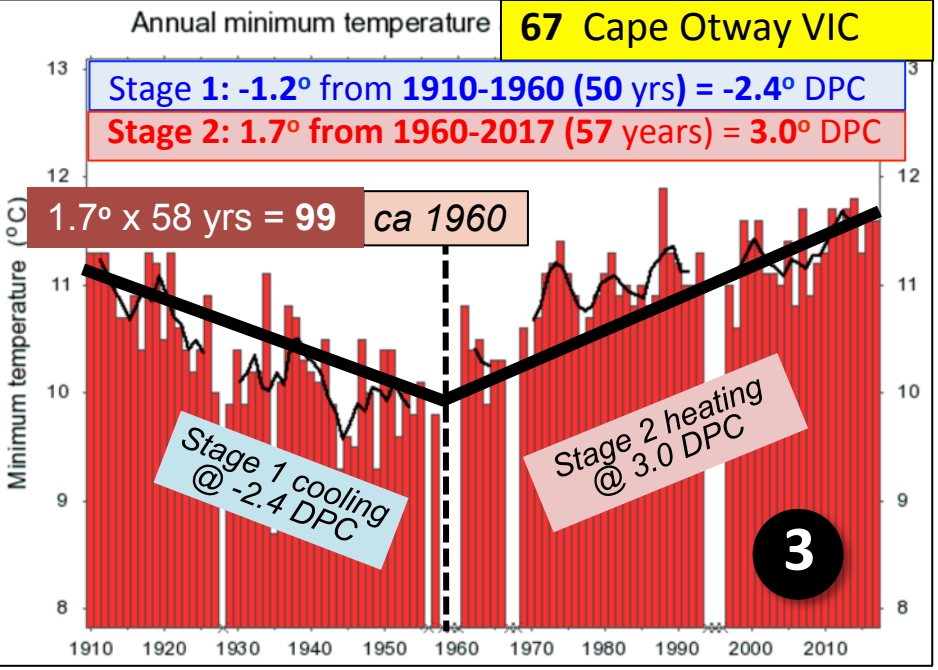

Annual minimum temperature
62 Launceston TAS
Stage 1: -0.35° from 1910-1955 (45 years) = -0.8 DPC
Stage 2: 2.1° from 1955-2017 (62 years) = 3.4 DPC
2.1° x 63 yrs = 132
1955
Minimum temperature
Stage 1 cooling @ -0.8 DPC
Stage 2 heating @ 3.4 DPC
3

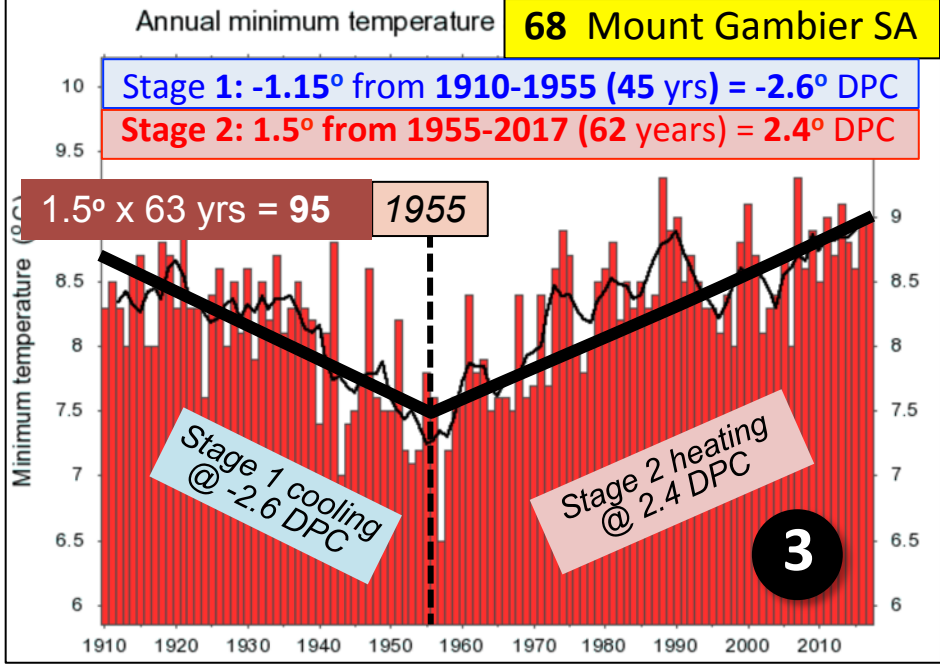

Annual minimum temperature
63 Sale VIC
Stage 1: 0° from 1946-1955 (9 years) = 0° DPC
Stage 2: 1.6° from 1955 (62 years) = 2.6° DPC
1955
1.6° x 63 yrs = 101
Minimum temperature (°C)
Stage 2 heating @ 2.6 DPC
2
Stage 1 neutral @ 0 DPC

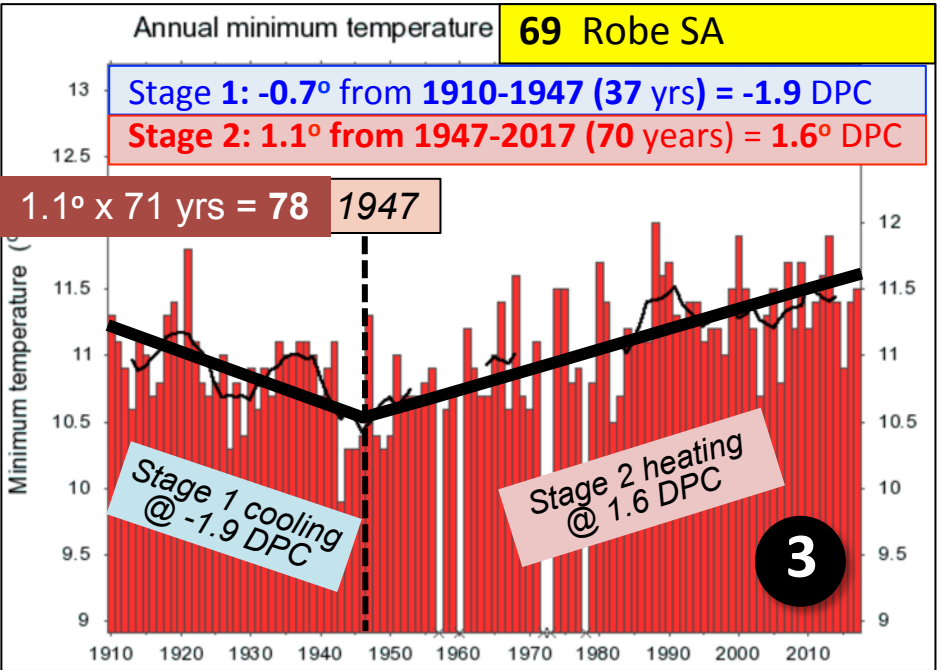

Annual minimum temp
64 Wilsons Promontory VIC
Stage 1: -1.4° from 1910-1955 (45 yrs) = -3.1 DPC
Stage 2: 1.6° from 1955 (62 years) = 2.6 DPC
1955
1.6° x 63 yrs = 101
Minimum temperature (°C)
Stage 1 cooling @ -0.8 DPC
Stage 2 heating @ 3.4 DPC
3

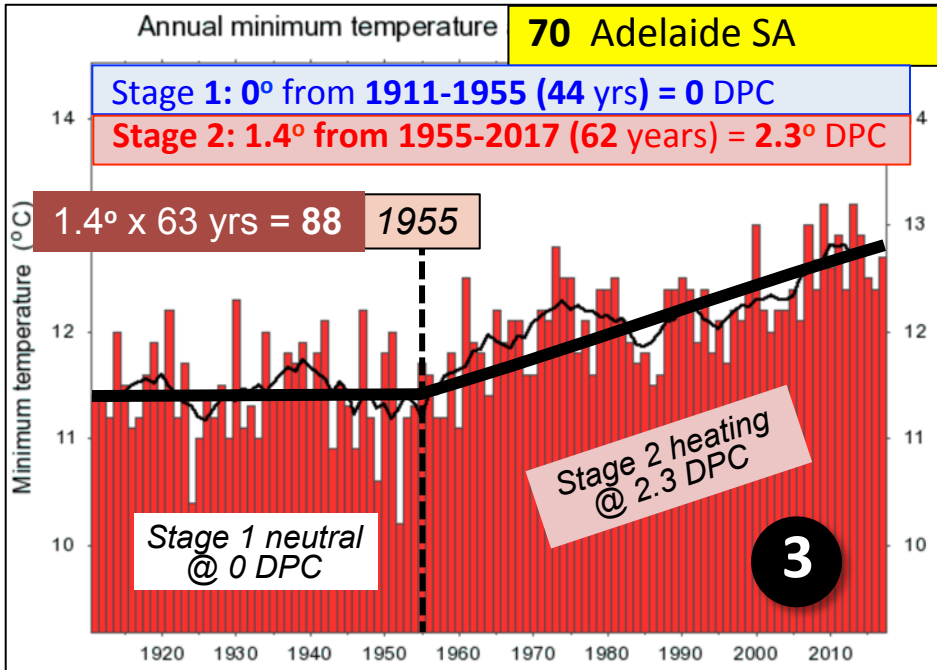

Annual minimum temperature
65 Melbourne VIC
Stage 1: -0.2° from 1910-1947 (37 yrs) = -0.5 DPC
Stage 2: 1.5° from 1947-2014 (67 years) = 2.2° DPC
1.5° x 71 yrs = 107
1947
Minimum temperature
Stage 1 cooling @ -0.5 DPC
Stage 2 heating @ 2.3 DPC
3

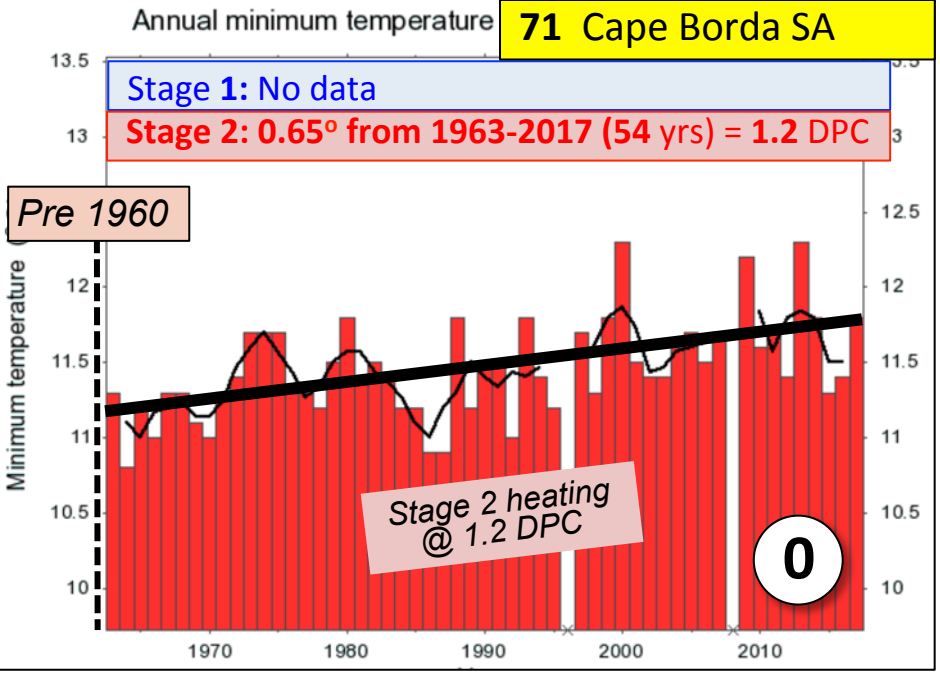

Annual minimum temperature
66 Laverton VIC
Stage 1: No data
Stage 2: 2.15° from 1945-2017 (72 years) = 3.0° DPC
Pre-1945
Minimum temperature (°C)
Stage 2 heating @ 3.0 DPC

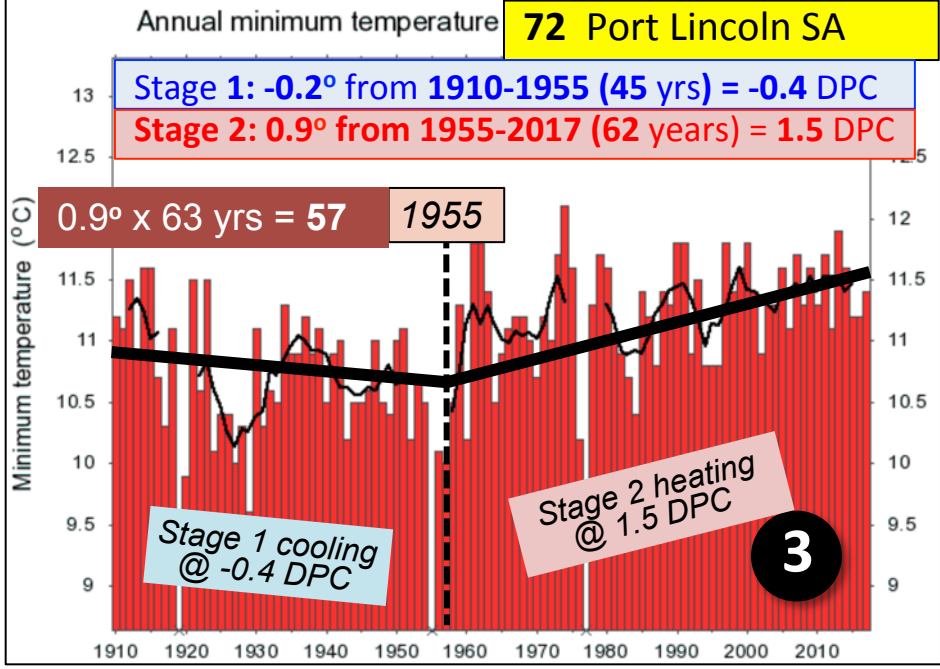

Annual minimum temperature
67 Cape Otway VIC
Stage 1: -1.2° from 1910-1960 (50 yrs) = -2.4° DPC
Stage 2: 1.7° from 1960-2017 (57 years) = 3.0° DPC
1.7° x 58 yrs = 99
ca 1960
Stage 1 cooling @ -2.4 DPC
Stage 2 heating @ 3.0 DPC
3
Minimum temperature (°C)

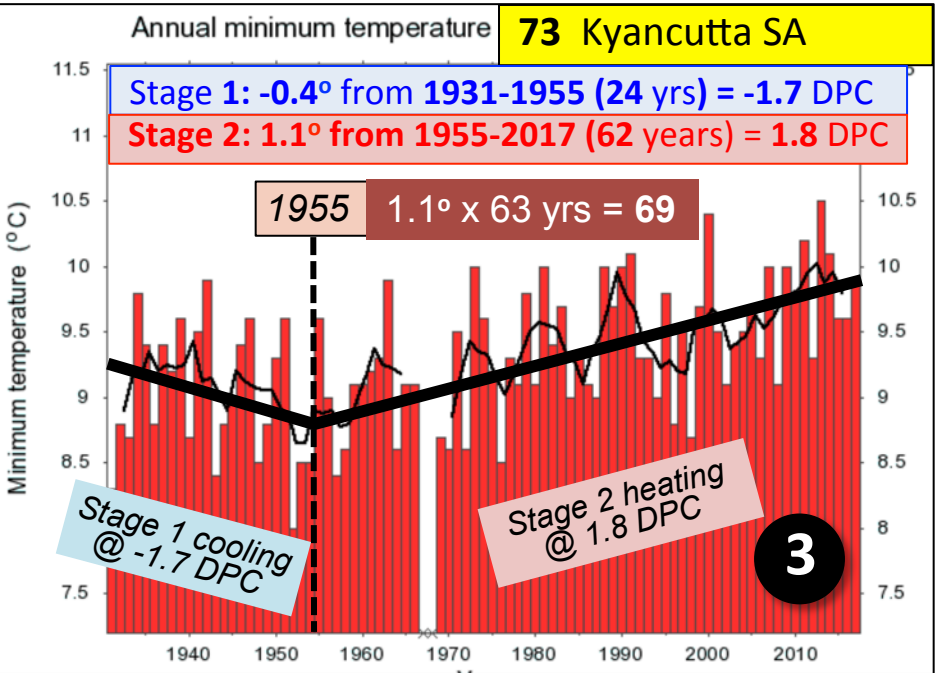

Annual minimum temperature
68 Mount Gambier SA
Stage 1: -1.15° from 1910-1955 (45 yrs) = -2.6° DPC
Stage 2: 1.5° from 1955-2017 (62 years) = 2.4° DPC
1.5° x 63 yrs = 95
1955
Stage 1 cooling @ -2.6 DPC
Stage 2 heating @ 2.4 DPC
3
Minimum temperature (°C)

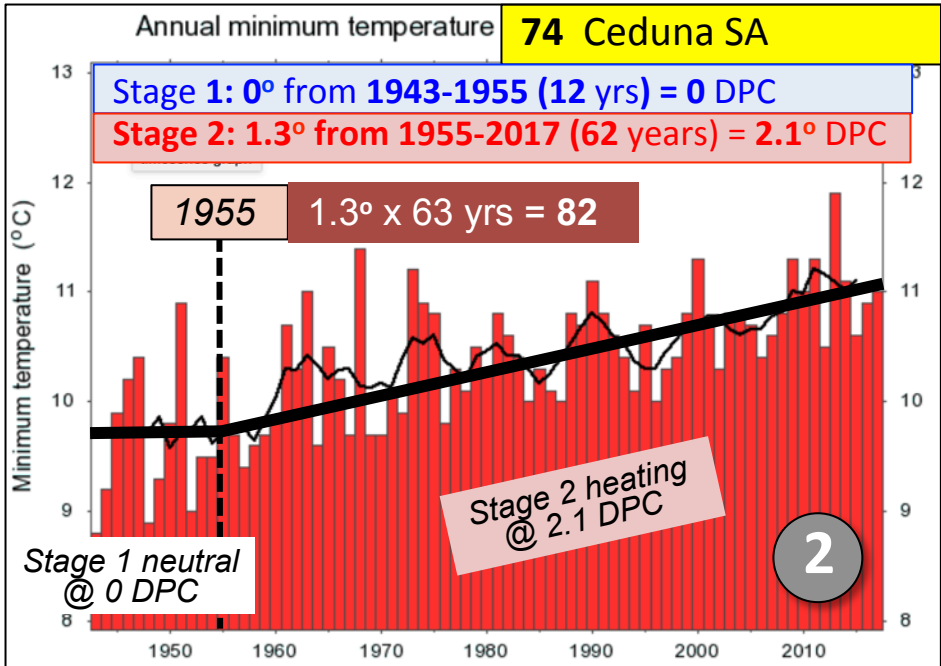

Annual minimum temperature
69 Robe SA
Stage 1: -0.7° from 1910-1947 (37 yrs) = -1.9 DPC
Stage 2: 1.1° from 1947-2017 (70 years) = 1.6° DPC
1.1° x 71 yrs = 78
1947
Stage 1 cooling @ -1.9 DPC
Stage 2 heating @ 1.6 DPC
3
Minimum temperature (°C)

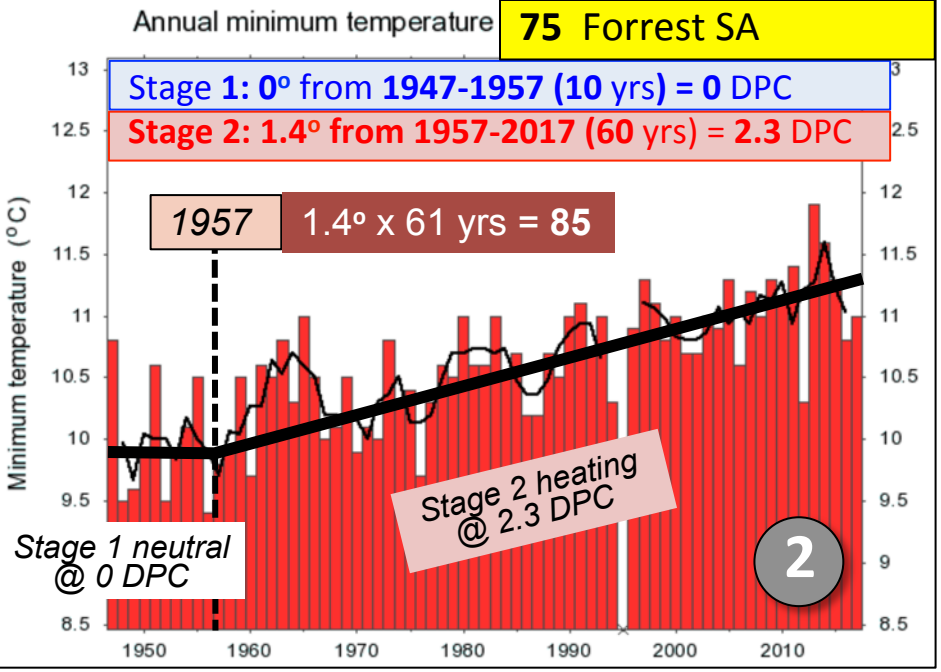

Annual minimum temperature
70 Adelaide SA
Stage 1: 0° from 1911-1955 (44 yrs) = 0 DPC
Stage 2: 1.4° from 1955-2017 (62 years) = 2.3° DPC
1.4° x 63 yrs = 88
1955
Stage 1 neutral @ 0 DPC
Stage 2 heating @ 2.3 DPC
3
Minimum temperature (°C)

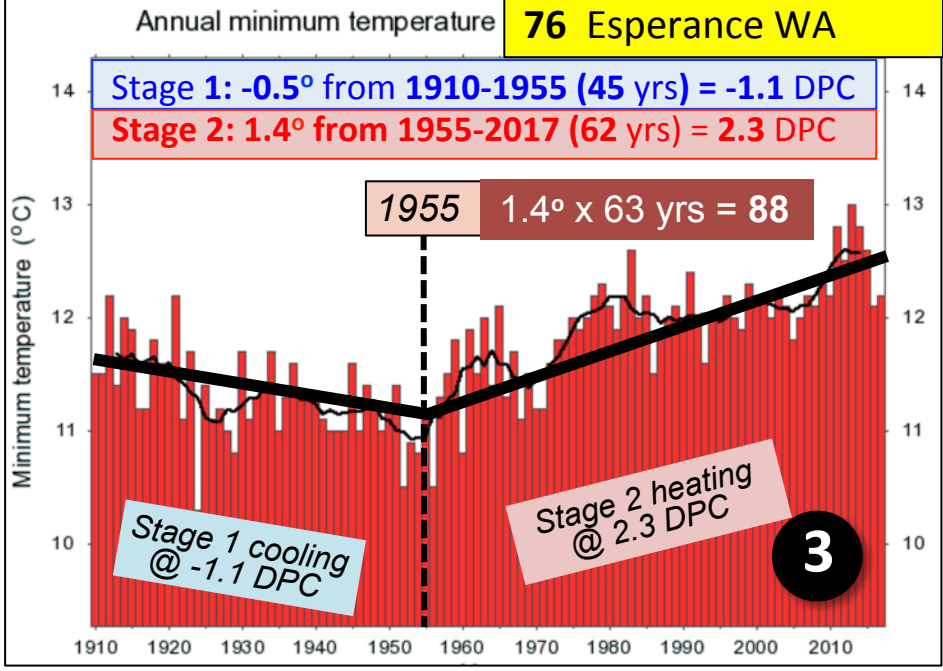

Annual minimum temperature
71 Cape Borda SA
Stage 1: No data
Stage 2: 0.65° from 1963-2017 (54 yrs) = 1.2 DPC
Pre 1960
Minimum temperature
Stage 2 heating @ 1.2 DPC
0

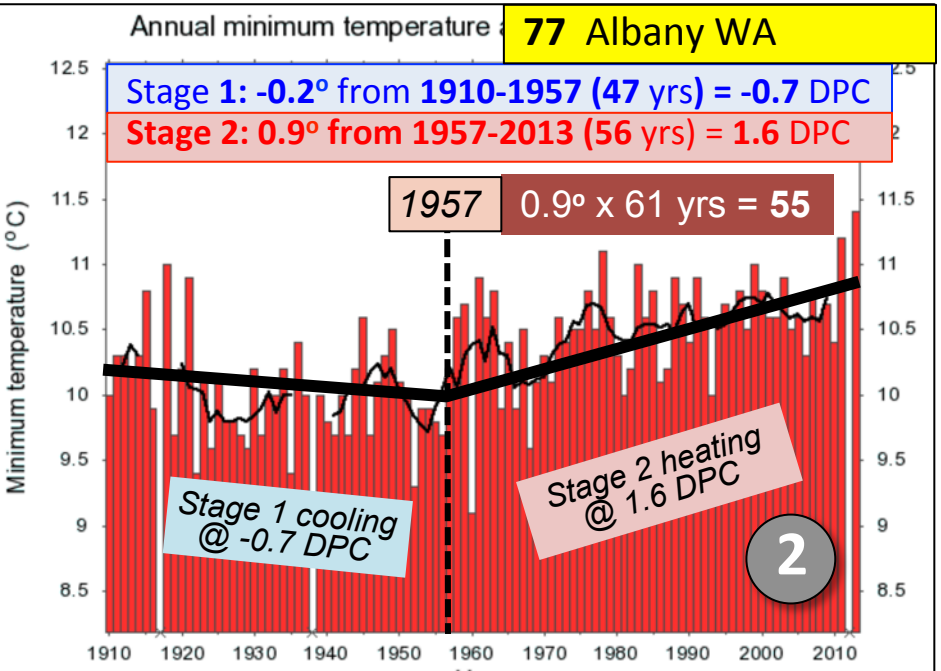

Annual minimum temperature
72 Port Lincoln SA
Stage 1: -0.2° from 1910-1955 (45 yrs) = -0.4 DPC
Stage 2: 0.9° from 1955-2017 (62 years) = 1.5 DPC
0.9° x 63 yrs = 57
1955
Minimum temperature (°C)
Stage 1 cooling @ -0.4 DPC
Stage 2 heating @ 1.5 DPC
3

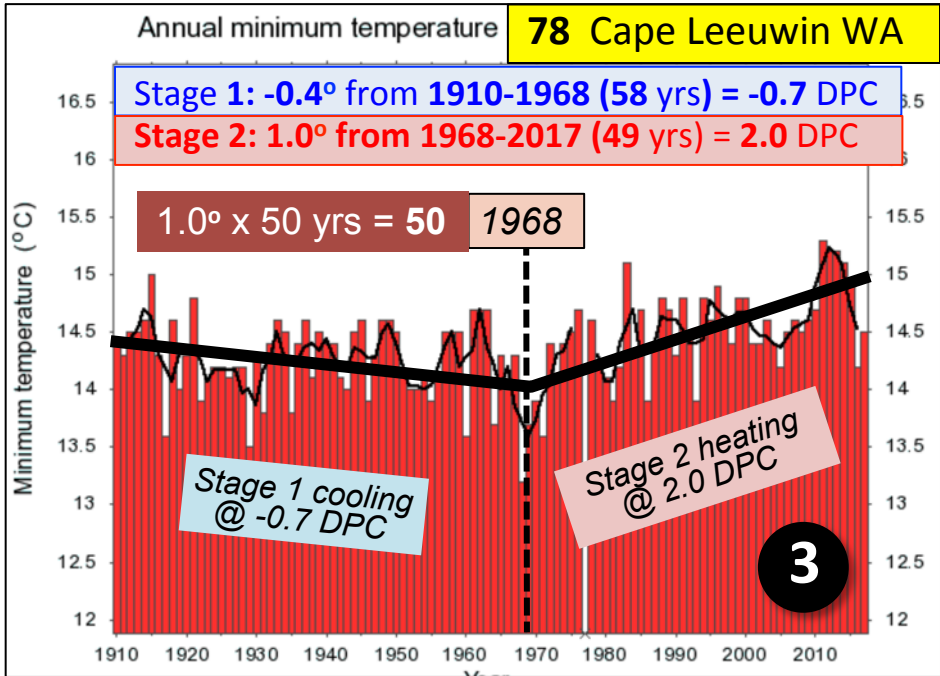

Annual minimum temperature
73 Kyancutta SA
Stage 1: -0.4° from 1931-1955 (24 yrs) = -1.7 DPC
Stage 2: 1.1° from 1955-2017 (62 years) = 1.8 DPC
1955
1.1° x 63 yrs = 69
Minimum temperature (°C)
Stage 1 cooling @ -1.7 DPC
Stage 2 heating @ 1.8 DPC
3

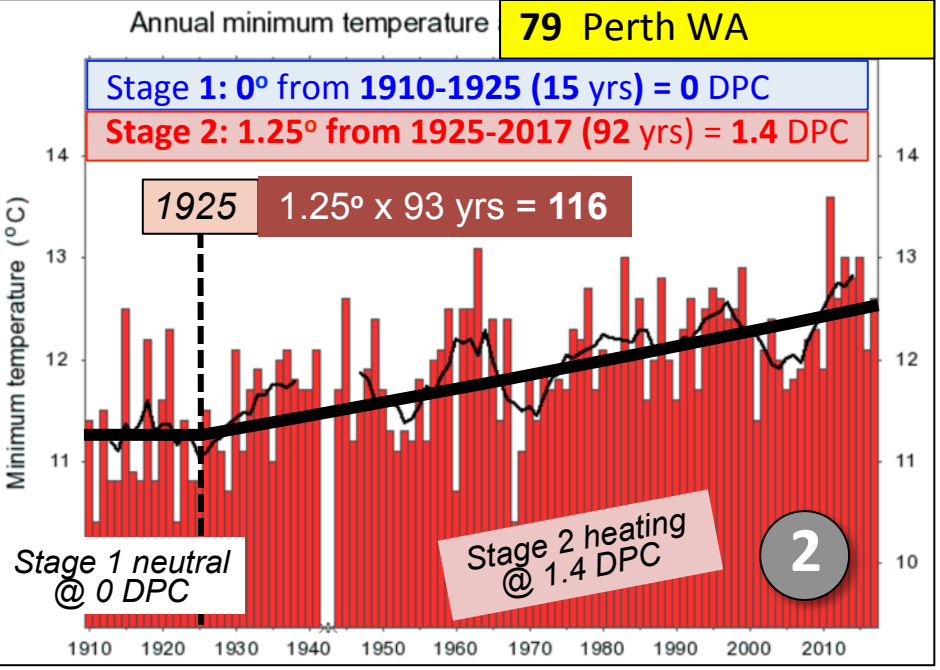

Annual minimum temperature
74 Ceduna SA
Stage 1: 0° from 1943-1955 (12 yrs) = 0 DPC
Stage 2: 1.3° from 1955-2017 (62 years) = 2.1° DPC
1955
1.3° x 63 yrs = 82
Minimum temperature (°C)
Stage 1 neutral @ 0 DPC
Stage 2 heating @ 2.1 DPC
2

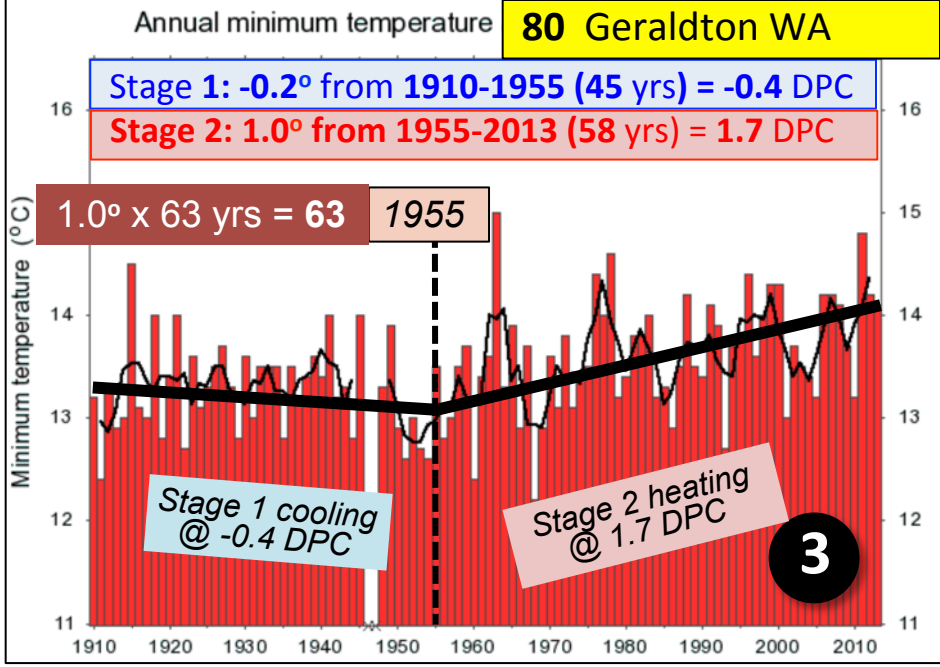

Annual minimum temperature
75 Forrest SA
Stage 1: 0° from 1947-1957 (10 yrs) = 0 DPC
Stage 2: 1.4° from 1957-2017 (60 yrs) = 2.3 DPC
1957
1.4° x 61 yrs = 85
Stage 2 heating @ 2.3 DPC
Stage 1 neutral @ 0 DPC
2
Minimum temperature (°C)

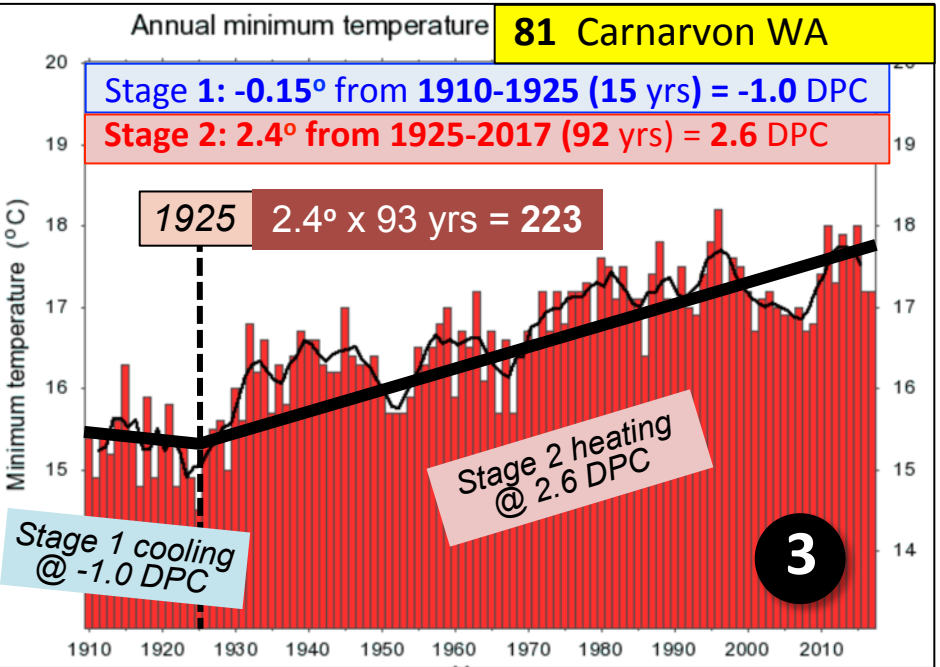

Annual minimum temperature
76 Esperance WA
Stage 1: -0.5° from 1910-1955 (45 yrs) = -1.1 DPC
Stage 2: 1.4° from 1955-2017 (62 yrs) = 2.3 DPC
1955
1.4° x 63 yrs = 88
Stage 1 cooling @ -1.1 DPC
Stage 2 heating @ 2.3 DPC
3
Minimum temperature (°C)

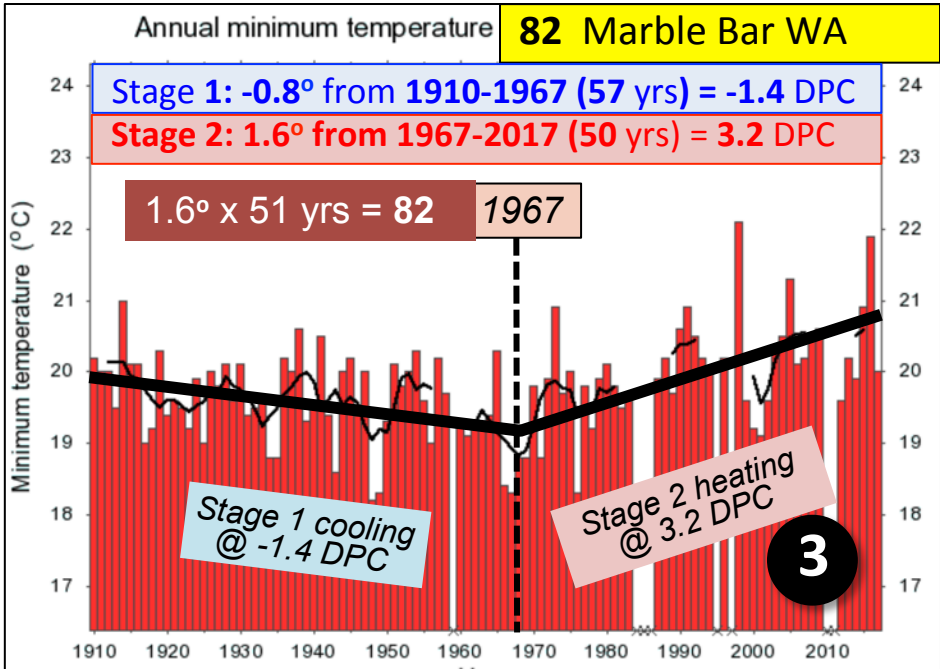

Annual minimum temperature
77 Albany WA
Stage 1: -0.2° from 1910-1957 (47 yrs) = -0.7 DPC
Stage 2: 0.9° from 1957-2013 (56 yrs) = 1.6 DPC
1957
0.9° x 61 yrs = 55
Stage 1 cooling @ -0.7 DPC
Stage 2 heating @ 1.6 DPC
2
Minimum temperature (°C)

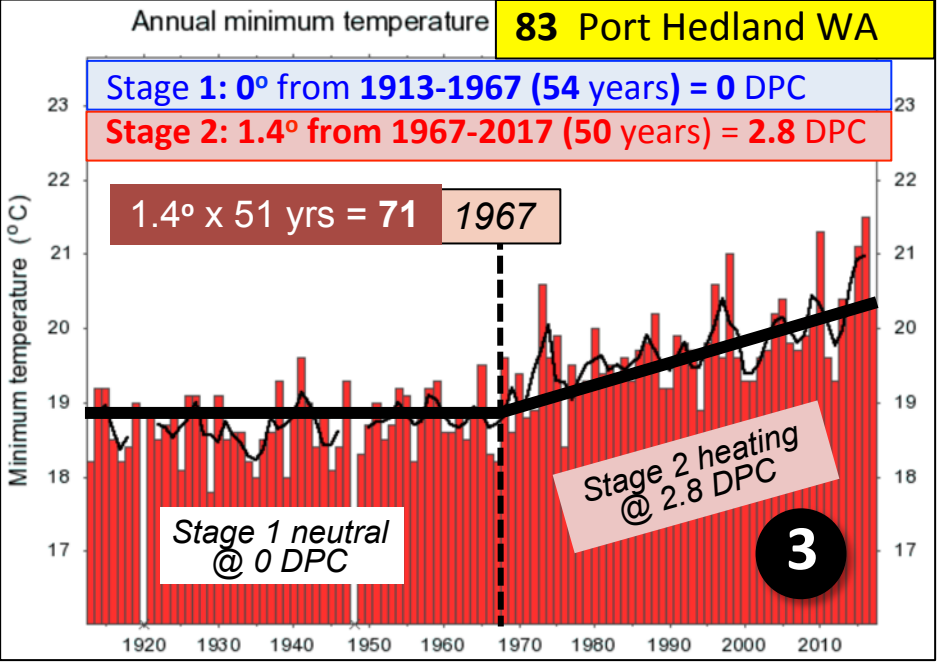

Annual minimum temperature
78 Cape Leeuwin WA
Stage 1: -0.4° from 1910-1968 (58 yrs) = -0.7 DPC
Stage 2: 1.0° from 1968-2017 (49 yrs) = 2.0 DPC
1.0° x 50 yrs = 50
1968
Stage 1 cooling @ -0.7 DPC
Stage 2 heating @ 2.0 DPC
3
Minimum temperature (°C)

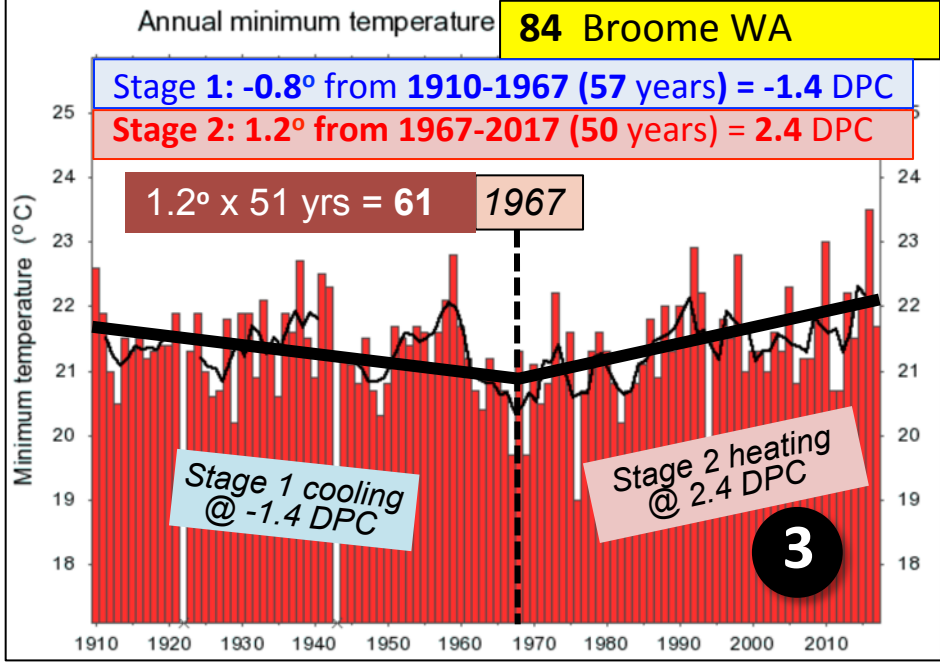

Annual minimum temperature
79 Perth WA
Stage 1: 0° from 1910-1925 (15 yrs) = 0 DPC
Stage 2: 1.25° from 1925-2017 (92 yrs) = 1.4 DPC
1925
1.25° x 93 yrs = 116
Minimum temperature (°C)
Stage 1 neutral @ 0 DPC
Stage 2 heating @ 1.4 DPC
2

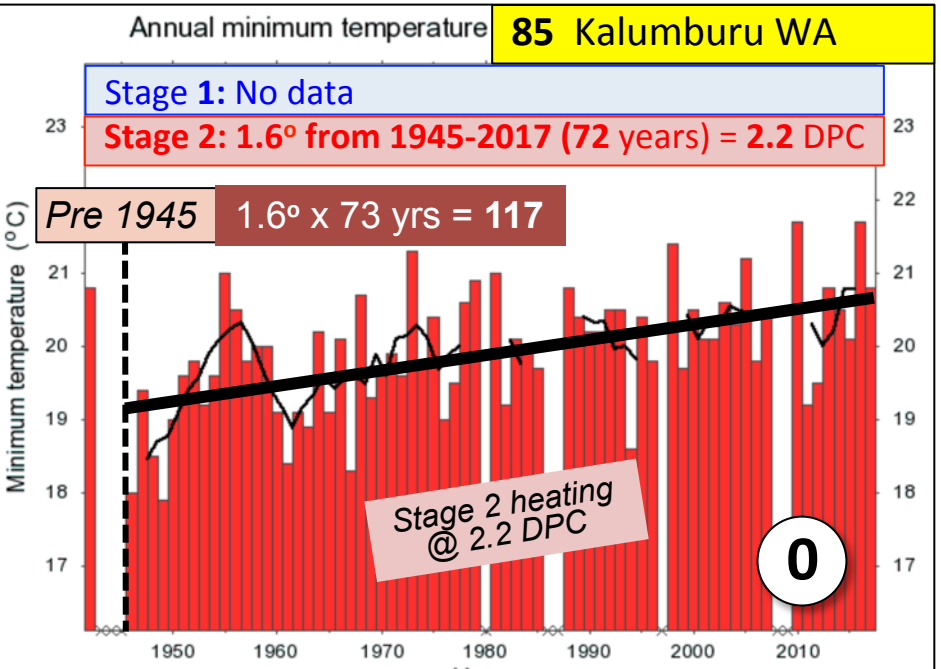

Annual minimum temperature
80 Geraldton WA
Stage 1: -0.2° from 1910-1955 (45 yrs) = -0.4 DPC
Stage 2: 1.0° from 1955-2013 (58 yrs) = 1.7 DPC
1.0° x 63 yrs = 63
1955
Minimum temperature (°C)
Stage 1 cooling @ -0.4 DPC
Stage 2 heating @ 1.7 DPC
3

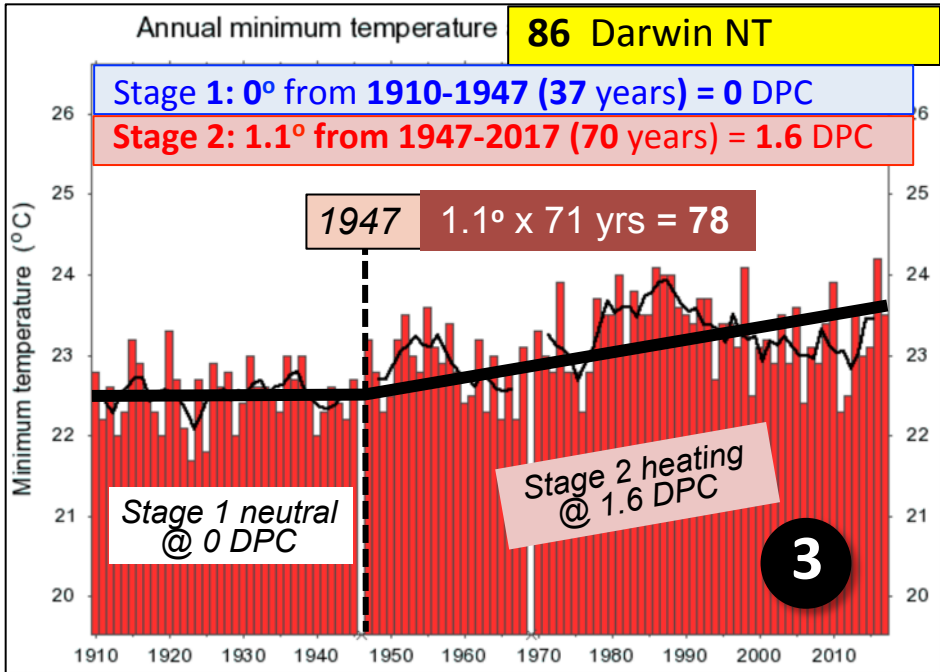

Annual minimum temperature
81 Carnarvon WA
Stage 1: -0.15° from 1910-1925 (15 yrs) = -1.0 DPC
Stage 2: 2.4° from 1925-2017 (92 yrs) = 2.6 DPC
1925
2.4° x 93 yrs = 223
Minimum temperature (°C)
Stage 1 cooling @ -1.0 DPC
Stage 2 heating @ 2.6 DPC
3

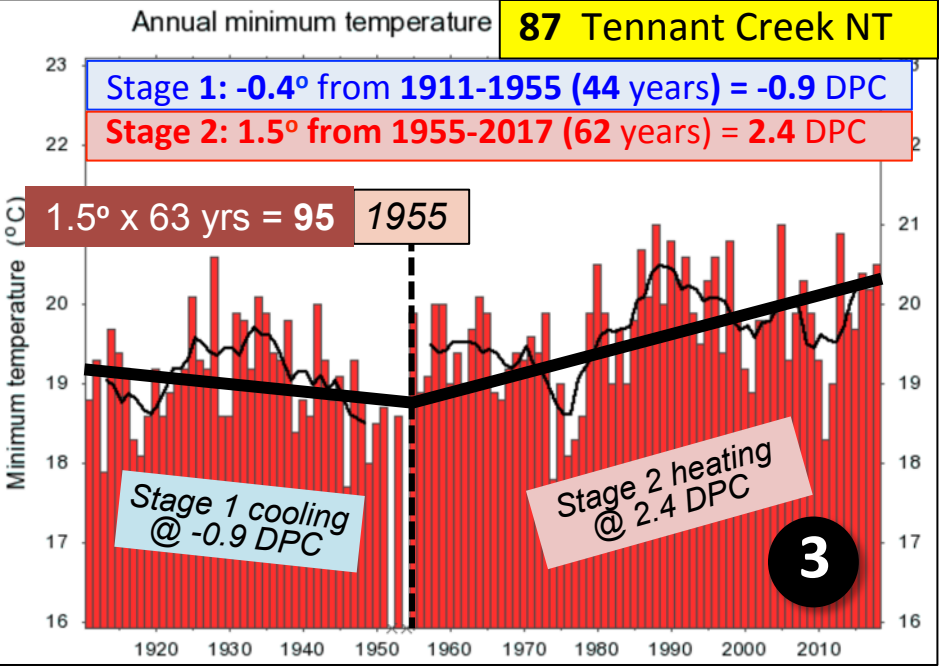

Annual minimum temperature
82 Marble Bar WA
Stage 1: -0.8° from 1910-1967 (57 yrs) = -1.4 DPC
Stage 2: 1.6° from 1967-2017 (50 yrs) = 3.2 DPC
1.6° x 51 yrs = 82
1967
Minimum temperature (°C)
Stage 1 cooling @ -1.4 DPC
Stage 2 heating @ 3.2 DPC
3

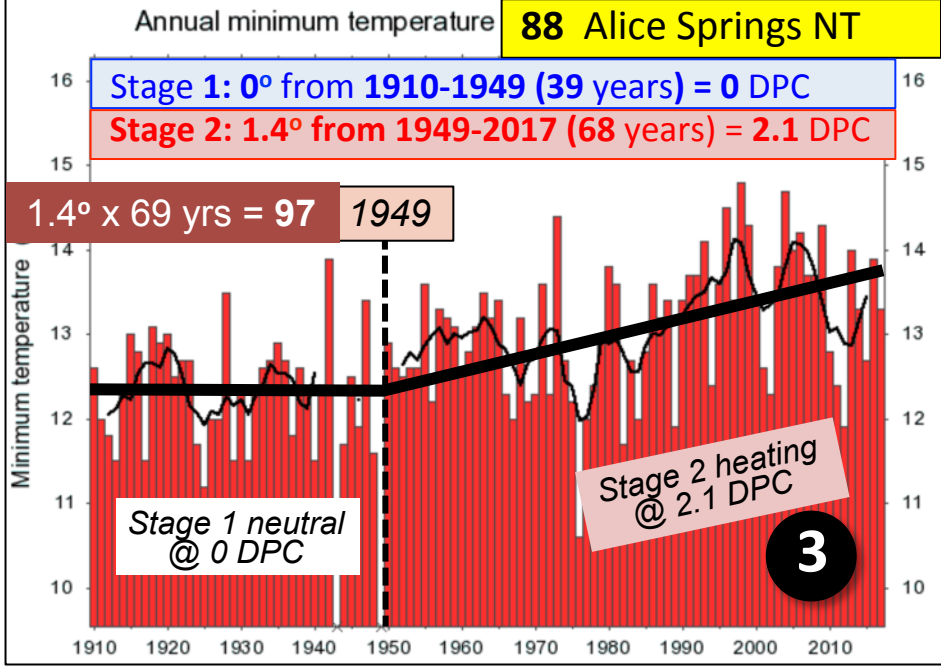

Annual minimum temperature
83 Port Hedland WA
Stage 1: 0° from 1913-1967 (54 years) = 0 DPC
Stage 2: 1.4° from 1967-2017 (50 years) = 2.8 DPC
1.4° x 51 yrs = 71
1967
Stage 1 neutral @ 0 DPC
Stage 2 heating @ 2.8 DPC
3
Minimum temperature (°C)

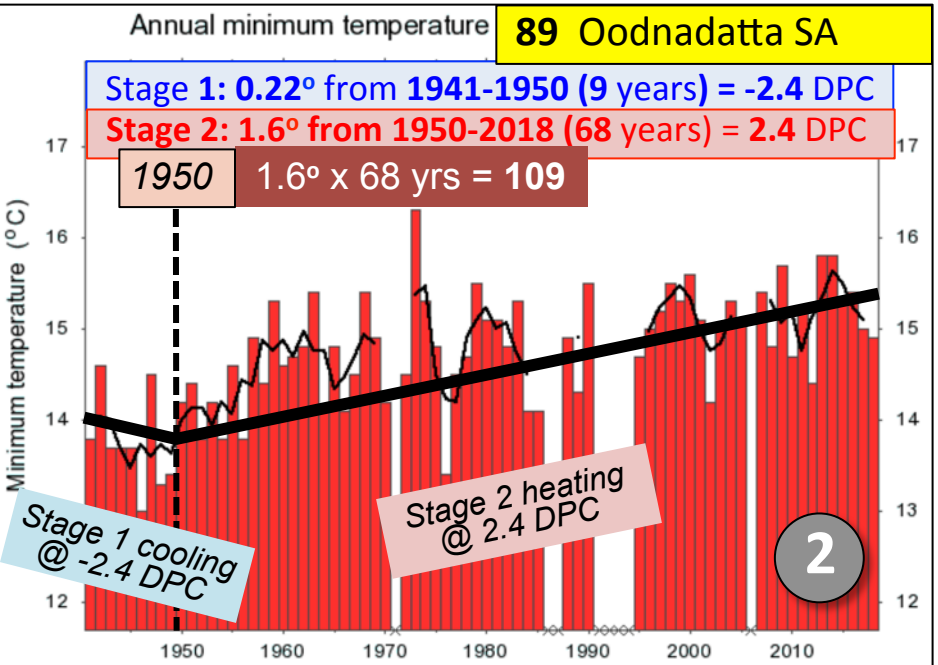

Annual minimum temperature
84 Broome WA
Stage 1: -0.8° from 1910-1967 (57 years) = -1.4 DPC
Stage 2: 1.2° from 1967-2017 (50 years) = 2.4 DPC
1.2° x 51 yrs = 61
1967
Stage 1 cooling @ -1.4 DPC
Stage 2 heating @ 2.4 DPC
3
Minimum temperature (°C)

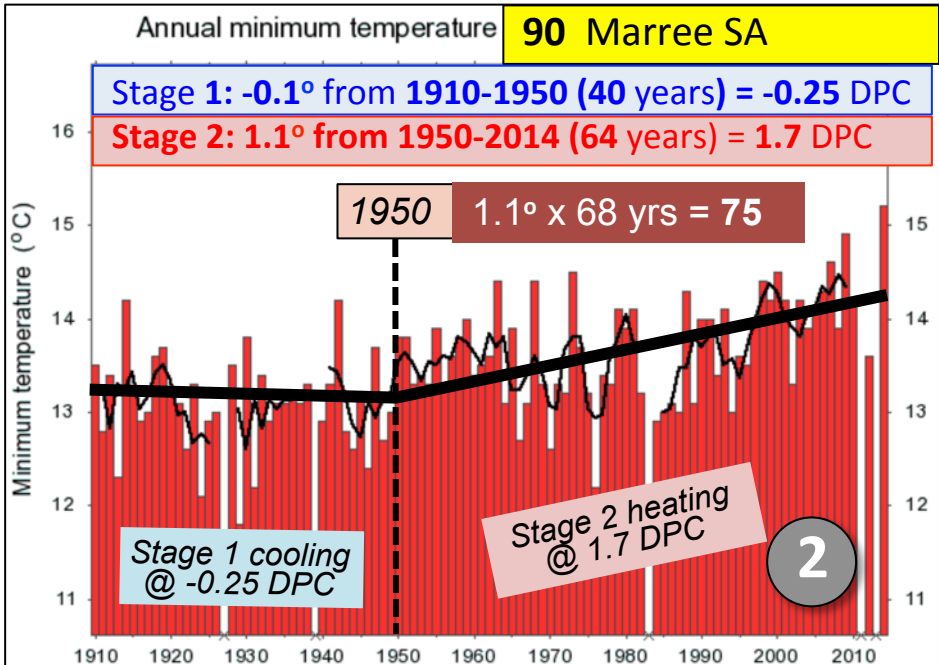

Annual minimum temperature
85 Kalumburu WA
Stage 1: No data
Stage 2: 1.6° from 1945-2017 (72 years) = 2.2 DPC
Pre 1945
1.6° x 73 yrs = 117
Stage 2 heating @ 2.2 DPC
0
Minimum temperature (°C)

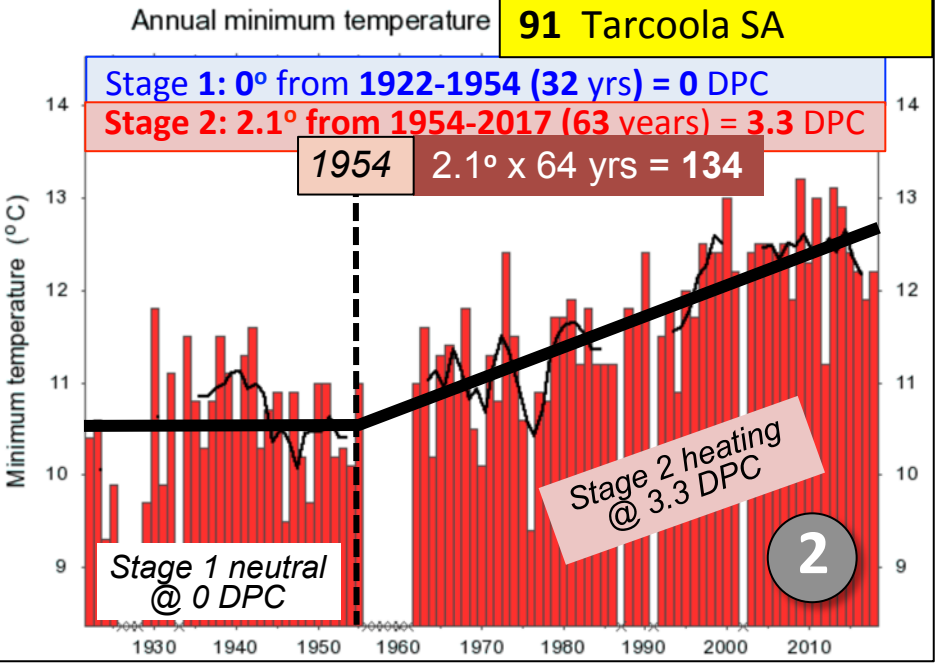

Annual minimum temperature
86 Darwin NT
Stage 1: 0° from 1910-1947 (37 years) = 0 DPC
Stage 2: 1.1° from 1947-2017 (70 years) = 1.6 DPC
1947
1.1° x 71 yrs = 78
Stage 1 neutral @ 0 DPC
Stage 2 heating @ 1.6 DPC
3
Minimum temperature (°C)

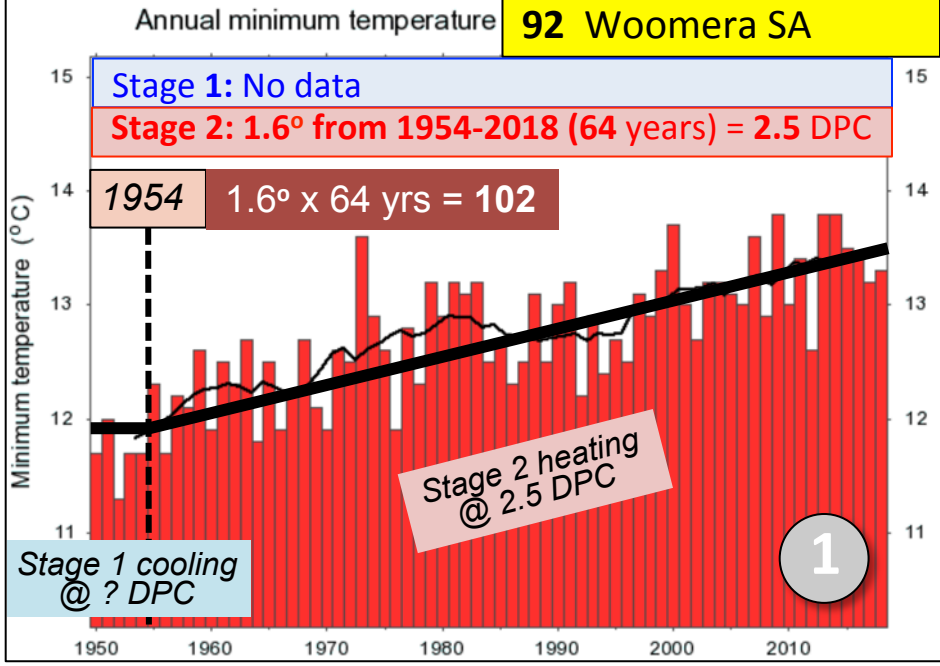

Annual minimum temperature
87 Tennant Creek NT
Stage 1: -0.4° from 1911-1955 (44 years) = -0.9 DPC
Stage 2: 1.5° from 1955-2017 (62 years) = 2.4 DPC
1.5° x 63 yrs = 95
1955
Minimum temperature (°C)
Stage 1 cooling @ -0.9 DPC
Stage 2 heating @ 2.4 DPC
3

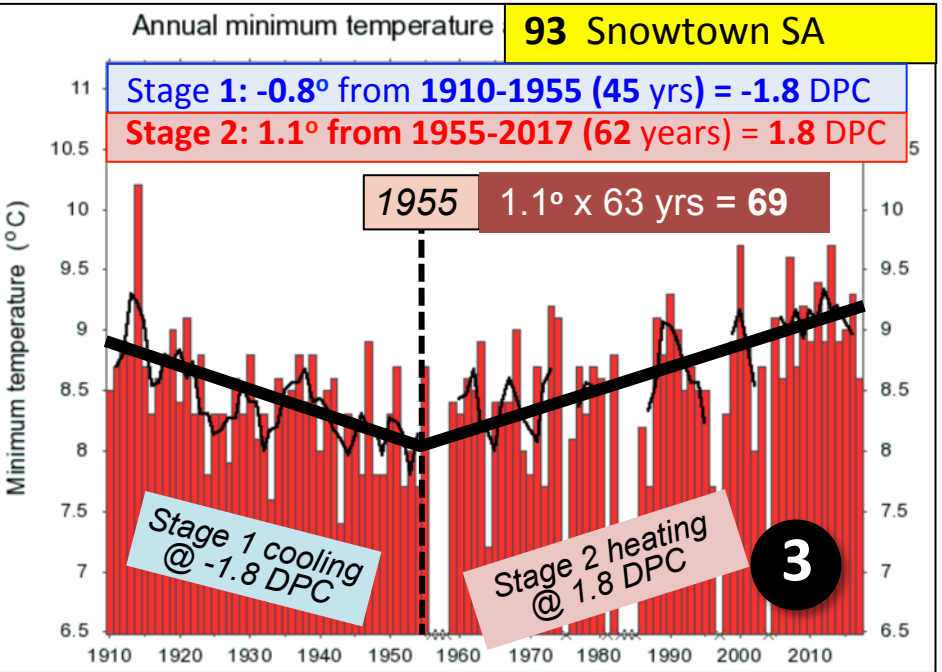

Annual minimum temperature
88 Alice Springs NT
Stage 1: 0° from 1910-1949 (39 years) = 0 DPC
Stage 2: 1.4° from 1949-2017 (68 years) = 2.1 DPC
1.4° x 69 yrs = 97
1949
Minimum temperature
Stage 1 neutral @ 0 DPC
Stage 2 heating @ 2.1 DPC
3

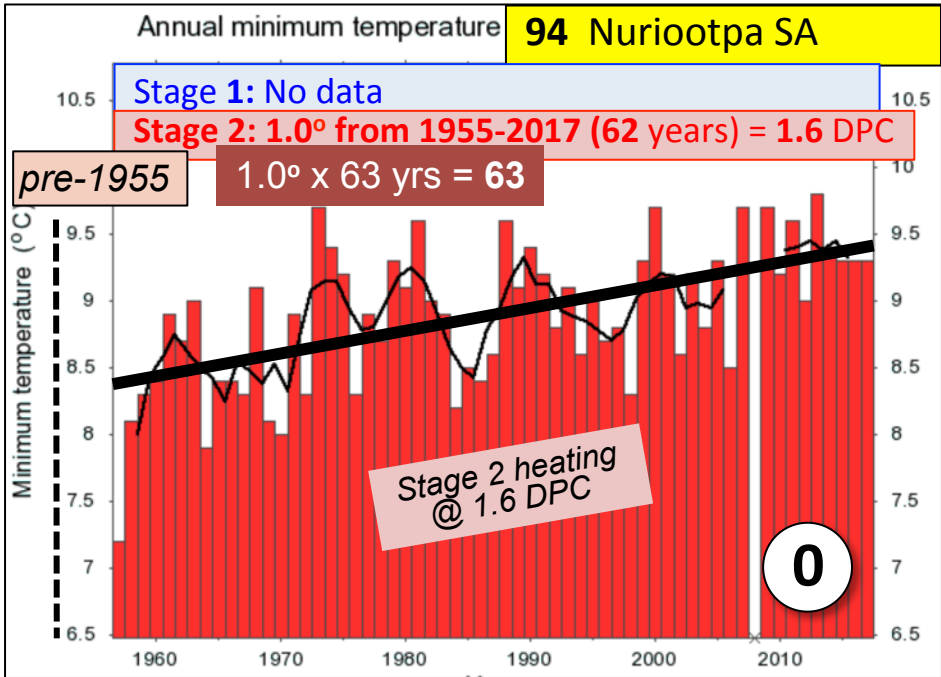

Annual minimum temperature
89 Oodnadatta SA
Stage 1: 0.22° from 1941-1950 (9 years) = -2.4 DPC
Stage 2: 1.6° from 1950-2018 (68 years) = 2.4 DPC
1950
1.6° x 68 yrs = 109
Minimum temperature (°C)
Stage 1 cooling @ -2.4 DPC
Stage 2 heating @ 2.4 DPC
2

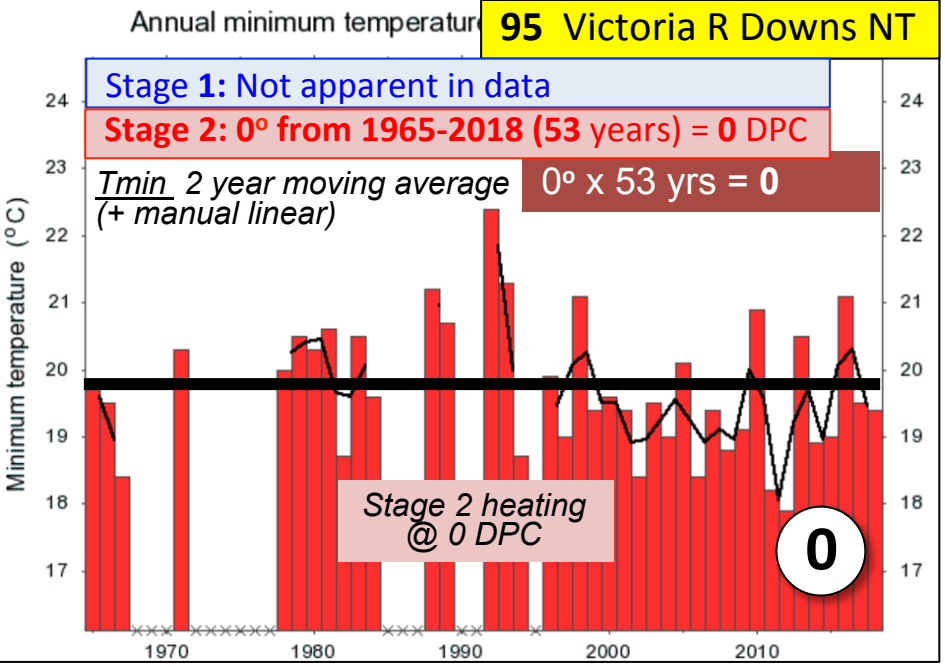

Annual minimum temperature
90 Marree SA
Stage 1: -0.1° from 1910-1950 (40 years) = -0.25 DPC
Stage 2: 1.1° from 1950-2014 (64 years) = 1.7 DPC
1950
1.1° x 68 yrs = 75
Minimum temperature (°C)
Stage 1 cooling @ -0.25 DPC
Stage 2 heating @ 1.7 DPC
2

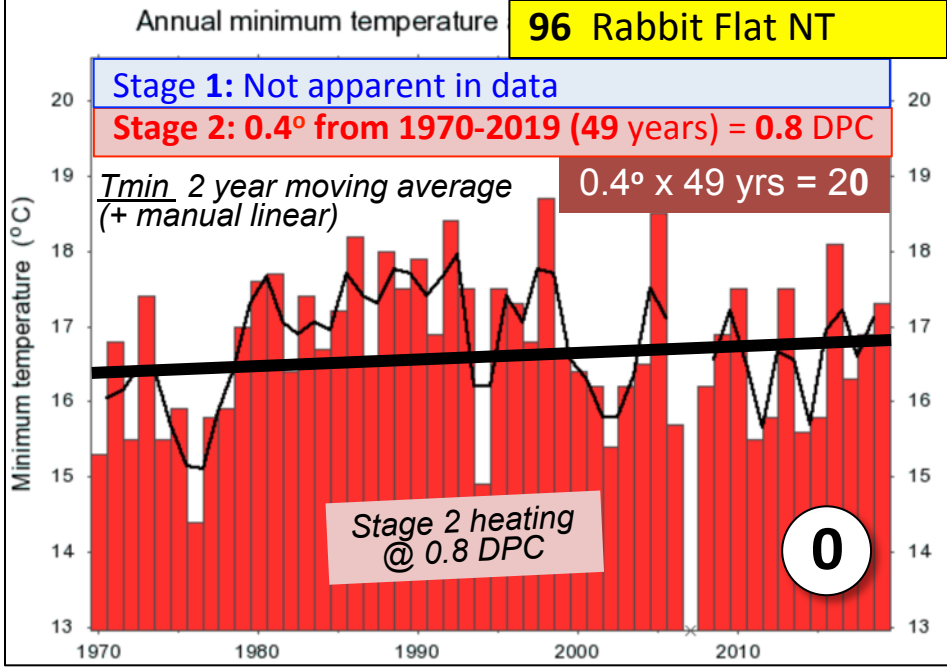

Annual minimum temperature
91 Tarcoola SA
Stage 1: 0° from 1922-1954 (32 yrs) = 0 DPC
Stage 2: 2.1° from 1954-2017 (63 years) = 3.3 DPC
1954
2.1° x 64 yrs = 134
Minimum temperature (°C)
Stage 2 heating @ 3.3 DPC
Stage 1 neutral @ 0 DPC
2

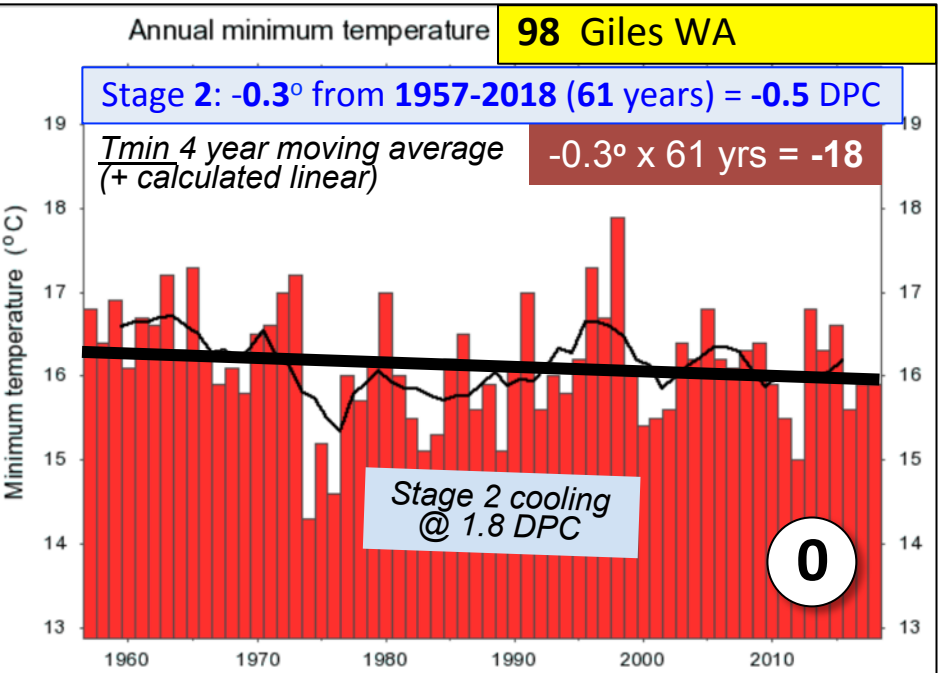

Annual minimum temperature
92 Woomera SA
Stage 1: No data
Stage 2: 1.6° from 1954-2018 (64 years) = 2.5 DPC
1954
1.6° x 64 yrs = 102
Minimum temperature (°C)
Stage 2 heating @ 2.5 DPC
Stage 1 cooling @ ? DPC
1

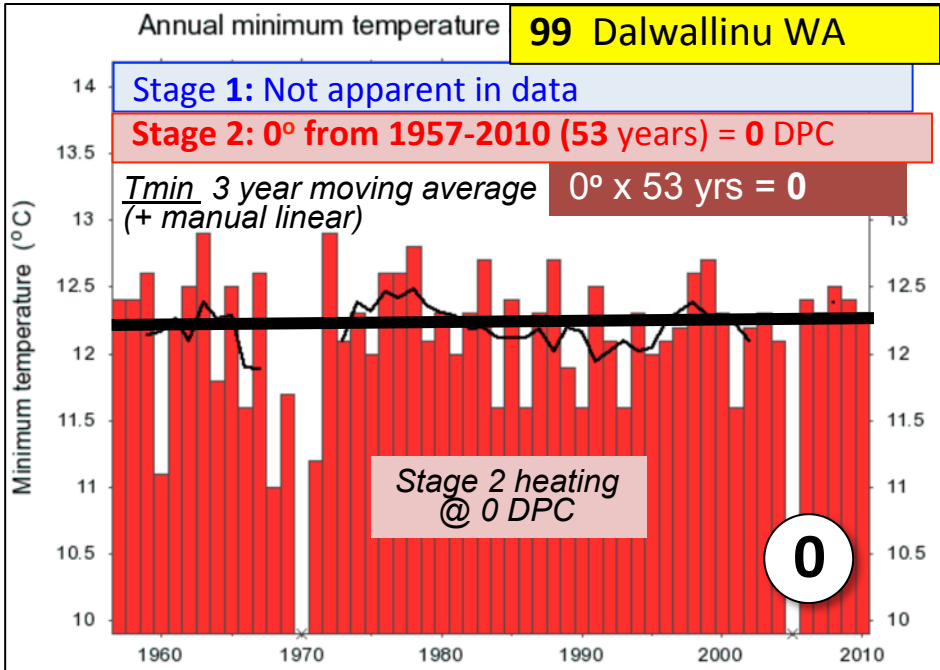

Annual minimum temperature
93 Snowtown SA
Stage 1: -0.8° from 1910-1955 (45 yrs) = -1.8 DPC
Stage 2: 1.1° from 1955-2017 (62 years) = 1.8 DPC
1955
1.1° x 63 yrs = 69
Minimum temperature (°C)
Stage 1 cooling @ -1.8 DPC
Stage 2 heating @ 1.8 DPC
3

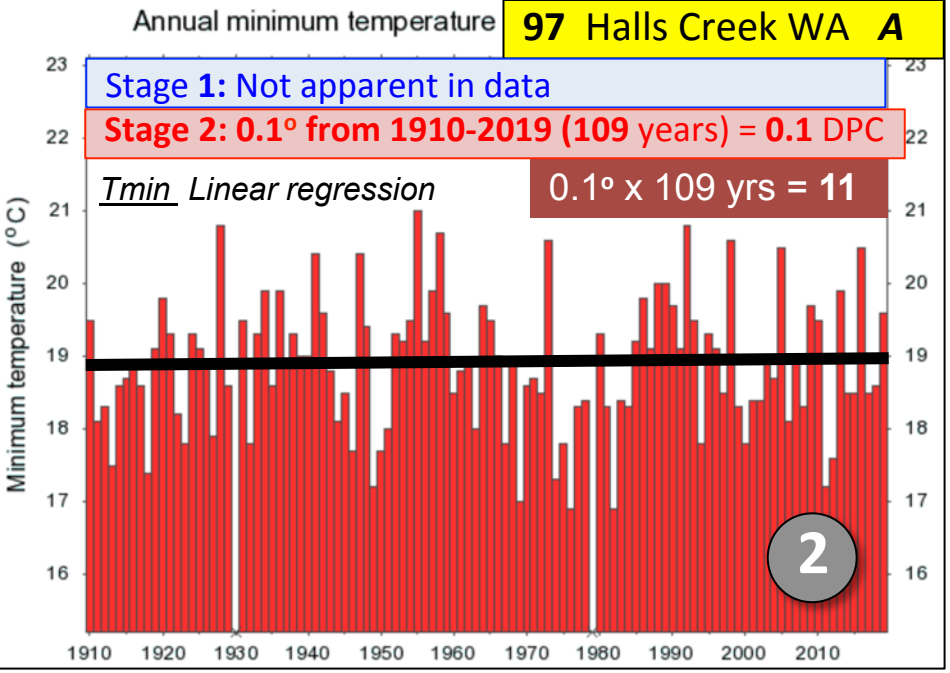

Annual minimum temperature
94 Nuriootpa SA
Stage 1: No data
Stage 2: 1.0° from 1955-2017 (62 years) = 1.6 DPC
pre-1955
1.0° x 63 yrs = 63
Minimum temperature (°C)
Stage 2 heating @ 1.6 DPC
0

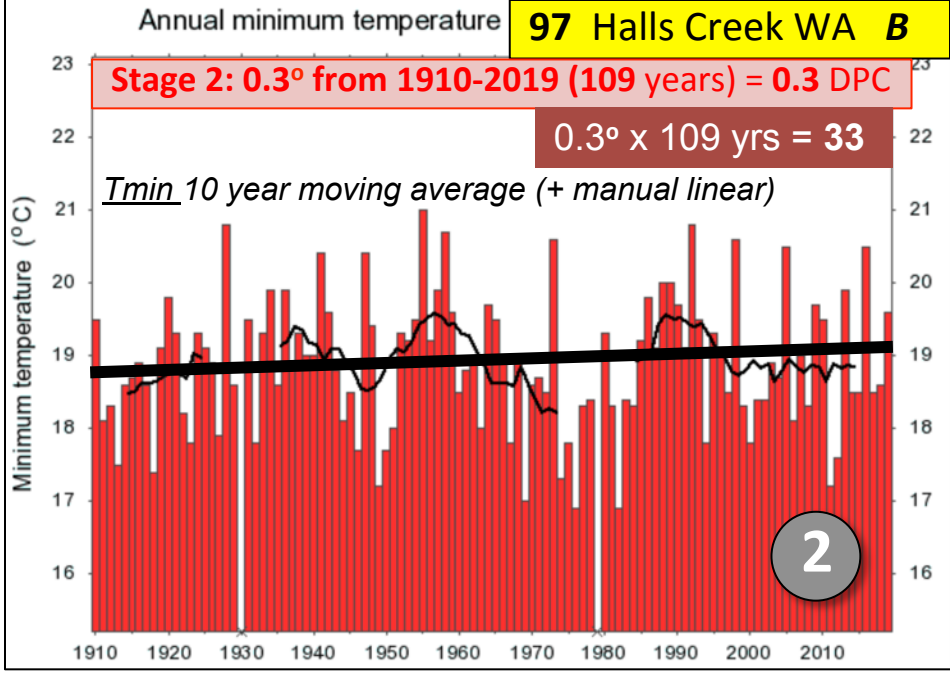

Annual minimum temperatur
95 Victoria R Downs NT
Stage 1: Not apparent in data
Stage 2: 0° from 1965-2018 (53 years) = 0 DPC
Tmin 2 year moving average
(+ manual linear)
0° x 53 yrs = 0
Stage 2 heating
@ 0 DPC
0
Minimum temperature (°C)
1970
1980
1990
2000
2010

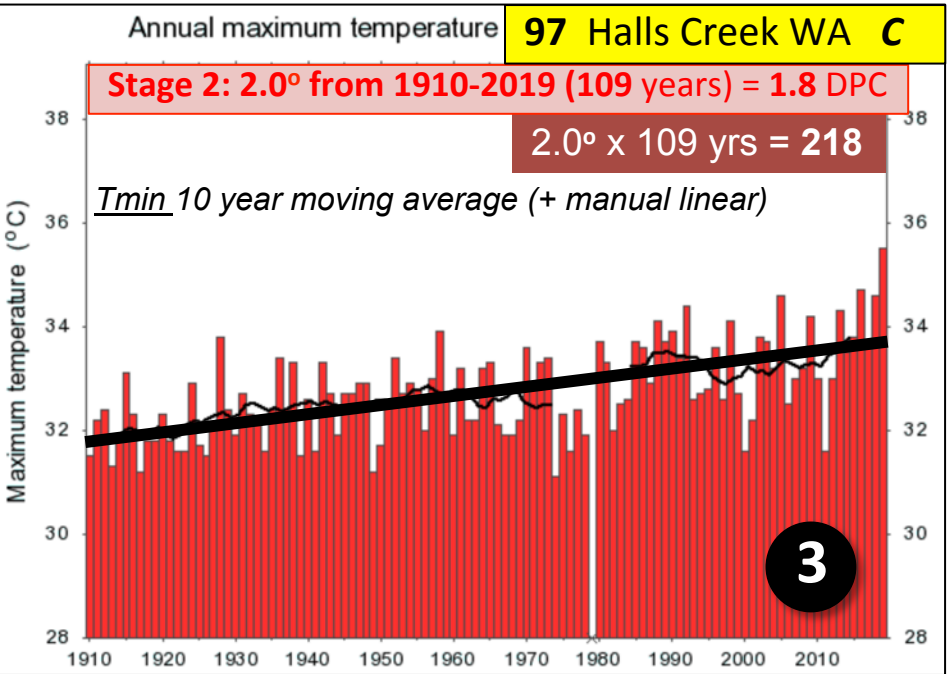

Annual minimum temperature
96 Rabbit Flat NT
Stage 1: Not apparent in data
Stage 2: 0.4° from 1970-2019 (49 years) = 0.8 DPC
Tmin 2 year moving average
(+ manual linear)
0.4° x 49 yrs = 20
Stage 2 heating
@ 0.8 DPC
0
Minimum temperature (°C)
1970
1980
1990
2000
2010


Annual minimum temperature
98 Giles WA
Stage 2: -0.3° from 1957-2018 (61 years) = -0.5 DPC
Tmin 4 year moving average
(+ calculated linear)
-0.3° x 61 yrs = -18
Stage 2 cooling
@ 1.8 DPC
0
Minimum temperature (°C)
1960
1970
1980
1990
2000
2010


Annual minimum temperature
99 Dalwallinu WA
Stage 1: Not apparent in data
Stage 2: 0° from 1957-2010 (53 years) = 0 DPC
Tmin 3 year moving average
(+ manual linear)
0° x 53 yrs = 0
Stage 2 heating
@ 0 DPC
0
Minimum temperature (°C)
1960
1970
1980
1990
2000
2010







The Halls Creek data over the record period 1910-2019 shows distinctly different patterns in Tmin and Tmax:

Tmin - Irregular, two regressions:

A *Linear:* +0.1 degree = climate neutral @ 0.1 DPC

B *10 yr moving:* +0.3 degree = climate neutral @ 0.3 DPC

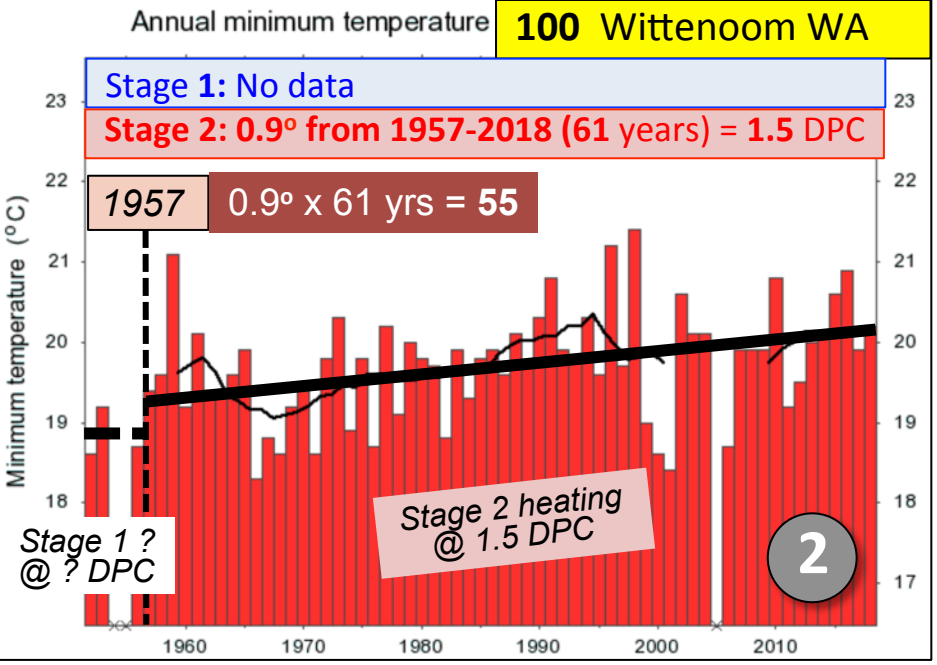
Tmax - Regular:

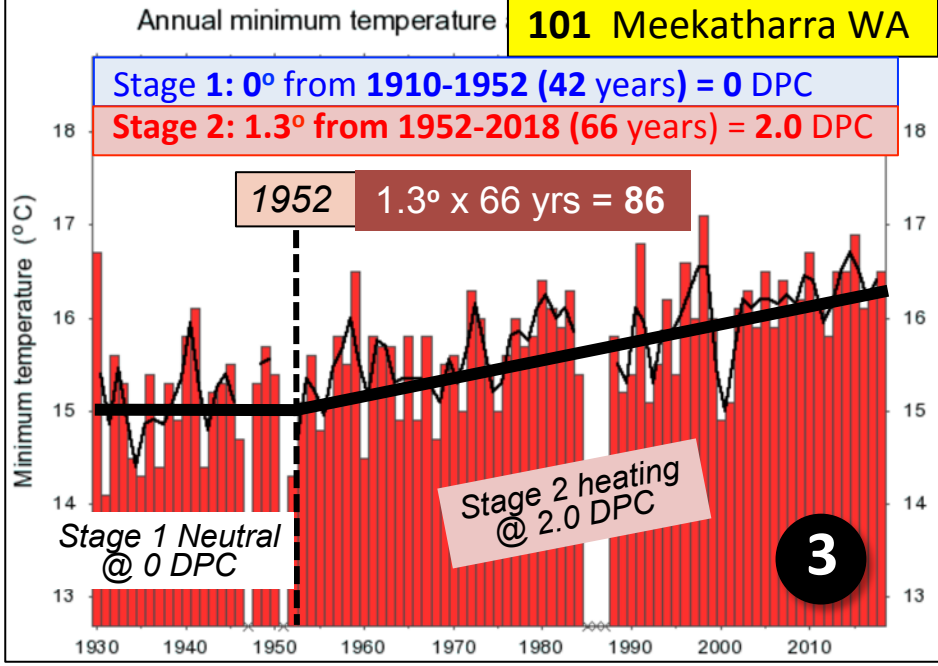
C *10 yr moving:* +2.0 degree = climate heating @ 1.8 DPC

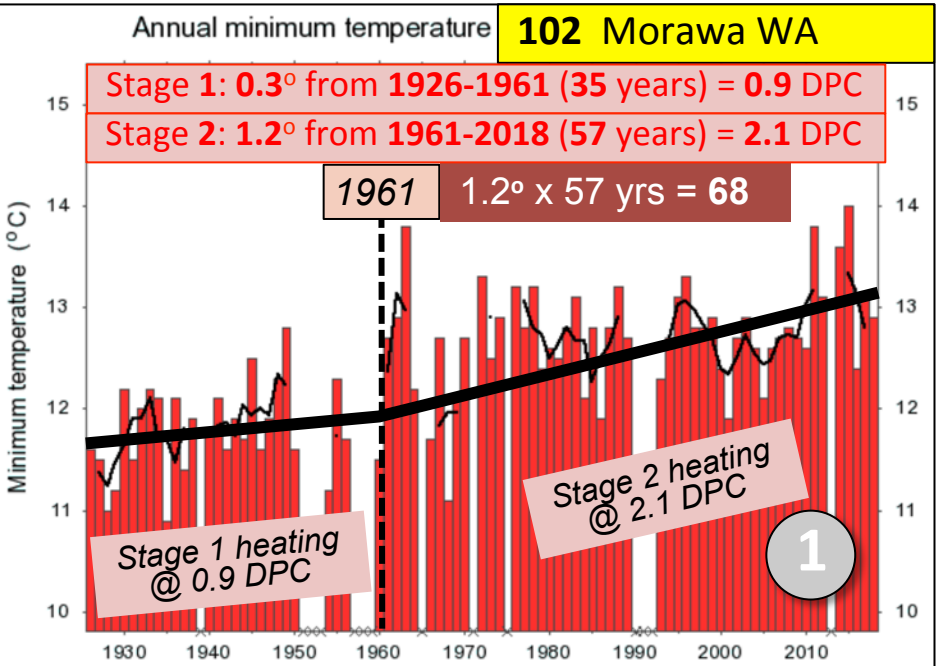
Hence Halls Creek reverses the normal global pattern wherein Tmin reveals greater sensitivity to heating than Tmax. The reason is unknown, but is undoubtedly related to the unique Stage 2 climate cooling experienced by the domain of interior Western Australia and Northern Territory.

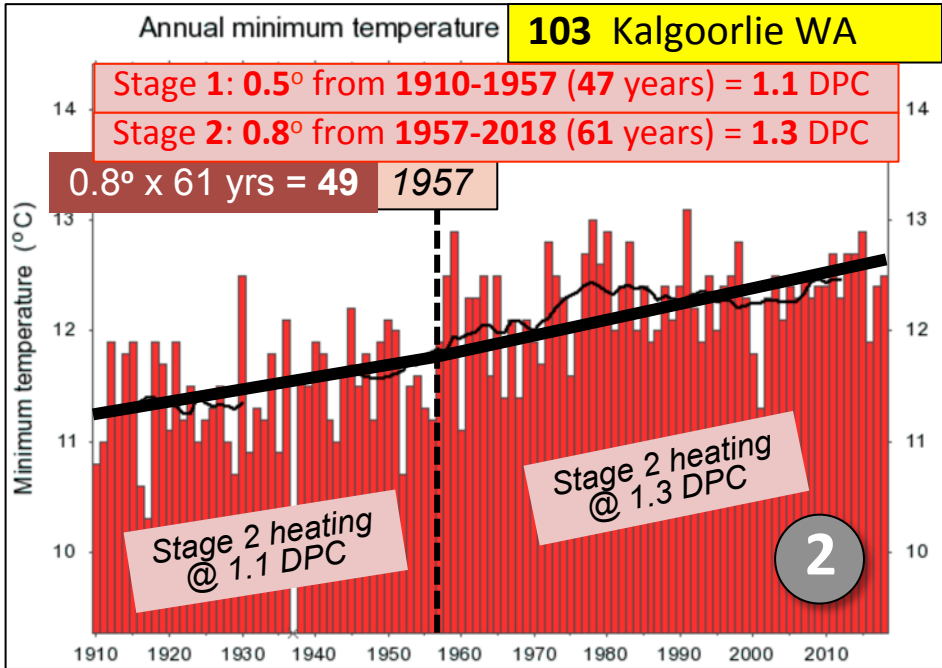
For consistency in this study Tmin is used. Selected values:

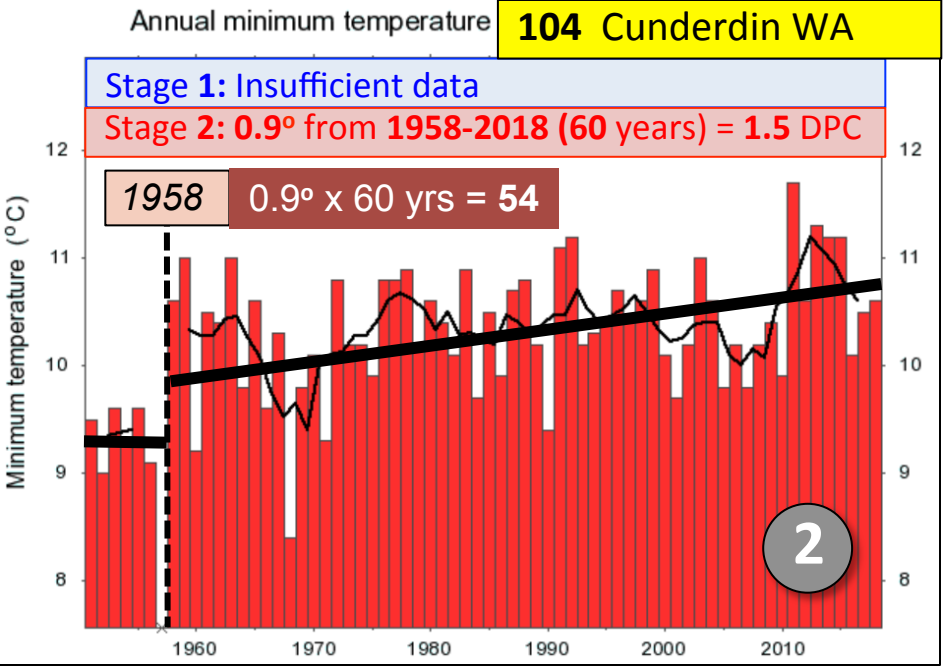
Stage 1 Cooling rate = R1 = **not detected**
Stage 2 Heating rate = R2 = **0.2** DPC
R2 Startdate = not detected: "pre-**1910**"
ΔH = R2 x 109 years = **22**
QI = **2** (combined Tmin + Tmax)

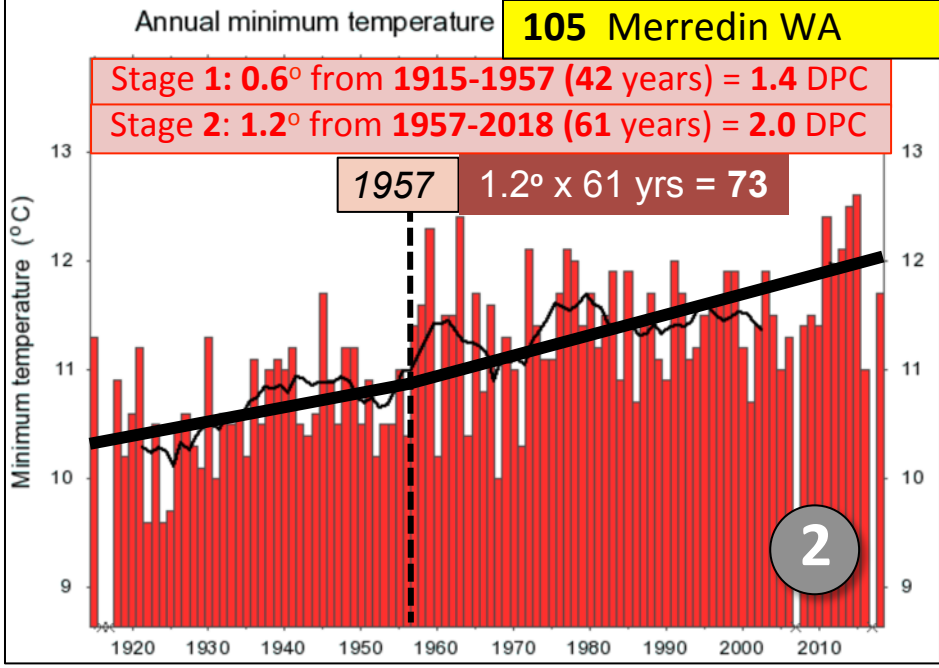

Annual minimum temperature
100 Wittenoom WA
Stage 1: No data
Stage 2: 0.9° from 1957-2018 (61 years) = 1.5 DPC
1957
0.9° x 61 yrs = 55
Minimum temperature (°C)
Stage 1 ?
@ ? DPC
Stage 2 heating
@ 1.5 DPC
2


Annual minimum temperature
101 Meekatharra WA
Stage 1: 0° from 1910-1952 (42 years) = 0 DPC
Stage 2: 1.3° from 1952-2018 (66 years) = 2.0 DPC
1952
1.3° x 66 yrs = 86
Minimum temperature (°C)
Stage 1 Neutral
@ 0 DPC
Stage 2 heating
@ 2.0 DPC
3

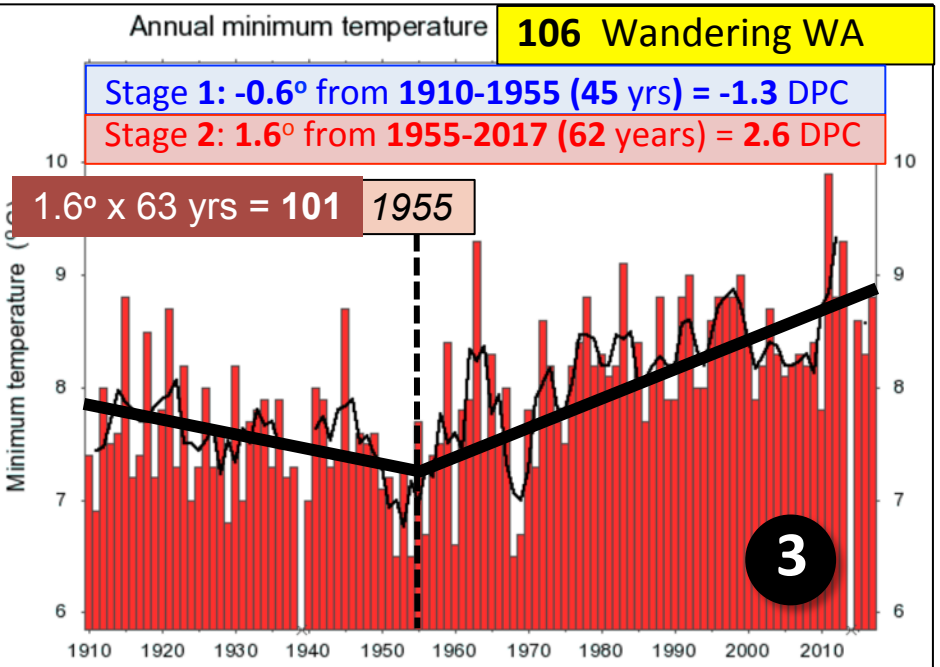

Annual minimum temperature
102 Morawa WA
Stage 1: 0.3° from 1926-1961 (35 years) = 0.9 DPC
Stage 2: 1.2° from 1961-2018 (57 years) = 2.1 DPC
1961
1.2° x 57 yrs = 68
Minimum temperature (°C)
Stage 1 heating
@ 0.9 DPC
Stage 2 heating
@ 2.1 DPC
1

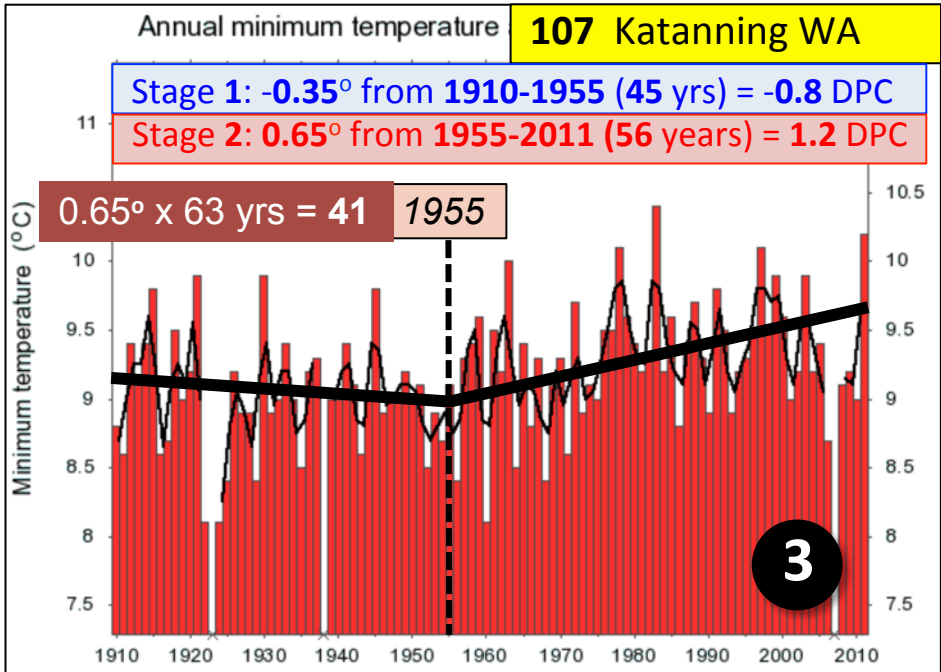

Annual minimum temperature
103 Kalgoorlie WA
Stage 1: 0.5° from 1910-1957 (47 years) = 1.1 DPC
Stage 2: 0.8° from 1957-2018 (61 years) = 1.3 DPC
0.8° x 61 yrs = 49
1957
Minimum temperature (°C)
Stage 2 heating
@ 1.1 DPC
Stage 2 heating
@ 1.3 DPC
2

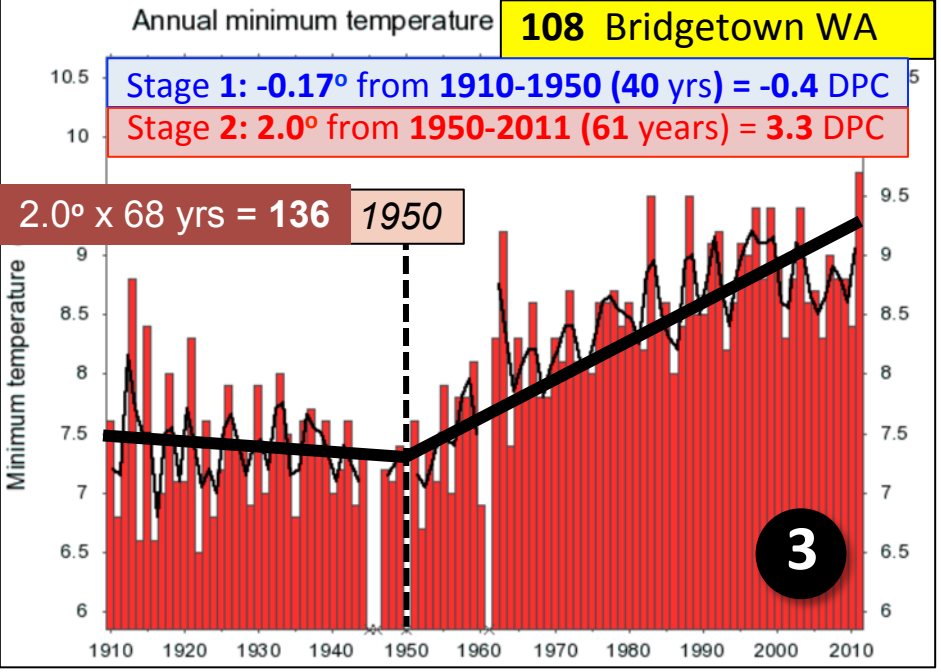


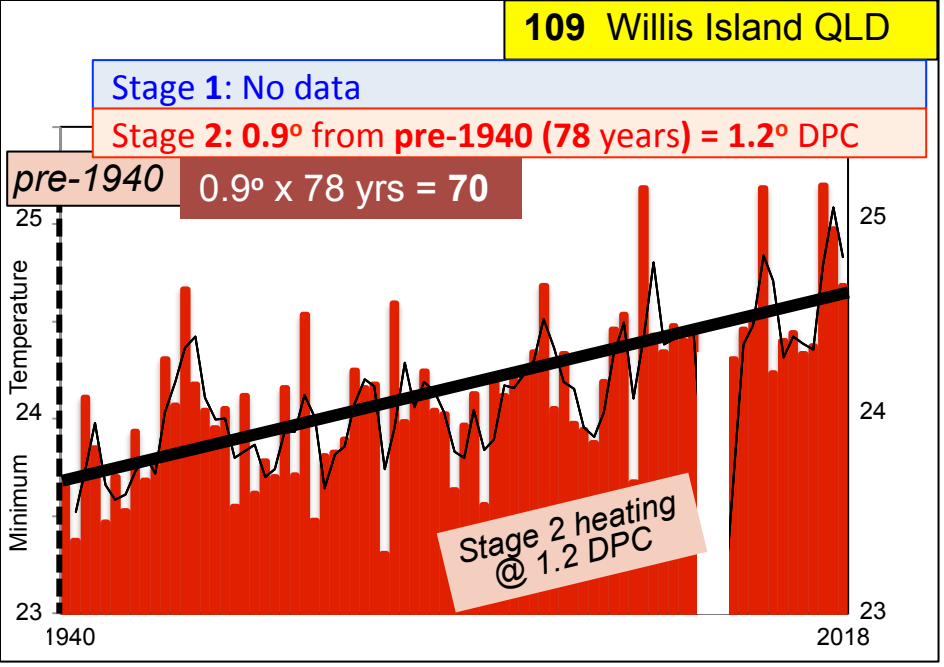


The **104** Cunderdin graph shows a distinctive discontinuity between Stages 1 and 2. This is also seen in some other stations: **100** Wittenoom, **62** Butlers Gorge, **18** Orbost, **6** St Lawrence, **4** Bowen, **2** Cardwell. It suggests a dynamic discontinuity, at the startdate, in the temperature drivers.






Annual minimum temperature
108 Bridgetown WA
Stage 1: -0.17° from 1910-1950 (40 yrs) = -0.4 DPC
Stage 2: 2.0° from 1950-2011 (61 years) = 3.3 DPC
2.0° x 68 yrs = 136
1950
Minimum temperature
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
3


109 Willis Island QLD
Stage 1: No data
Stage 2: 0.9° from pre-1940 (78 years) = 1.2° DPC
pre-1940
0.9° x 78 yrs = 70
Minimum Temperature
25
24
23
1940
2018
Stage 2 heating @ 1.2 DPC