From the ashes: a new quantitative Bushfire Climate-Vulnerability Index for the world

Submission to the House Standing Committee on the Environment and Energy in respect of the Climate Change (National Framework for Adaptation and Mitigation) Bill 2020 and Climate Change (National Framework for Adaptation and Mitigation) (Consequential and Transitional Provisions) Bill 2020

Dr Bill Laing
Climate scientist & former Geological Consultant to the international mining industry

4 December 2020

Support I support the Climate Change Bill. As a climate scientist responsible for a new empirical synthesis of Australia's climate, which delivers a stark warning that our nation is heating at double the world rate, at the same time I am identifying a number of practical strategies deriving from the climate study, which will help fix our climate issues.

Personal statement I have developed a new parameter ΔHeat, which will serve the world as a Bushire Climate-Vulnerability Index (BCVI). I want the Climate Bill to proceed, so that bushfires - which have been exacerbated by climate heating - can be better managed by Australia's disaster services. My nephew is Captain of the Mummulgum SES in bushfire-vulnerable northeastern NSW; he was deeply troubled by the events of our horrific bushfires season in 2018-19, and both my sisters and families live in this region. My BCVI will make their lives, and the lives of tens of thousands of Aussies in disaster areas and the disaster industry, a little more predictable and positive. I submitted the BCVI to the NSW Bushfire Enquiry in 2020 but it was ignored in the Enquiry Report. The Report identified dryness of vegetative fuel load as the paramount factor in the catastrophic size (and longevity) of the bushfires, and this is a direct outcome of the two components of ΔHeat; however the enquiry failed to join the dots and recommend the adoption of ΔHeat as our climatic predictor of catastrophic bushfires. ΔHeat is an extremely simple Index to calculate, and is readily accessible in all historic weather databases.

FIRE WATER AIR
Solar Hydro Wind

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Key points:

- I am a Climate Scientist who has completed a two year study delivering a new synthesis of Australia's climate since our weather records started in 1856.
- Using the publicly available weather data from the Bureau of Meteorology, I have developed a Bushire Climate Vulnerability Index (BCVI): *ΔHeat = how much a location has climate-heated x its period of heating to the present*. A direct analogue is the baking of a cake; the cake's baking progress is measured by the oven temperature (= climate-induced temperature increase) and the length of time to cook (the climate heating period). The BCVI measures how much a place has climate-baked.
- The BCVI is a simple parameter which can be calculated for any location around the globe with historic weather data. I have already determined ΔHeat for the 109 trans-Australian locations of the BOM ACORN-SAT database. The BVCI can be incorporated into, for example, California's climate database as a quantitative, evidence-based, locality-based, predictor of wildfire vulnerability; see next page.
- The BCVI is *the one and only tool for integrating climate heating into bushfire management: there is no other way to do it.*
- **ΔHeat is also acutely relevant to our biosphere**. Many plants and small organisms are susceptible to changes in temperature over time. ΔHeat is the one and only measure of temperature changes which are climate-induced. ΔHeat delivers a new tool for biologists now operating in the world's new paradigm: the integration of climate heating into the modelling of our biosphere. The Great Barrier Reef's climate heating is measured by the Great Barrier Reef Marine Park Authority (GBRMPA) in Degree Heating Days (DHD) and Degree Heating Day Count (DHDC). Their "*degree days*" is a quantitative parameter directly analogous to ΔHeat measured in "*degree years"* for Australia's climate.
- **"Climate preparation" for catastrophic wildfire**

  The NSW Bushfire Enquiry (31 July 2020) recognised the impact of ΔHeat as a prime driver of bushfire vulnerability, when on page 1 of its Report, in the opening paragraphs of the Executive Summary, it stated "*The 2019-2020 bush fire season challenged conventional assumptions. For example, it appears that the extreme dryness of forested regions over large continuous areas was the determining factor in the size of the fires*". Elsewhere and throughout, the Report was clear in ranking all other factors as secondary to extreme dryness of the vegetative fuel. These included other factors previously ranked as paramount, such as the amount of fuel, and the amount and type of prescribed burning and hazard reduction. Notwithstanding this conclusion, in 2.5 pages of Executive Summary the Report mentioned climate change only twice. My Submission and its Proposal to incorporate ΔHeat as a Bushire Climate Vulnerability Index in Australia and worldwide was ignored. This was a lost opportunity, because ΔHeat is the simple factor which, when adopted by bushfire jurisdictions everywhere as it will be, will permit decision-making on the basis of *ΔHeat, and only ΔHeat, directly measures "climate preparation" for catastrophic wildfire. ΔHeat is the big-picture parameter which tells us how bushfitre vulnerability has been created: over big timeframes (half-centuries to centuries) and over big regions*: which parts of coastal NSW versus coastal Queensland - versus California - are more climate-prepared for catastrophic bushfires?

- ΔHeat is an extremely simple Index to calculate, is readily accessible in all historic weather databases worldwide, and maps of ΔHeat at state and continent scale can be created instantly. ΔHeat in regional databases is available digitally for insertion into a wide range of community studies and planning campaigns.
- ΔHeat maps will become vital planning resources in a gamut of applications:
  - bushfire management
  - agriculture and forestry: ΔHeat directly controls many plants and organisms' existence, spatial distribution, and evolution; and soil fundamentals inorganic and organic
  - biosphere threats to species: both faunal and floral
  - transport and infrastructure engineering: soil conditions and stability
  - insurance: long-term bushfire risk, agribusiness risk
  - societal wellbeing: it is well-established that extreme drought is a mental health driver; large ΔHeat equates to extreme drought felt at a psychological and spiritual level

Conscience vote: I ask that the decision by Parliamentarians be a conscience vote, to allow MPs to represent the views and voices of Australians in their electorate. In 2019 300,000 ordinary Australians went on strike, in the middle of a working Friday, to express their plea for action on climate change and to express their anger at politicians and the Federal Government for their failure to act on climate change. Bushfires are one of Australia's worst nightmares, but we can act to mitigate bushfires for future generations.

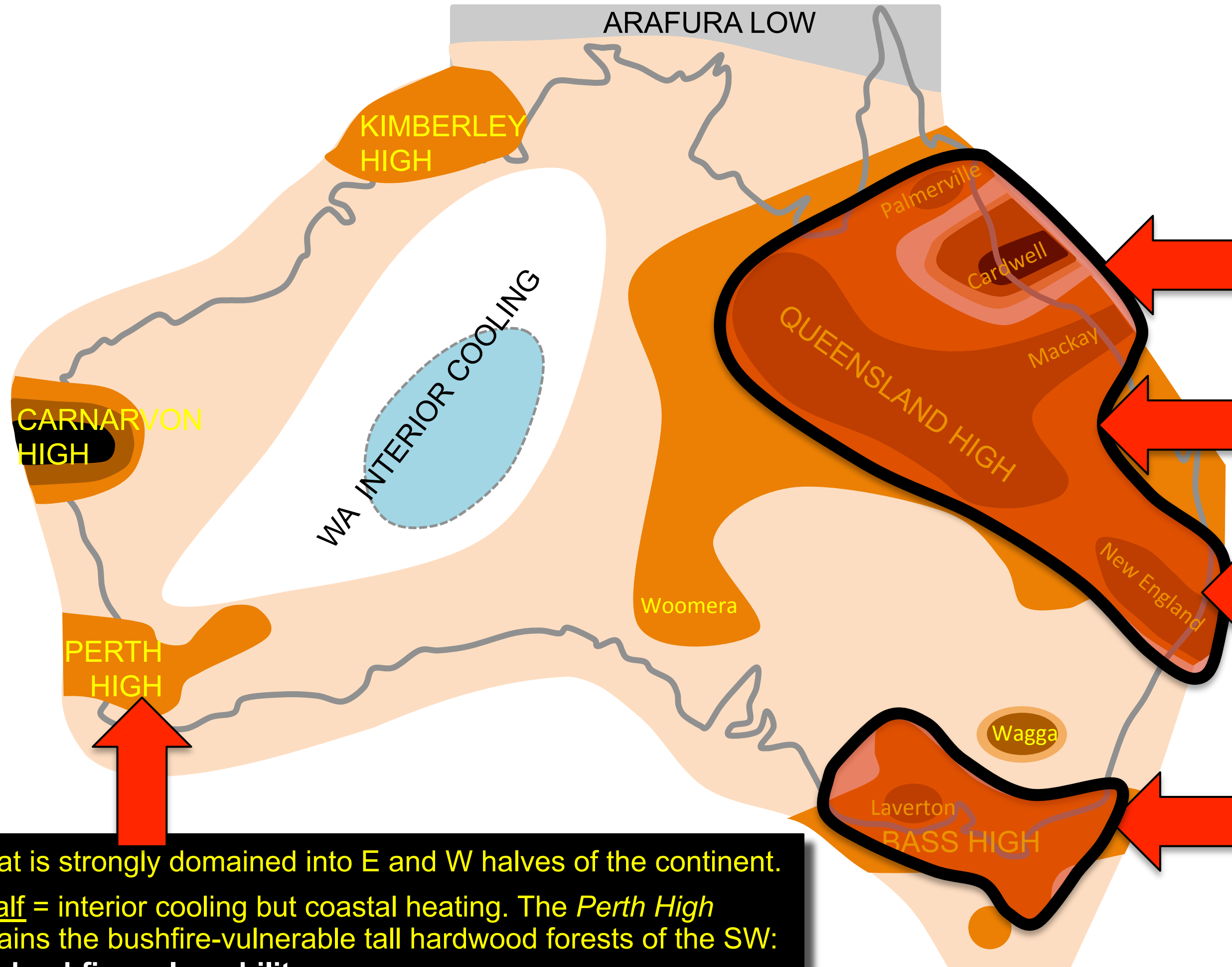
This Submission addresses the following aspects of the Bill:

1	√√	**Objectives and long-term emissions reduction commitment**
2	√√	**Why legislating Net Zero by 2050 and regular 5 year budgets is important**
3	√	**Guiding principles to be applied**
4	√√	**Risk and adaptation assessments for all sectors**
5	√	**Technology readiness assessment**
6		**Independent climate change Commission and skills needed on the Commission**

ΔHeat identifies Australia's bushfire-vulnerable regions, into the future

ΔHeat is the quantum of heat, at a location or over a region, that has been added by climate change.
It does not relate to "how hot is a place" - Victoria shows a cool climate with a high ΔHeat.

ΔHeat = ΔTemperature** x **Length of heating period (degree years)



QLD: High to extreme climate heating throughout the State. The coastal tropics have high **bushfire vulnerability** and include all the virgin rainforest burnt in 2018-19: *Japoon, Eungella, Mt Tamborine*. The NW-SE Queensland High includes the *brigalow terrain, Pilliga Scrub, New England Plateau, and NSW coastal rainforest (Terania Creek)* **extreme bushfire vulnerability.**

NSW: Climate heating over most of State is at the Australian mean (still 2x world rate). However the *New England High* is part of the *Queensland High* - Australia's strongest heating belt: **extreme bushfire vulnerability**.

VIC: Most of the State has heated well above the Australian mean: **high bushfire vulnerability.**

ΔHeat is strongly domained into E and W halves of the continent.

W half = interior cooling but coastal heating. The *Perth High* contains the bushfire-vulnerable tall hardwood forests of the SW: **high bushfire vulnerability.**

E half = heating throughout greater than Australia's mean rate. Queensland and Victoria have heated much more than this. See other box for details.

Continent-scale features shown in block letters
Local heating hotspots shown by place names

A case study of ∆Heat as the world's Bushfire Climate Vulnerability Index

California is heating slower than E Australia, but ∆Heat is an equally valid proxy for BCVI in both places

What makes a Bushfire Climate Vulnerability Index (BCVI)?

Los Angeles provides a case study of the validity, the precision, and the uniqueness, of ∆Heat as the world's BCVI.

Could not just the Heating rate be sufficient?

Los Angeles' heating rate R is 2.4 DPC. While this is double the world rate, it is only equal to Australia's mean rate, and it is half the magnitude of some Australian locations. Bushfire-vulnerable Australian regions are bounded approximately by R = 3.0 DPC (see later pages in this Submission) which would place Los Angeles outside the bushfire-vulnerable region - which given its wildfire history is manifestly invalid. By itself a location's heating rate is not an index of bushfire vulnerability.

∆Heat = how much a location has climate-heated x its period of heating to the present: why this the right index

∆Heat has a direct analogue, in the baking of a cake. The cake's baking progress is measured by two parameters: the oven temperature (= climate-induced temperature increase) and the length of time to cook (the climate heating period). ∆Heat measures how much a place has climate-baked.

Is there any other parameter which would proxy for climate heating as an index of bushfire vulnerability?

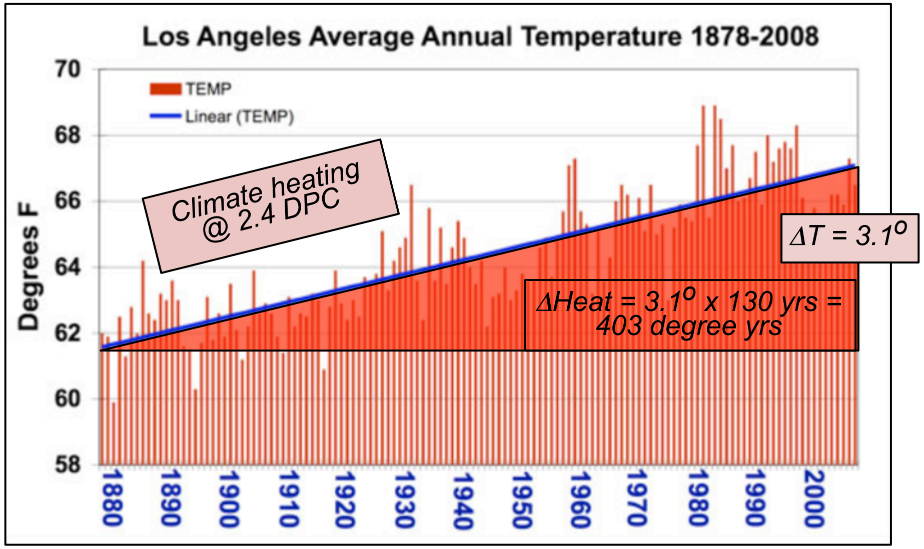
The more heated an object is, the higher its temperature. Hence, an object being heated will at any time have acquired heat proportional to the time it has been heated. The object's acquired heat will also be proportional to its temperature rise. Hence Amount of heating α Heating time and Temperature increase.

The case study of Los Angeles

The graph on R shows Los Angeles' climate-induced temperature rise, since start of records in 1878, of 3.1^{o}C. Los Angeles' heating period is (at least) from 1878 to 2008 = 130 years. Hence the relevant parameters for Los Angeles' wildfire vulnerabiity are:

Temperature increase ∆T = 3.1, *∆Heat* = 403 degree years.

https://climate.nasa.gov/news/23/southern-californians-get-a-cool-summer-but-a-warm-future/



A case study of ΔHeat as the world's Bushfire Climate Vulnerability Index

California is heating slower than E Australia, but ΔHeat is an equally valid proxy for BCVI in both places

We have seen above that Los Angeles' *Heating rate*, which is well below the Heating rate of Eastern Australia's bushfire-vulnerable regions, does not directly measure its BCVI. On the other hand Los Angeles' *ΔHeat* at 403 is much higher than Eastern Australia, whose bushfire vulnerability becomes substantial at circa 150 (Submission). Eastern Australia has only been climate-heating for 65 years (mean) but at rates higher than Los Angeles, while the latter has been heating for double the time. Both regions have acquired high ΔHeat = BCVI.

Conclusion

ΔHeat is a valid, a precise, and the only, Bushfire Climate Vulnerability Index (BCVI) available. Its two components, Heating time and Temperature rise, by themselves are not direct indicators of BCVI. Together they deliver what we need.

A new, global, quantitative Index of climate-induced bushfire vulnerability: ΔHeat

Ignored in Enquiry Report

Dr W. P. Laing

Climate Analyst

43 pages

26 May 2020

Submission to: ***NSW Bushfire Enquiry***

ΔHEAT AS THE CLIMATE PARAMETER WHICH CAPTURES BUSHFIRE VULNERABILITY DUE TO CLIMATE HEATING

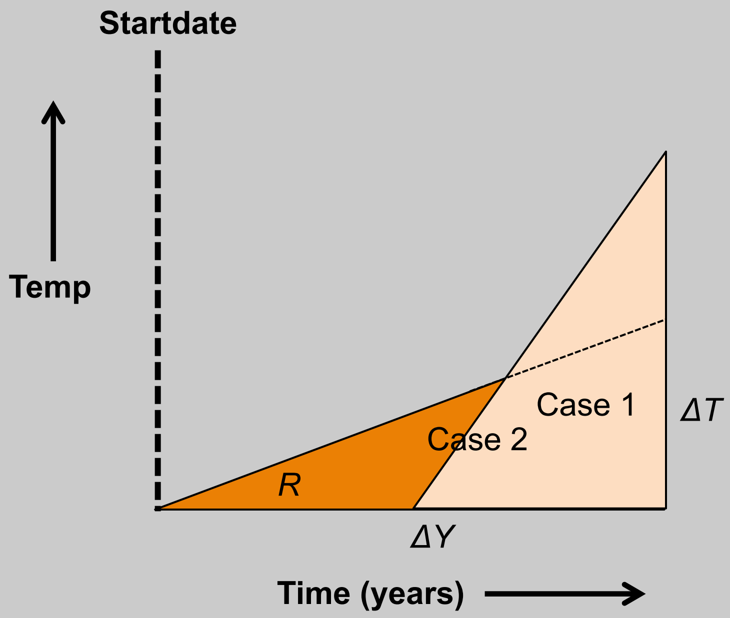
ΔHeat: the only climate parameter which captures how much Australia has heated

The world's climate heating is measured in 3 parameters:

1 The *amount* a location has heated since climate heating began (in the 20th century): the temperature increase **ΔTemperature**
2 The *period* over which the heating has occurred: the number of years **ΔYears**
3 The *product* of these two parameters **ΔHeat = ΔTemperature x ΔYears**

The heat applied to a location depends on 2 factors: the temperature increase, and the time over which that increase has been applied. These factors are **ΔT** and **ΔY** from above. The direct analogy is a cake being baked in an oven. Its baking to "ready" involves (1) switching the oven to the desired **temperature**, and (2) leaving it to cook for the desired **time**. Its successful cooking depends on both these parameters.

Each of parameters 1 and 2 captures "half" of the heating story at any location. **ΔHeat is the only parameter which captures the whole story.**



Case 1 heats at 2 DPC for 30 years. **ΔHeat = 60** degree years.

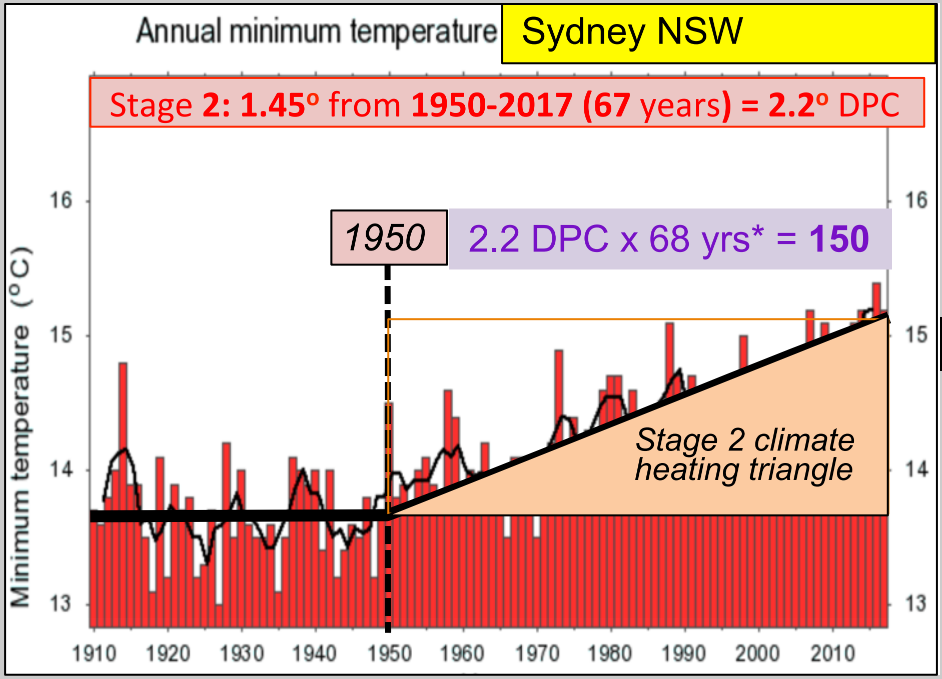
Case 2 heats at 1 DPC for 60 years. **ΔHeat = 60** degree years.

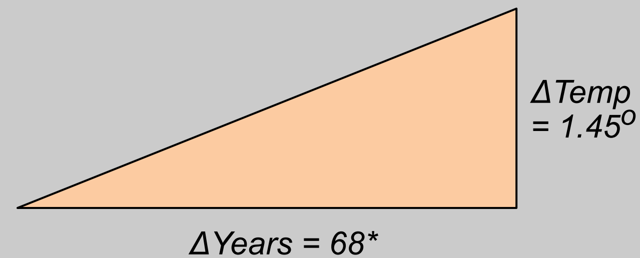
The greater *heating rate* is Case 3

The longer *heating period* is Case 2.

However both have received the same climate heating (**ΔHeat**).

ΔHeat: its definition and calculation



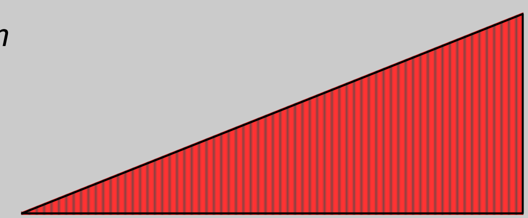


* The total heating for all locations is projected until end 2018. Data for many sites end at 2017 (some earlier) so these are recalculated to end 2018. For Sydney ΔY = 67 + 1 = 68 years

The total heat experienced at a location is, in general, the integration - the sum - of every annual T average, over the heating period. For Australian stations, whose Stage 2 heating is essentially a straight-line heating curve, this reduces to the sum of every year's T averaged as a monotonic linearly increasing sequence. That is,

ΔHeat = Area of heating triangle
= Sum of every year's T over the 67 year heating period
= Σ(from 1-67) of mean T each year
= (1.45x1/67) + (1.45x2/67) + (1.45x3/67) + ... + (1.45x67/67)
= Area of heating triangle
= 1/2 (ΔY x ΔT)

For our climate parameter ΔHeat we ignore the constant 1/2.



68 yearly Tmean values, linearly increasing over a range of 1.45°

For Sydney, ΔY = 68 years and ΔT = 1.45° so ΔHeat = 1.45 x 68 = 150 degree years

ΔHeat: its equivalent useage by GBRMPA Australia

Sea Surface Temperature Anomaly (SSTA)

SSTA is the difference between SST values and climatology, the monthly long term mean SST. Two climatologies are used to produce products. The first is an IMOS climatology for 2002–2011, constructed for each month using IMOS L3S 1-day night-only SST products in that period. The second climatology used is the CSIRO 1993–2003 climatology that the ReefTemp V1 system utilised. The use of both climatologies allows for comparisons of products based on different reference periods. All SSTA values appear in the range -4°C to 4°C.

Degree Heating Days (DHD)

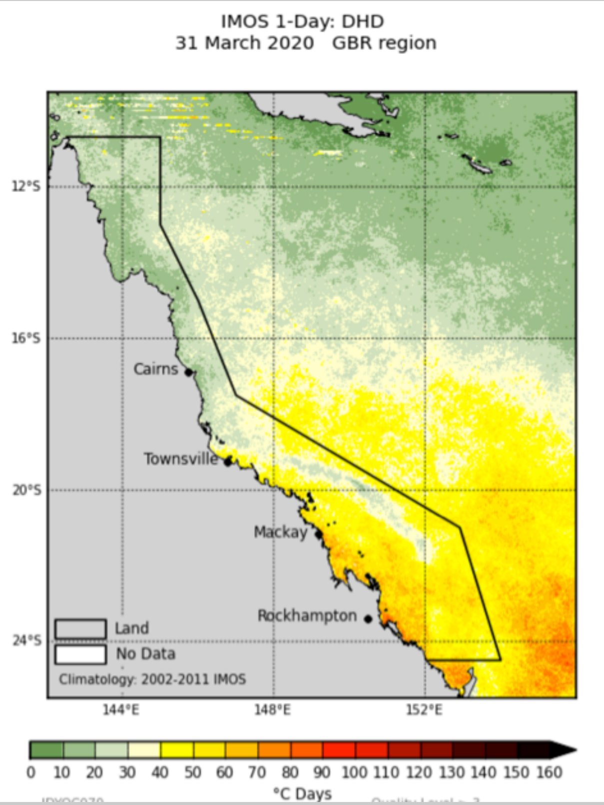
Degree Heating Days (DHD) are the accumulation of positive SSTA values over the summer (1 December to 31 March) at each grid cell. The visualisation range for DHD values is 0–240 °C days.

Degree Heating Day Count (DHDC)

The number of days in which temperatures have exceeded the long-term average (when data was available) at each grid cell ie positive SSTA values observed.

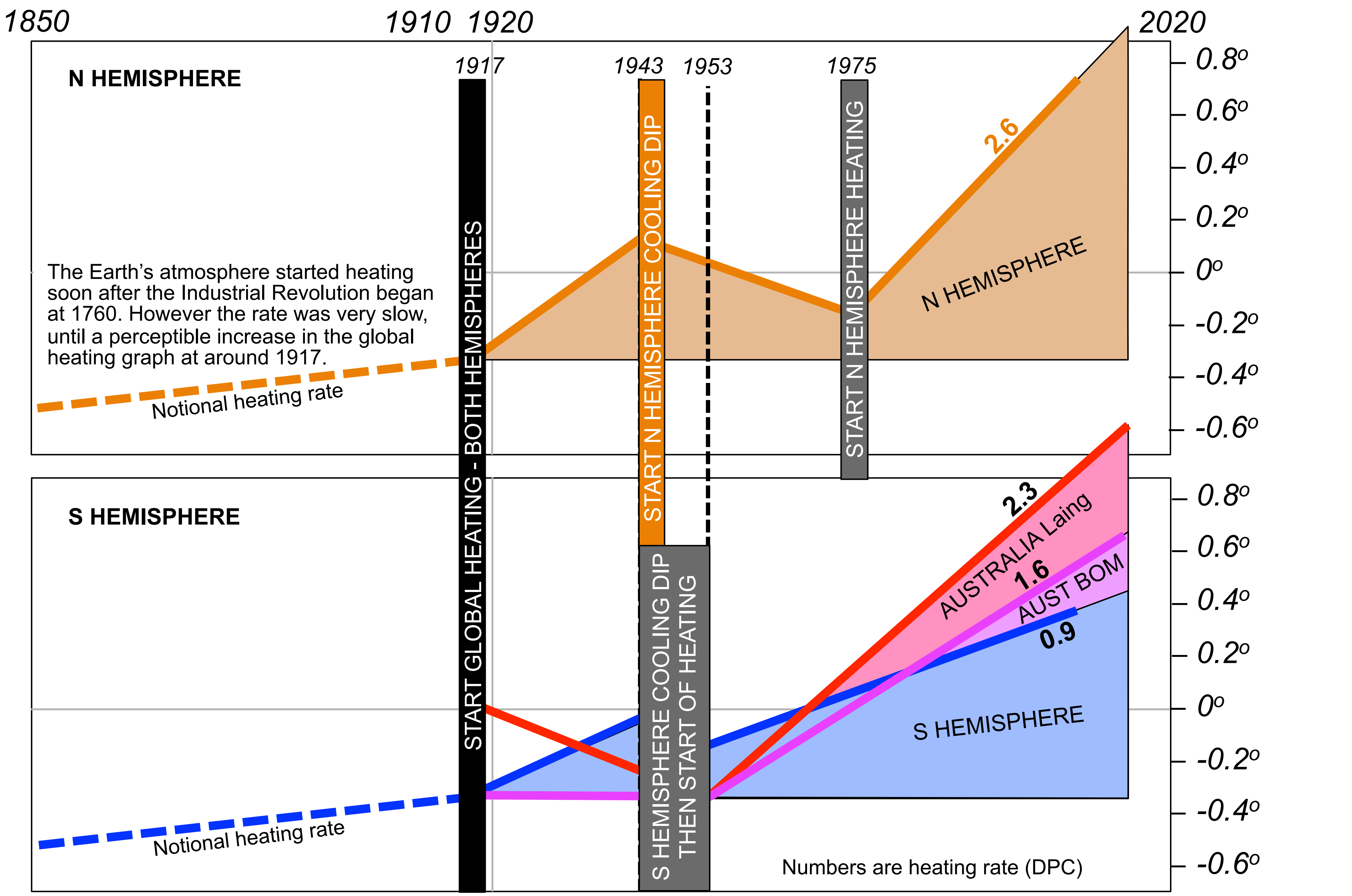
http://www.bom.gov.au/environment/activities/reeftemp/glossary.shtml

DHD for the Great Barrier Reef is measured in "*degree days*". This is a detailed quantitative parameter. It is directly analogous to **ΔHeat** (Laing) for Australia's climate, which is measured in "*degree years*".

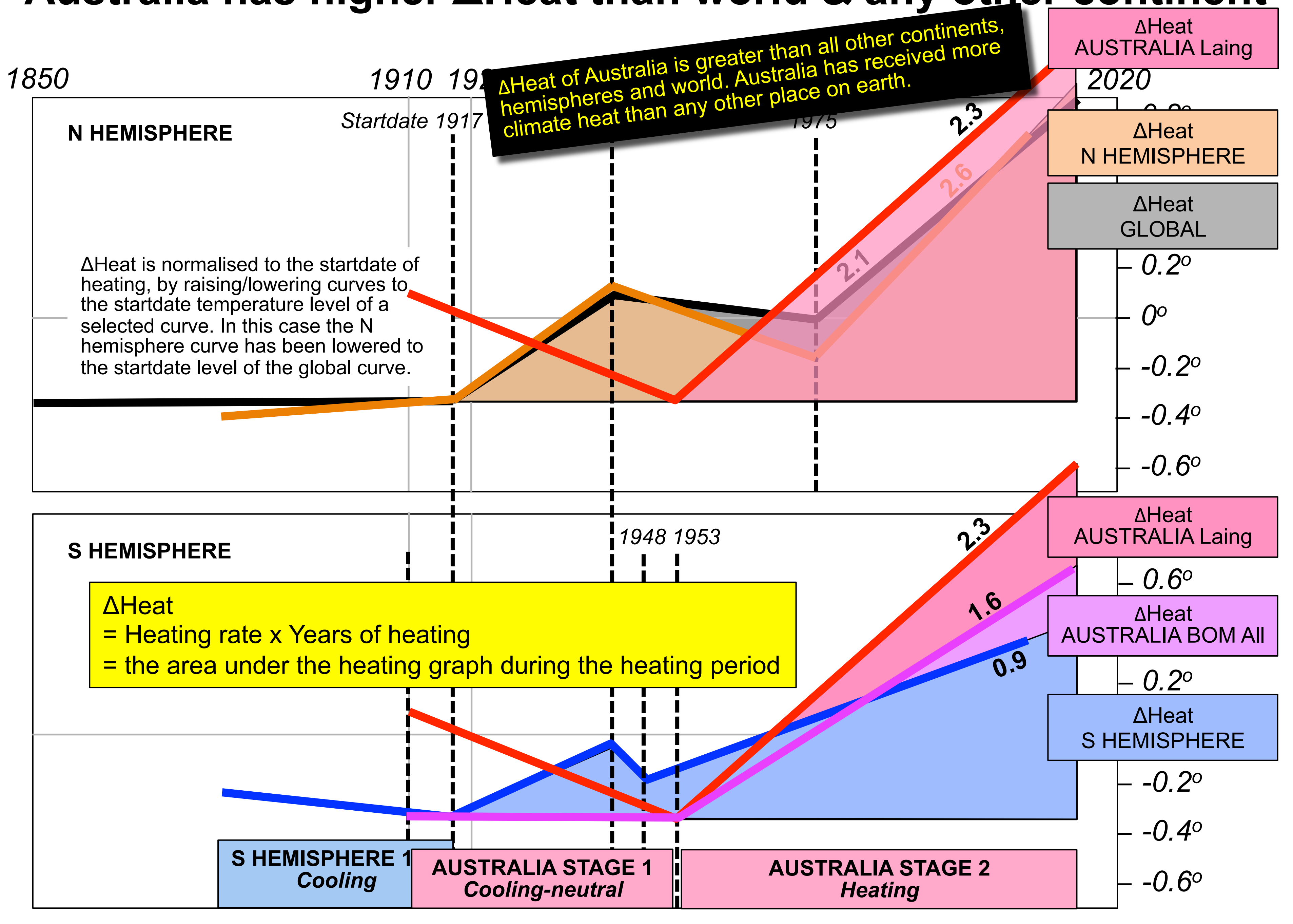


AUSTRALIA’S CLIMATE HEATING IS AMONG THE HIGHEST IN THE WORLD, AND IT IS ACCELERATING

Australia has higher ΔHeat than world & any other continent



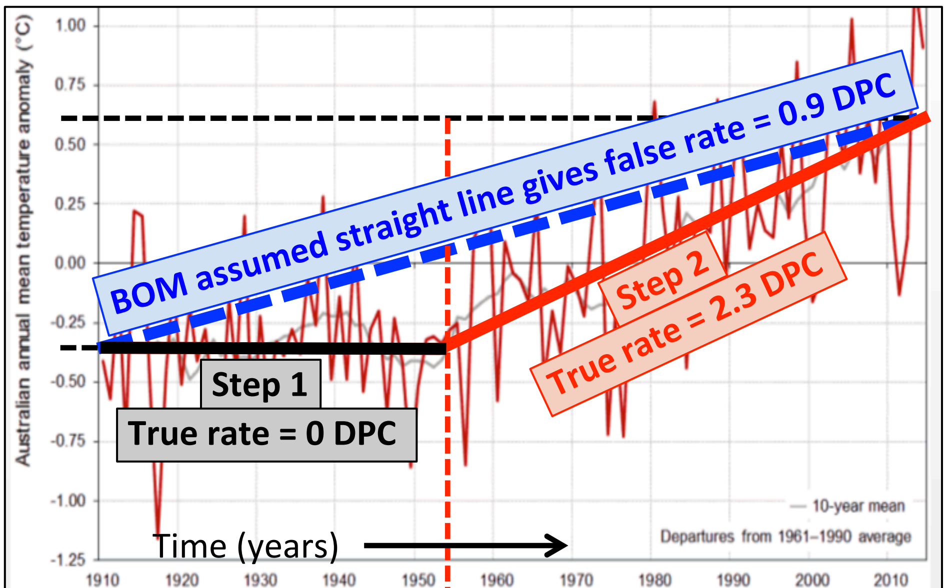
Australia has higher ΔHeat than world & any other continent



Australia’s heating graph: we have misinterpreted our climate heating rate

Australia’s heating rate has been calculated and published up till now as circa **0.9-1.0** DPC^*.
However Australia’s heating did not start until 1954 (mean ±10 years) so our true heating rate is **1.6** DPC.
Step 1 heating = 1910-1954 = **0º**. **Step 2 heating = 1954-present = 1.0º = 1.6** DPC.

Average temperature Australia



1.0º heating

1.0º heating spread over 117 years = **0.9** DPC
but
1.0º heating spread over 65 years = **2.3** DPC

Total period of records = 1910-2017 = 117 years

True (Step 2) heating = 1954-2017 = 63 years

* DPC = degrees C per century
^ Including BOM 2019

Australia is heating faster than the BOM says

Bureau of Meteorology position on climate change in May 2019 - unchanged for a decade

"The ACORN-SAT dataset reaffirms climate trends identified previously by the Bureau of Meteorology. Data show that Australia has warmed by over 1 degree since 1910. The warming has occurred mostly since 1950."

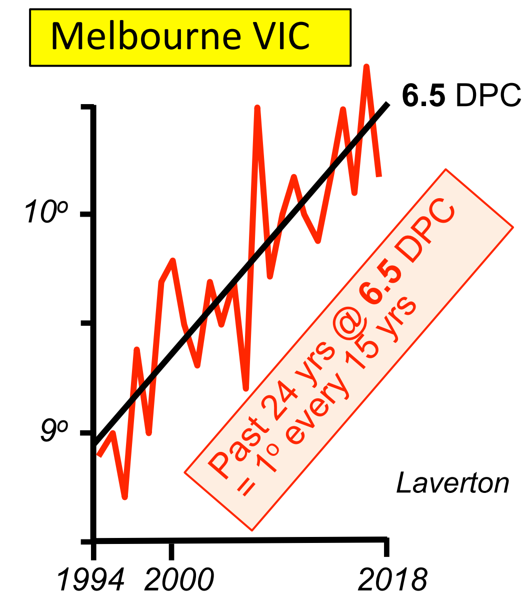
Laing study of Australian climate change in May 2019 - a brand new picture

"The BOM position on climate change is based on the heating data for all Australian weather stations integrated into a single curve. BOM assumes this single statistical curve as the best fit and calculates a heating rate over its whole 117 years. However when this single curve is deconstructed into 50 individual stations representative of the continent, the 50 curves reveal an unambiguous two-step climate regime: Step 1 cooling until circa 1954, followed by Step 2 heating to the present. Prior to 1954 extending back as far as 1910, most of Australia had a cooling or neutral climate. Australia's heating by over 1.0 degrees since records began in 1910 has been only effected by Step 2, since 1954. Australia's true heating rate, Step 2, is thus significantly higher than the hitherto accepted "1 degree per century". A specific event(s) around 1954 catalysed Australia's global heating. This simplifies the search for controls on Australia's (and the world's) climate heating."

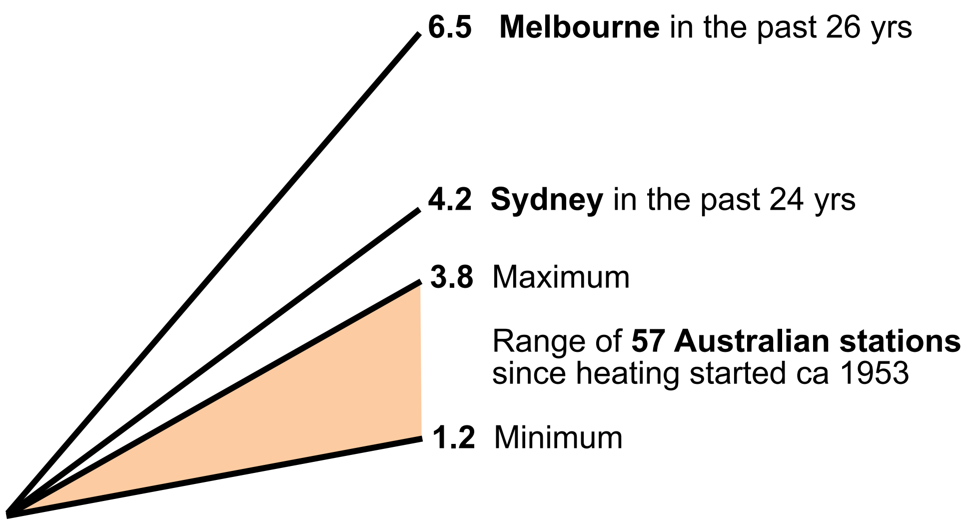
Sydney & Melbourne's climate heating is accelerating

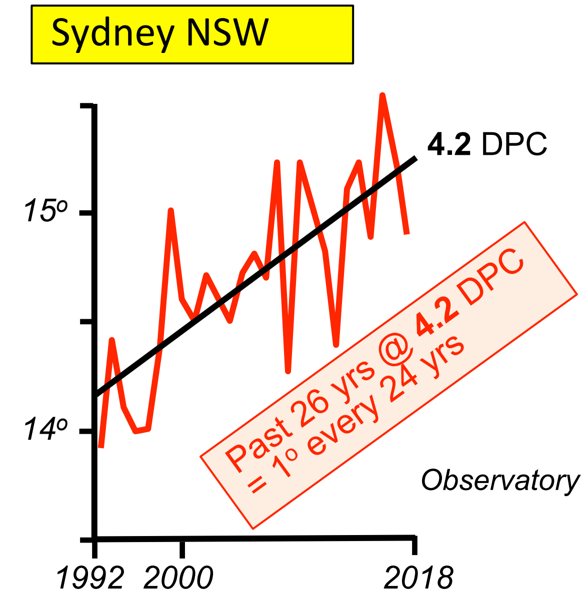
Minimum temperatures for Sydney and Melbourne in the past quarter century, with calculated linear regression lines showing heating rates respectively 4.2 and 6.5 DPC. These are 210% and 295% greater than each city's heating rate since heating started ca 1945: 2.0 and 2.2 DPC. These apparent accelerations in the past quarter century average 250%. Given the evidence of accelerated climate heating in some parts of the world, such acceleration over 25 years, in Australia where our heating exceeds global and southern hemispheric rates, is quite plausible.

The axes are scaled to the same ratio as the heating graphs of Australian stations, to permit direct comparison of their slopes, as below.

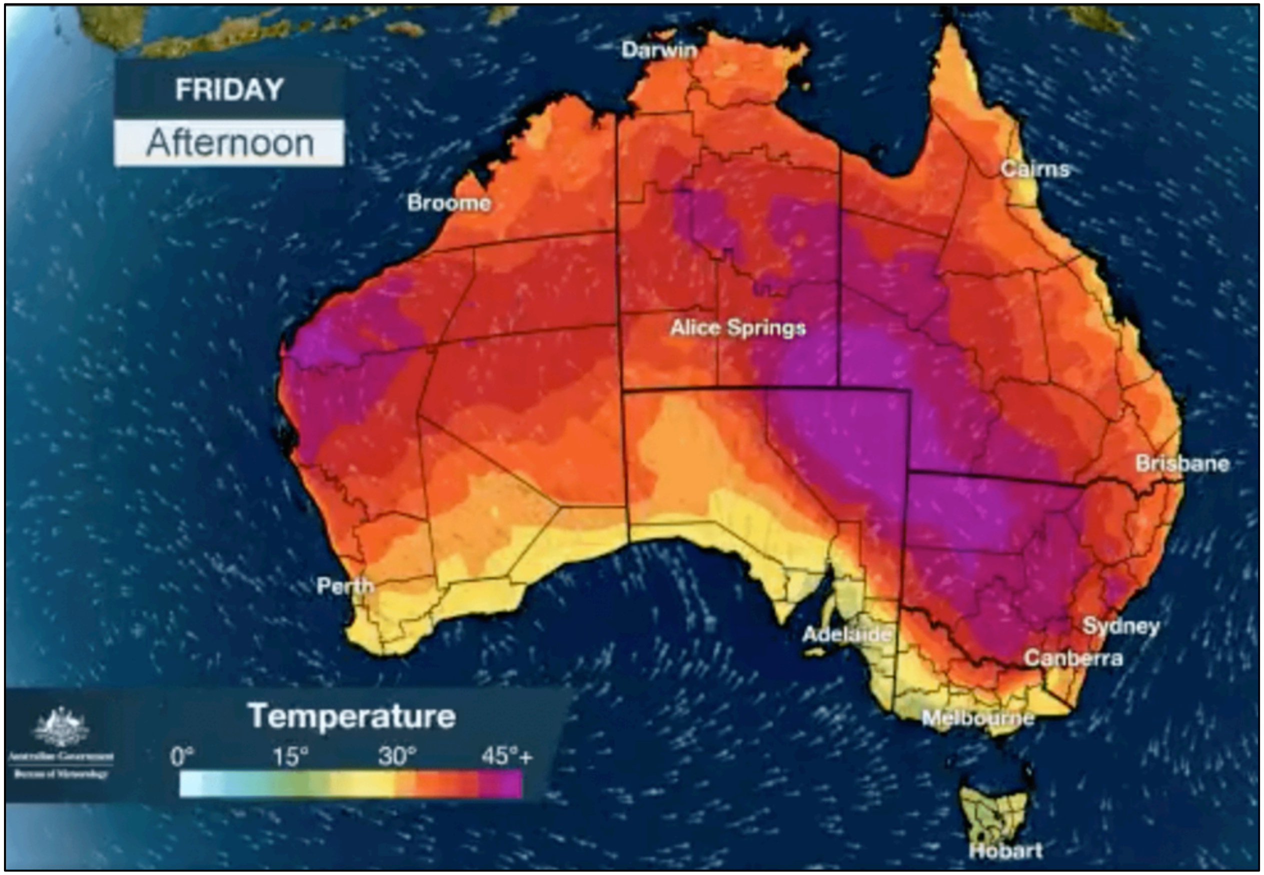


HEATING RATES: HISTORICAL & RECENT





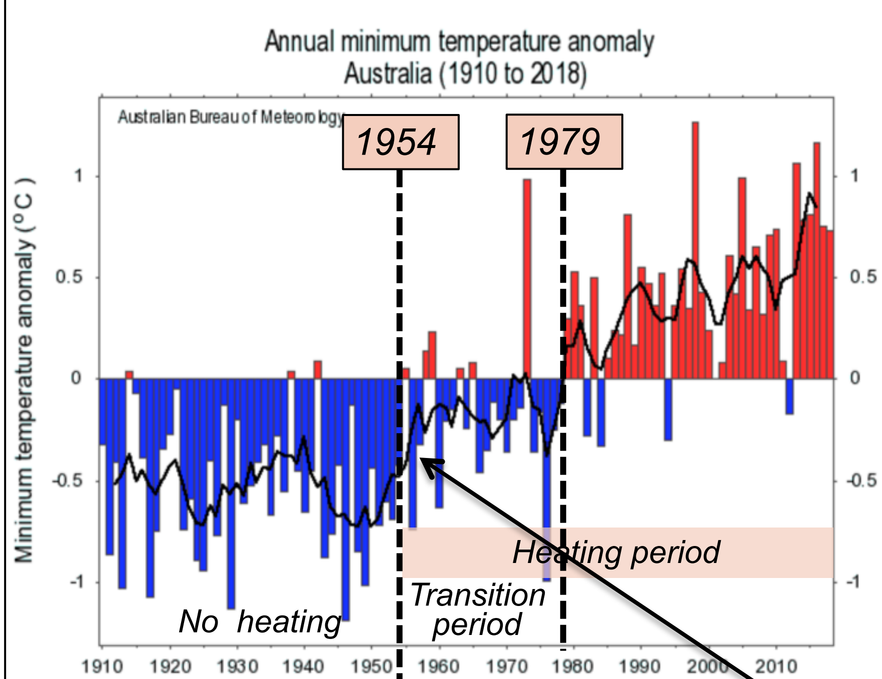
Australia continues heating, most likely at an accelerating rate

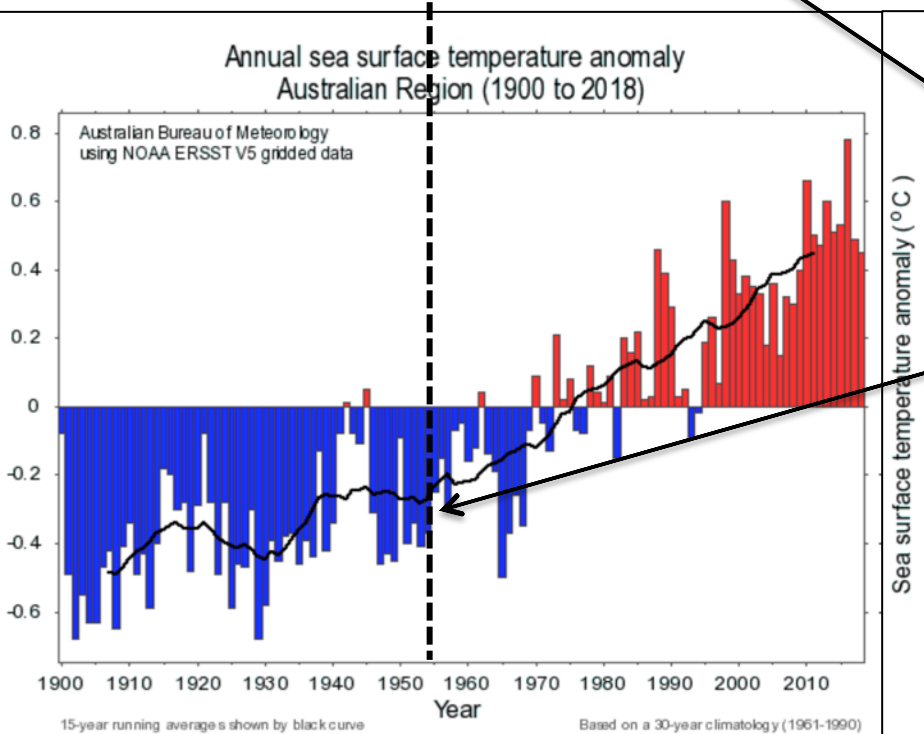


Australia's weather forecast for 18 January 2019. January was Australia's hottest month on record, with record mean, maximum and minimum temperatures. Australia's mean temperature exceeded 30oC for the first time since records began in 1910. The Bureau of Meteorology said the widespread heatwave conditions and daily extremes were "unprecedented". "There's been so many records it's really hard to count," said Andrew Watkins, a senior climatologist at the BOM.

THE 2 STEPS ALSO IN OUR OCEAN'S HEATING

Figure 12-1





Graphs on left - ATMOSPHERIC HEATING:

Australia's atmosphere has experienced stepped heatiing, with commencement of heating around 1954.

Graph below - OCEANIC HEATING:

The oceans surrounding the continent show the same pattern. They commenced heating around 1965 (graph below). A small heating event started in 1940, but the trend is best defined from 1965.

Key results for Australia's **oceans**:
Australia's heating start = (1940-)1965 (approximately)
Australia has heated 1.0 degree so far
Australia has heated 0.8 degree in Step 2 since 1965 ie
Australia's later ocean heating rate = 1.6 degrees per century

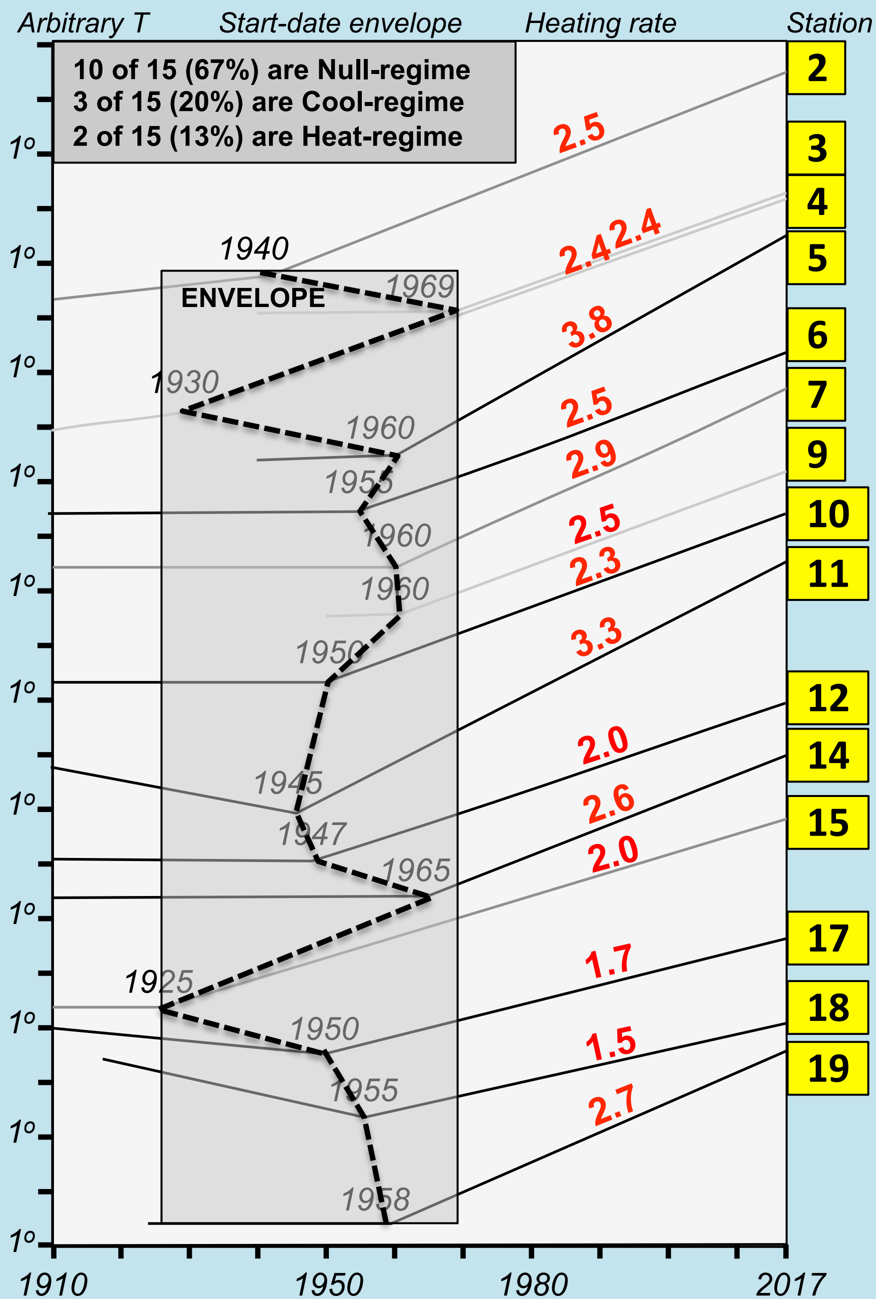
Monotonic heating startdate - **atmosphere**

Monotonic heating startdate - **oceans**

AUSTRALIA’S CLIMATE REGIME: THE EAST COAST

Figure 2-1

EAST COAST
N (top) to **S** (bottom)



STAGE 1 HEATING REGIME

for n = 15 stations

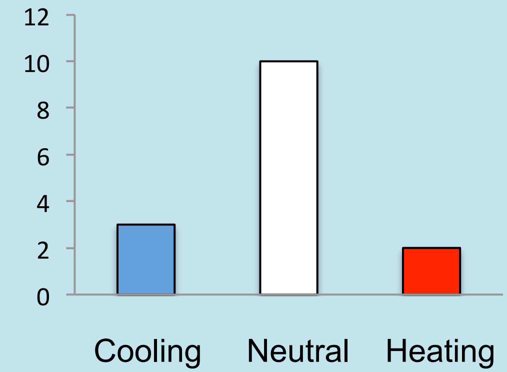
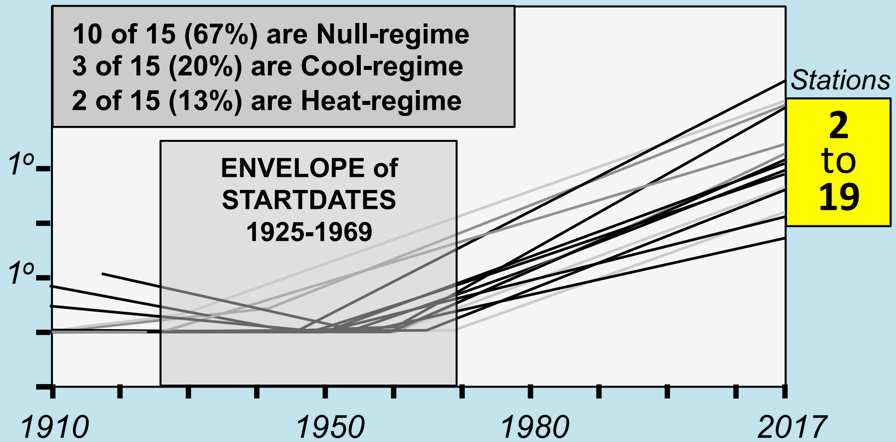


Figure 3-1

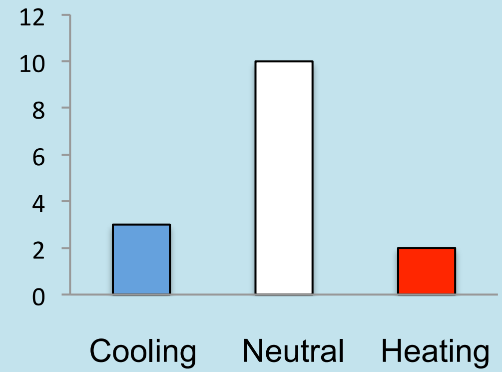
EAST COAST

Graphs normalised spatially

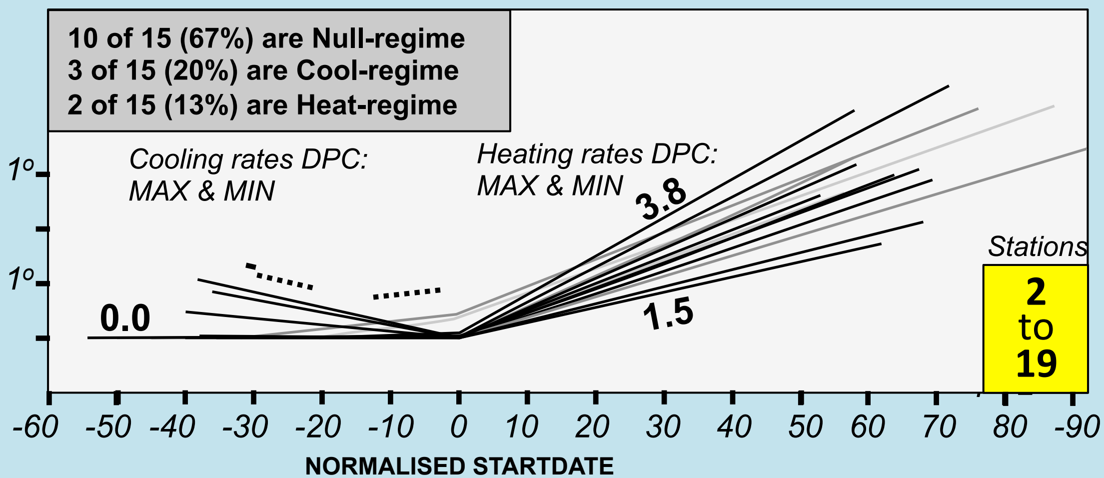


STAGE 1 HEATING REGIME

for n = 15 stations



Graphs normalised spatially & temporally



East Australia Current is heating at 4 times global ocean rate

Australia's climate emergency: the dead sea

The Guardian, 24 February 2020

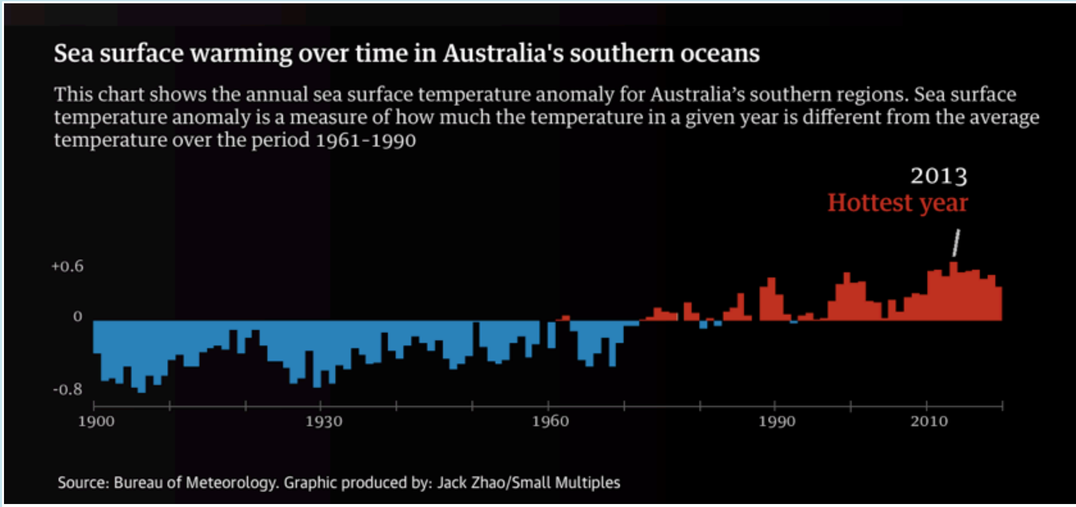
The sea along the Tasmanian east coast is a global heating hotspot. Temperatures there have risen at nearly 4 times the global average. They are about 2 degrees hotter than a little over a century ago.

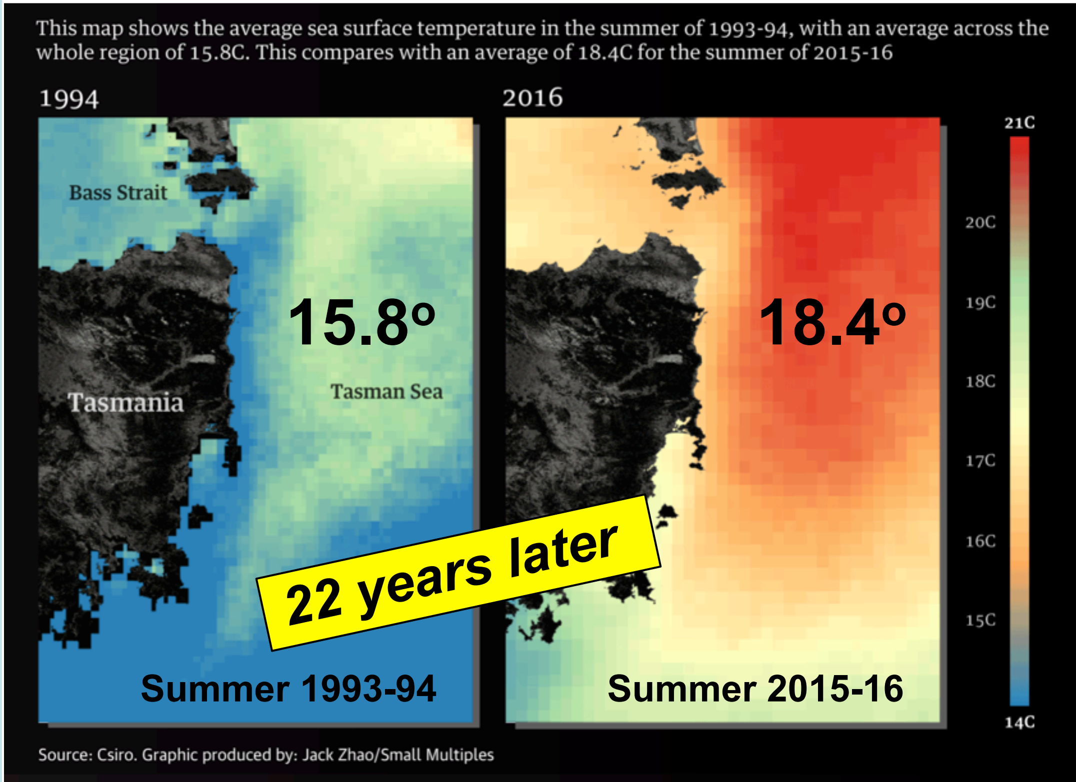
Warm water pushed down the coast by the East Australian Current has stripped the area of nutrients, brought new marine species, and killed more than 95% of the giant kelp. The impact on local ecosystems and fisheries has been severe.

Mick Baron, a dive instructor and trained biologist, has watched entire giant kelp forests disappear in his lifetime. Growing up to 40 metres from the ocean floor, the forests protected a vibrant ecosystem of sponge garden, fur seals, crayfish, weedy sea dragons and countless fish species.

The forests started to die in the north of Tasmania in the 1960s. Baron first noticed them vanishing from Deep Glen Bay, a short boat ride north-east of his dive centre at Eaglehawk Neck, in the late 1990s.

https://www.theguardian.com/environment/ng-interactive/2020/feb/24/the-dead-sea-tasmanias-underwater-forests-disappearing-in-our-lifetime



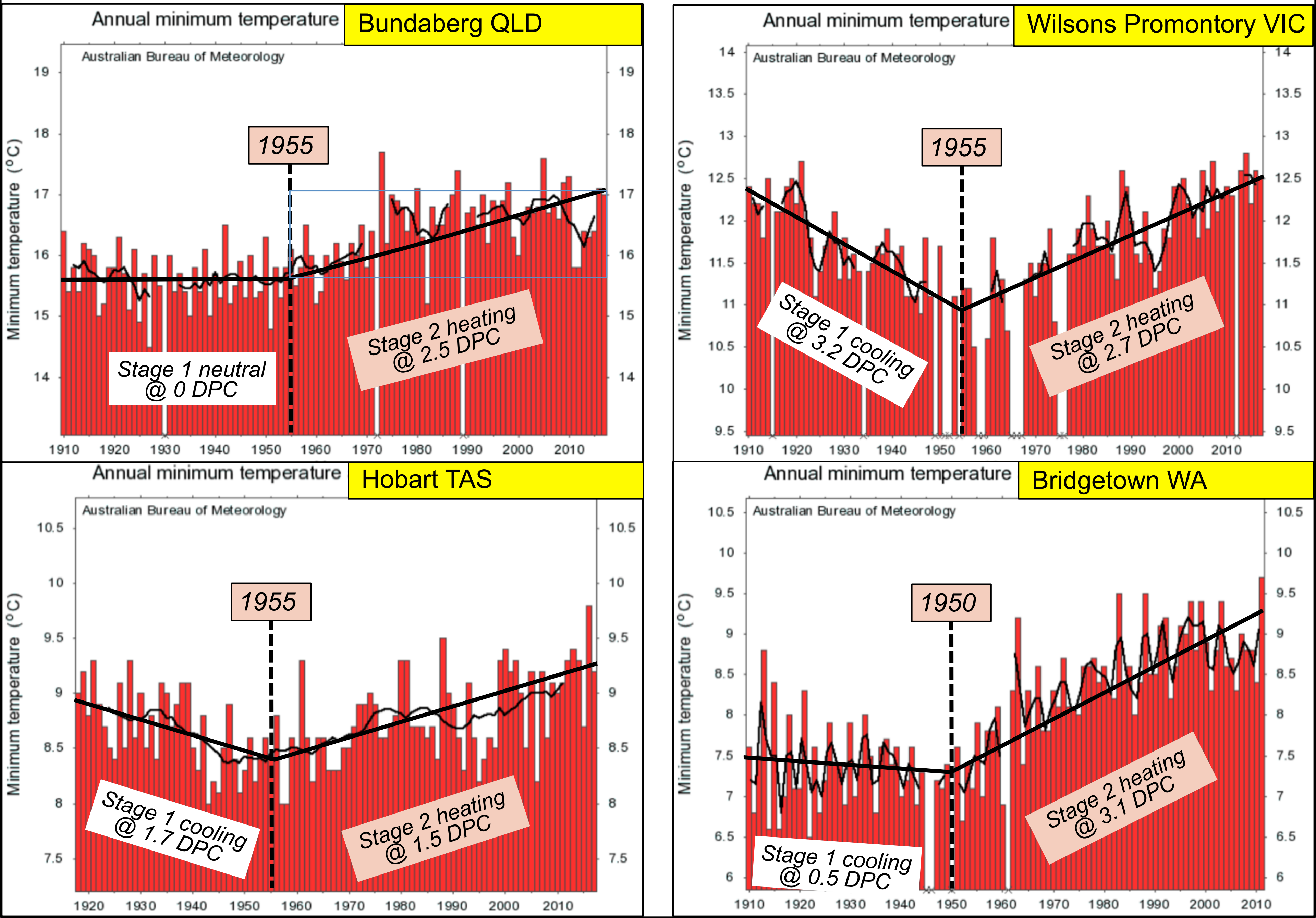


Australia's climate regime 1920-2018: a coherent transcontinental system sequestered from the other continents, with Stage 1 cooling followed at 1955±10 by Stage 2 heating faster than the world mean, and the system significantly informing the global heating model

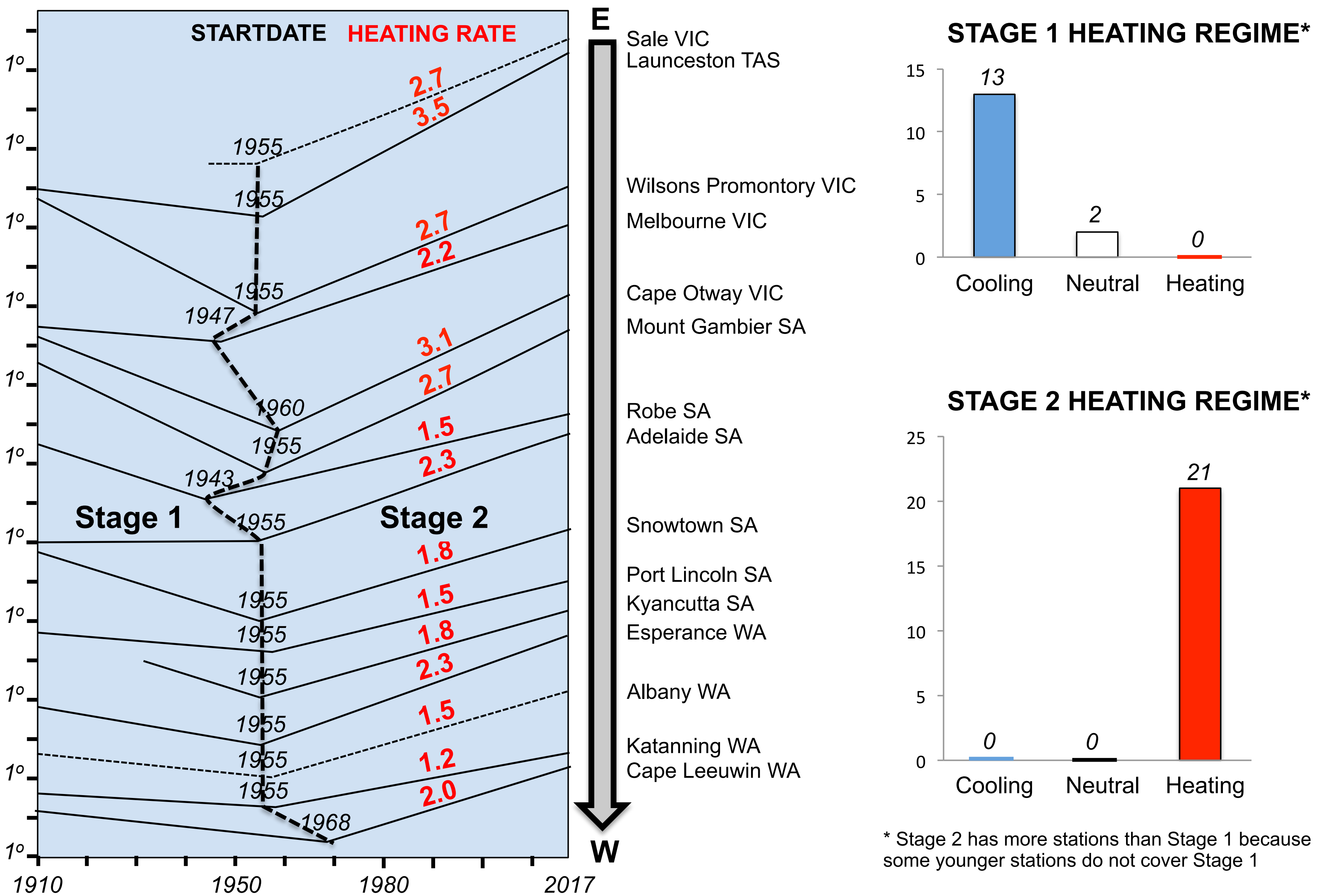
Dr Bill Laing

19 December 2019

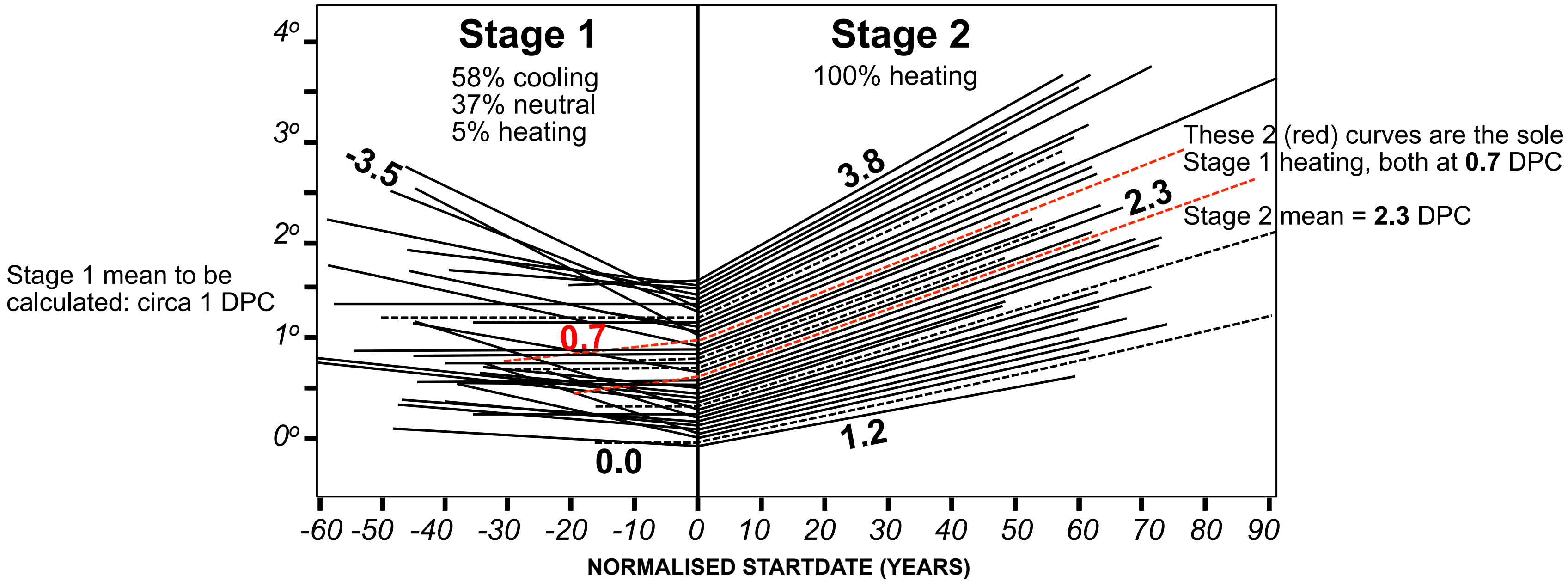
Heating graphs of typical ACORN-SAT coastal stations. Selected to illustrate: Cities-towns-isolated stations, Stage 1 cooling @ 0 to 3.2 DPC, Stage 2 heating @ 1.5 to 3.1 DPC. The opposed stage 1-2 "V" topology delivers reliability = 3/3



Transect of heating graphs (minimum temperature) along Australia's South coast domain, using only high-reliability stations (score 3/3) plus Sale and Albany (2/3). Transect is E to W (arrow, top to bottom). The strong differentiation of each station's opposing-slope stages 1 and 2 permits the two-stage "V-shaped" manual linear regression shown.



The heating graphs of coastal Australia, normalised to startdate “0”, and arranged to display their array of Stage 2 heating rates. Stage 1 curves range from 2 heating (red), through 15 neutral, to 23 cooling. Numbers indicate heating (+) or cooling (-) rates in DPC. Solid curves have reliability 3/3, dashed curves have reliability 2/3.

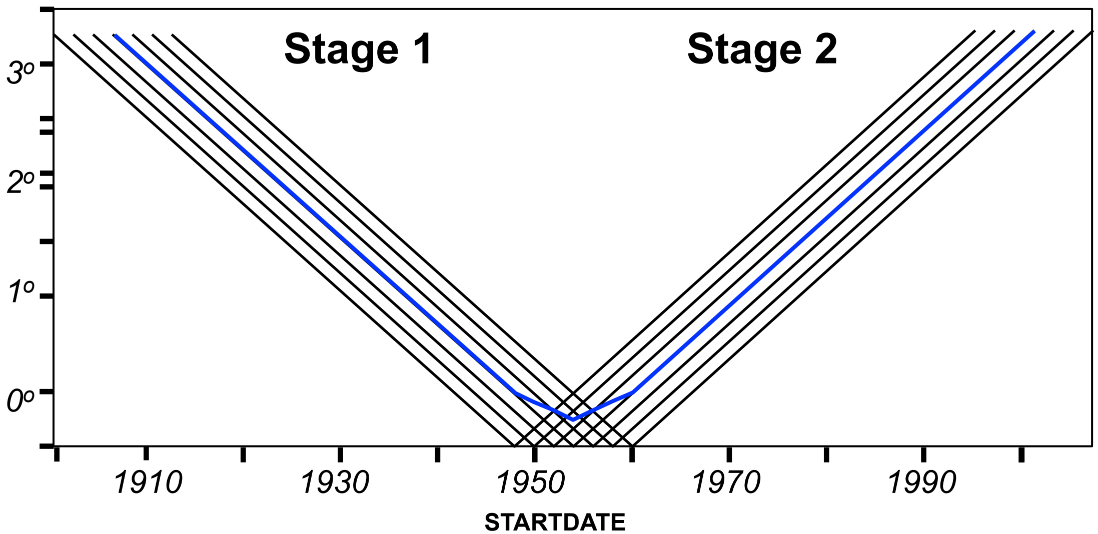


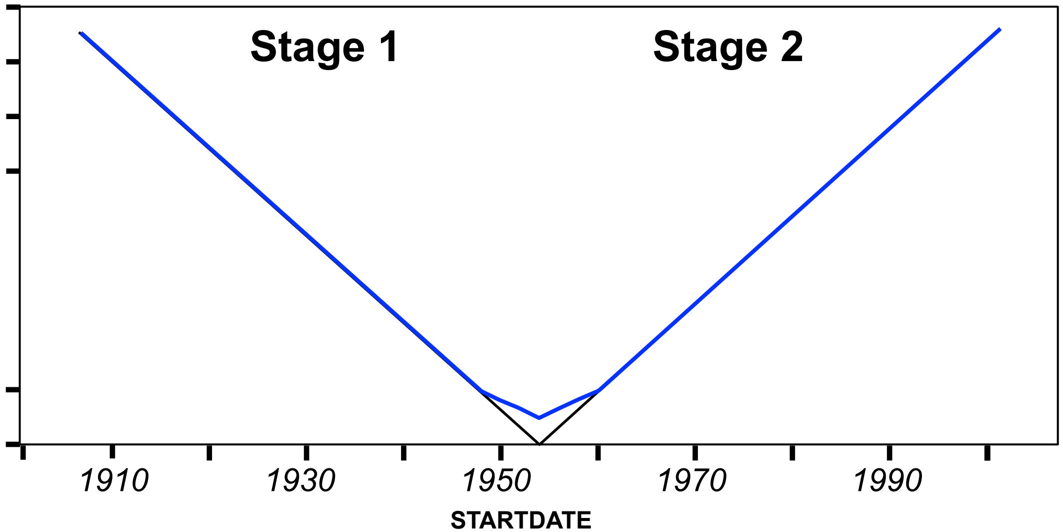
SUMMARY*

STAGE 1	**Predominantly cooling**	
Maximum heating rate	**0.7**	In 2 stations
Maximum cooling rate	**-3.5**	Over 38 stations
Minimum cooling rate	**0.0**	Over 38 stations
Mean cooling rate	ca **-1**	Over 40 stations
STAGE 2	**Completely heating**	
Maximum heating rate	**3.8**	Over 57 stations
Minimum heating rate	**1.2**	Over 57 stations
Mean heating rate	**2.3**	Over 57 stations

* In degrees per century (DPC)

A manufactured example which shows the power of individual site heating graphs to reveal climate dynamics which large dataset strategies inherently tend to conceal. Figure 2a contains 7 site heating graphs, all identical in topology, but separated by 2.5 years. The blue graph is their mean. Figure 2b shows the real graph for each station (black) and the mean graph (blue). The mean graph has degraded its heating quantum (it shows a minimum temperature almost half a degree warmer than the real temperature experienced at each station) and degraded its sensitivity to showing the heating startdate (the sensitivity being inversely proportional to the reversal of slope angle, which is no longer the real 96o, it is now 132o ie 40% degraded). I can manipulate the individual curves but once merged I cannot do so - .....can always lump but can never split" .....





Stage 1 heating regimes in each domain. Only high-reliability stations (3/3) are employed.

TOTAL COASTLINE

n = 40

2 domains **Cooling**, 1 domain **Neutral**

EAST COAST

n = 15

Predominantly **Neutral**

SOUTH COAST

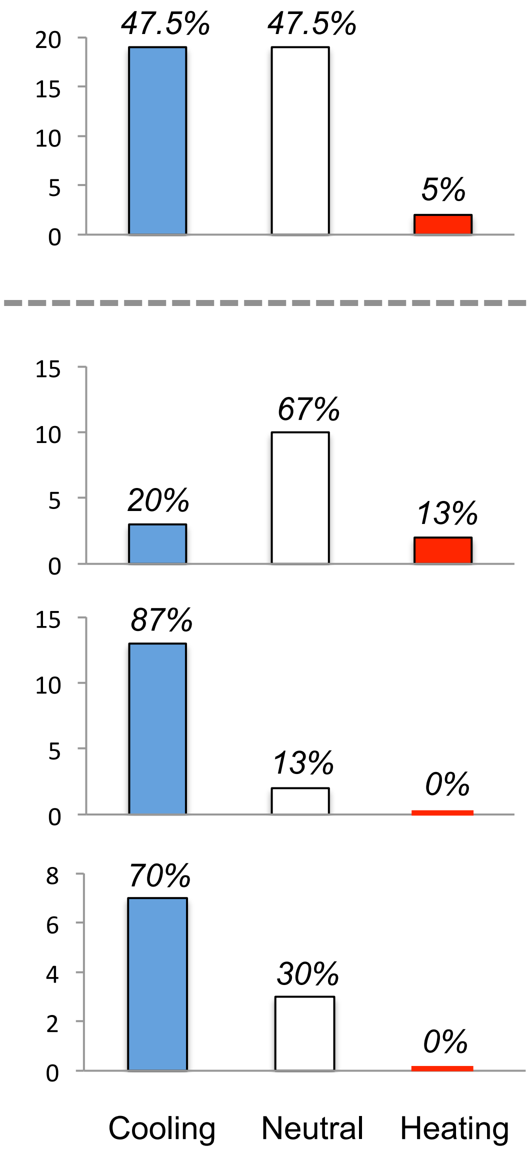
n = 15

Predominantly **Cooling**

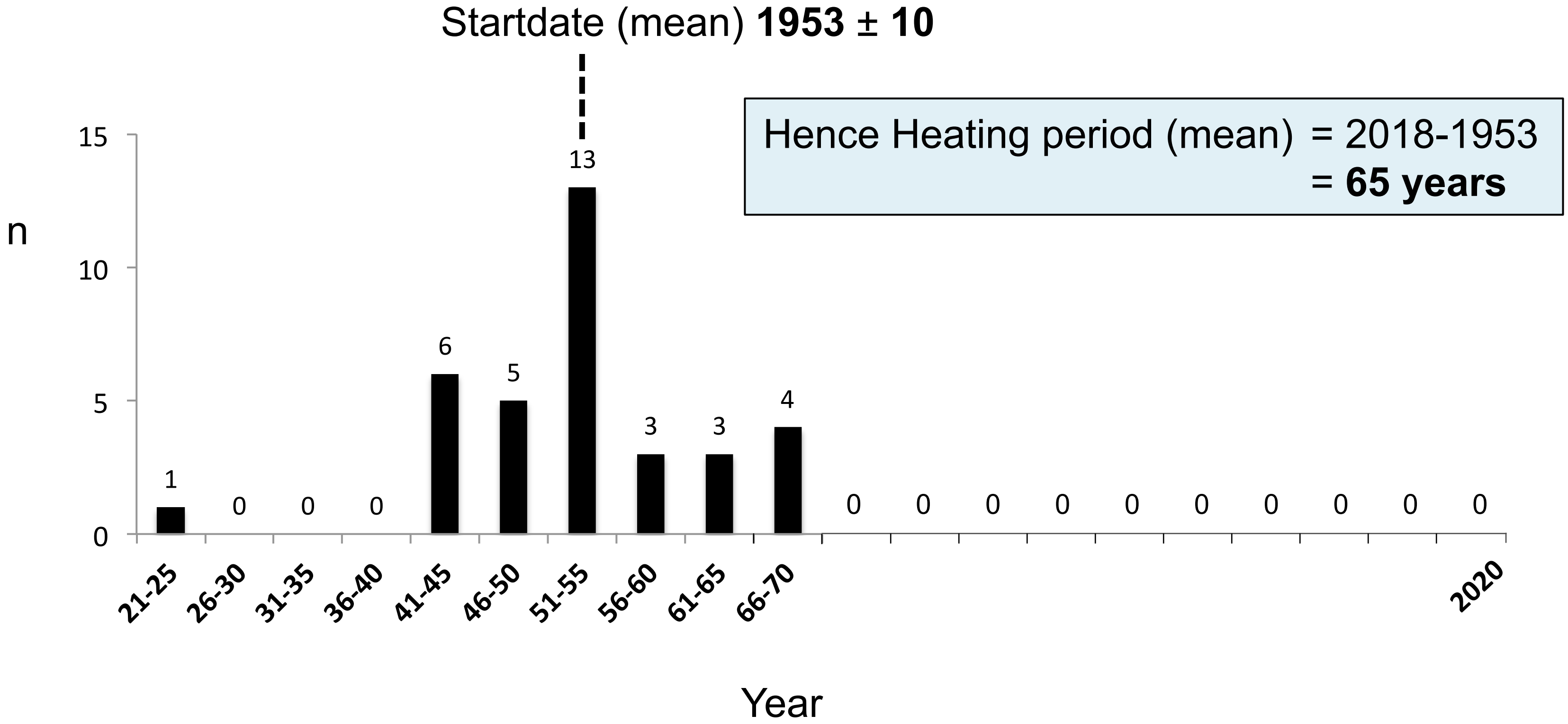
WEST-NORTH COAST

n = 10

Predominantly **Cooling**

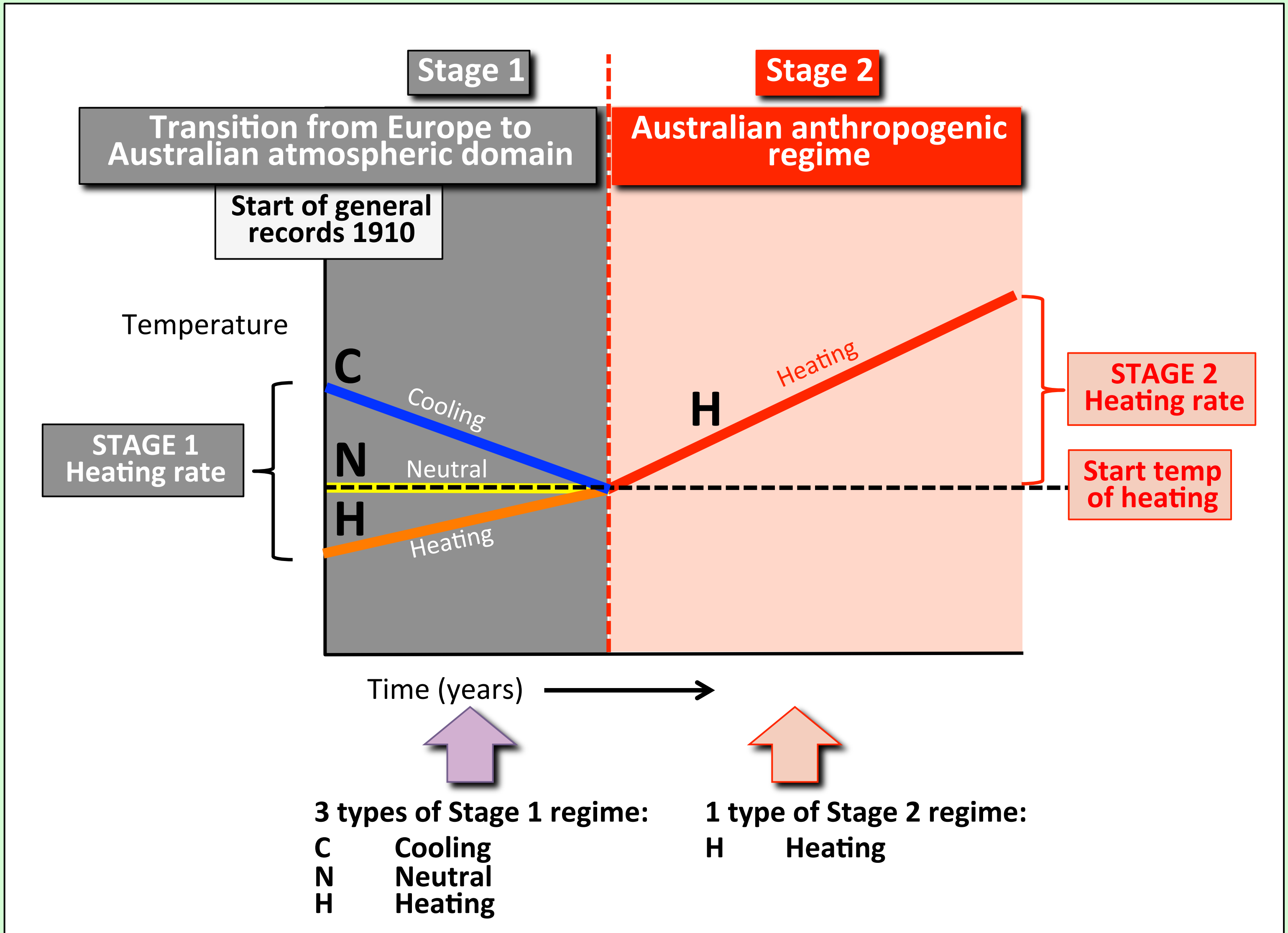


Frequency plot of Stage 2 startdates, from high-reliability stations (3/3 - 35 stations).

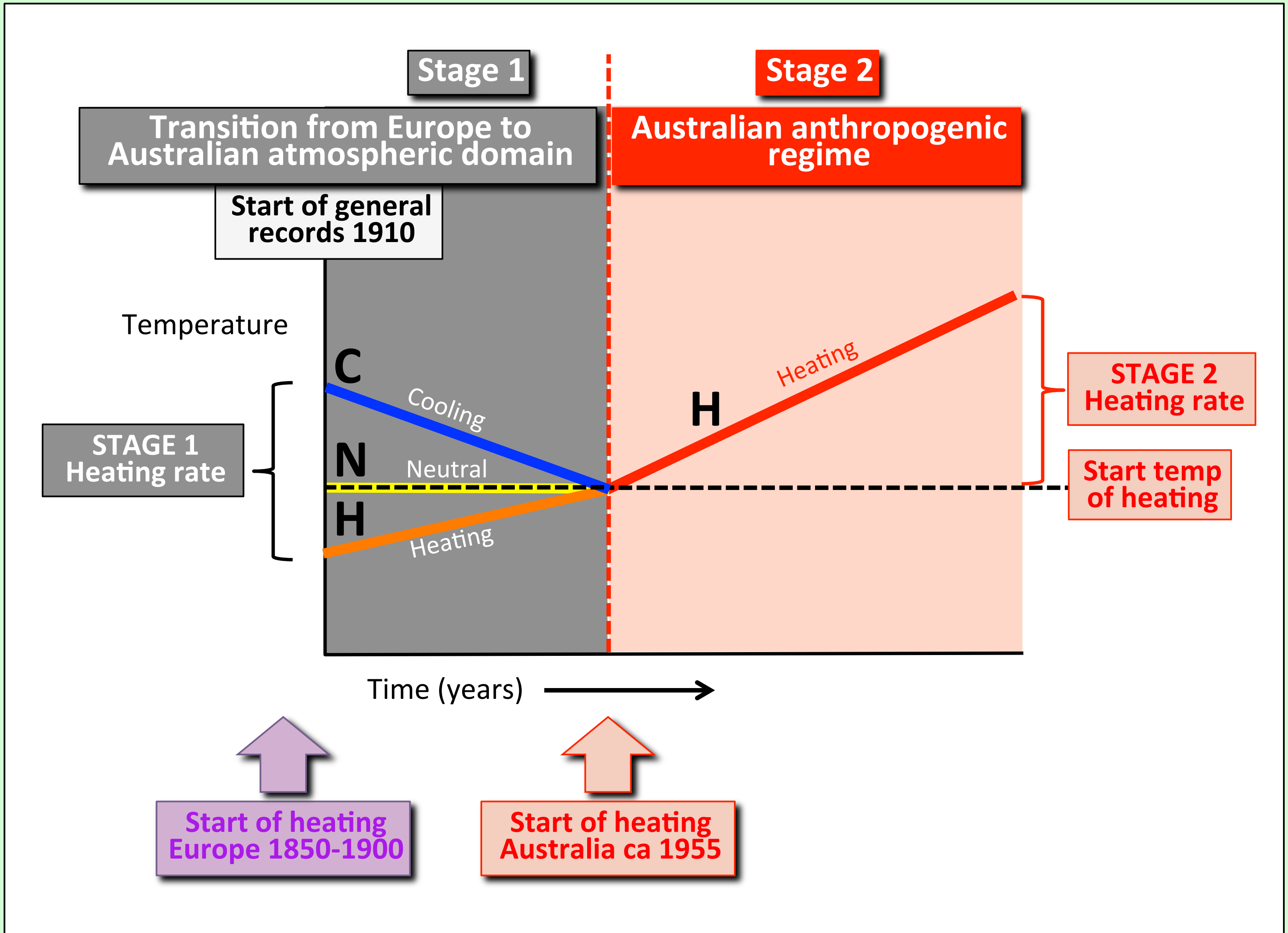


AUSTRALIA’S CLIMATE REGIME: STAGES 1 & 2

Australia's climate
Stages 1 and 2
Contrasting heating & dynamics

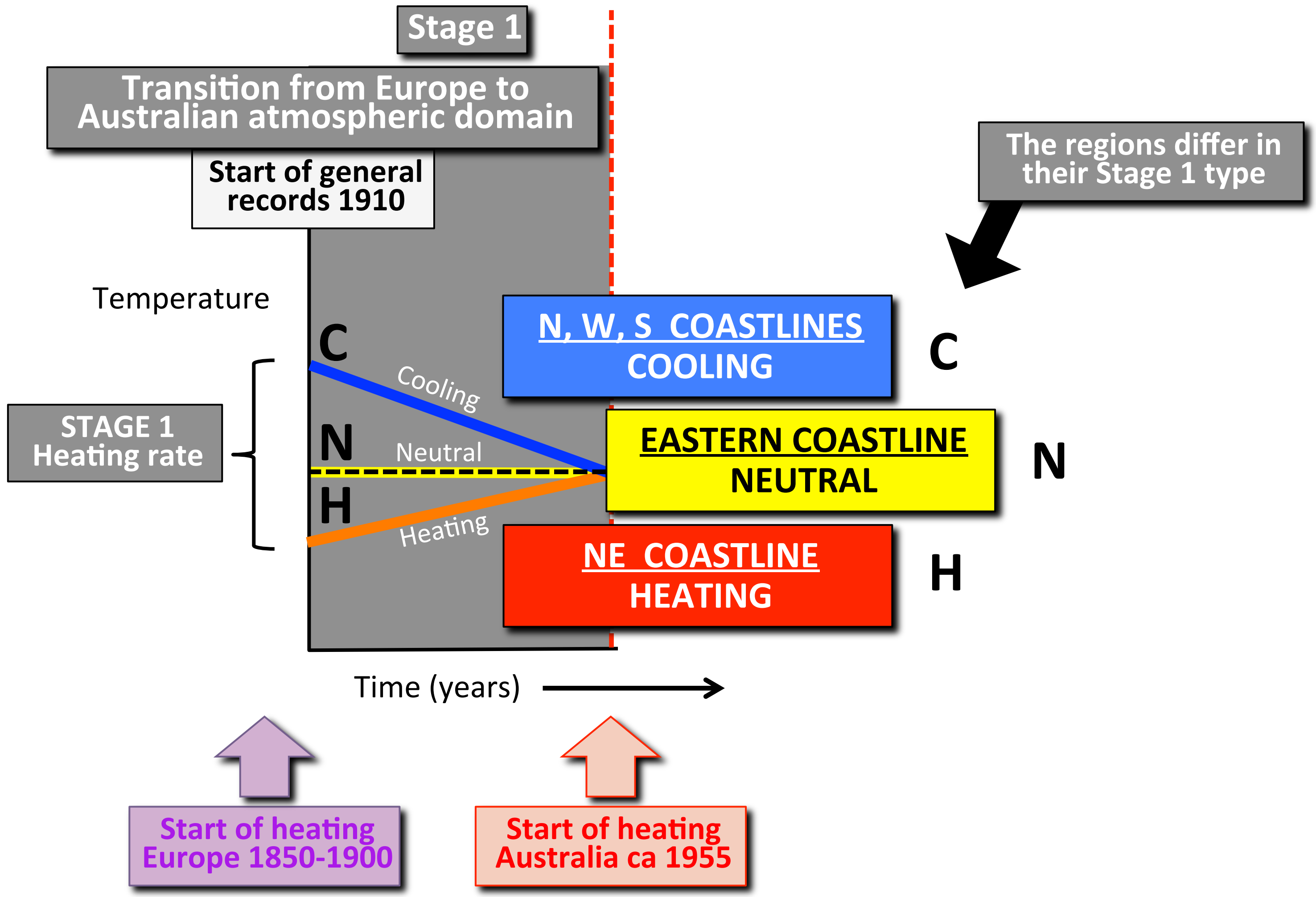


Australia's climate
Stages 1 and 2
Contrasting heating & dynamics



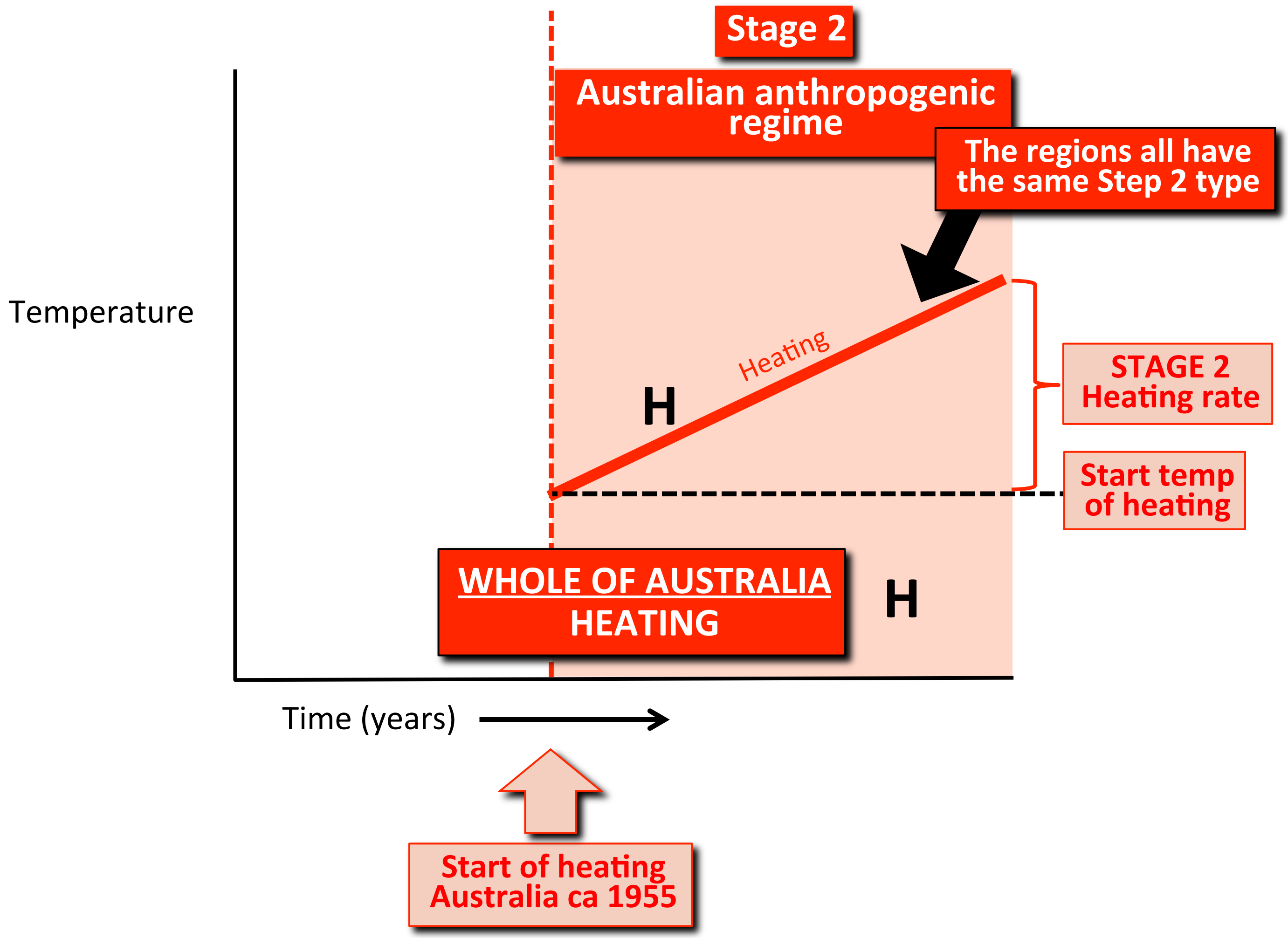
Australia's climate
Stage 1
Variable, mostly cooling to 1955

Australia had a **Stage 1** regime prior to our current heating of **Stage 2**. **Stage 1** was cooling on W & S coasts, and on N & E coasts systematically changing from W to E & N to S: heating→neutral→cooling



Australia’s climate
Stage 2
Heating from 1955

Australia’s current heating of **Stage 2** comprises heating throughout the continent, with a systematic pattern in each region around the coast: cooling → heating anticlockwise in all regions: N, W, S and E.



Australian climate change versus world climate change

Australia's rates from ACORN-SAT stations: 112 around continent

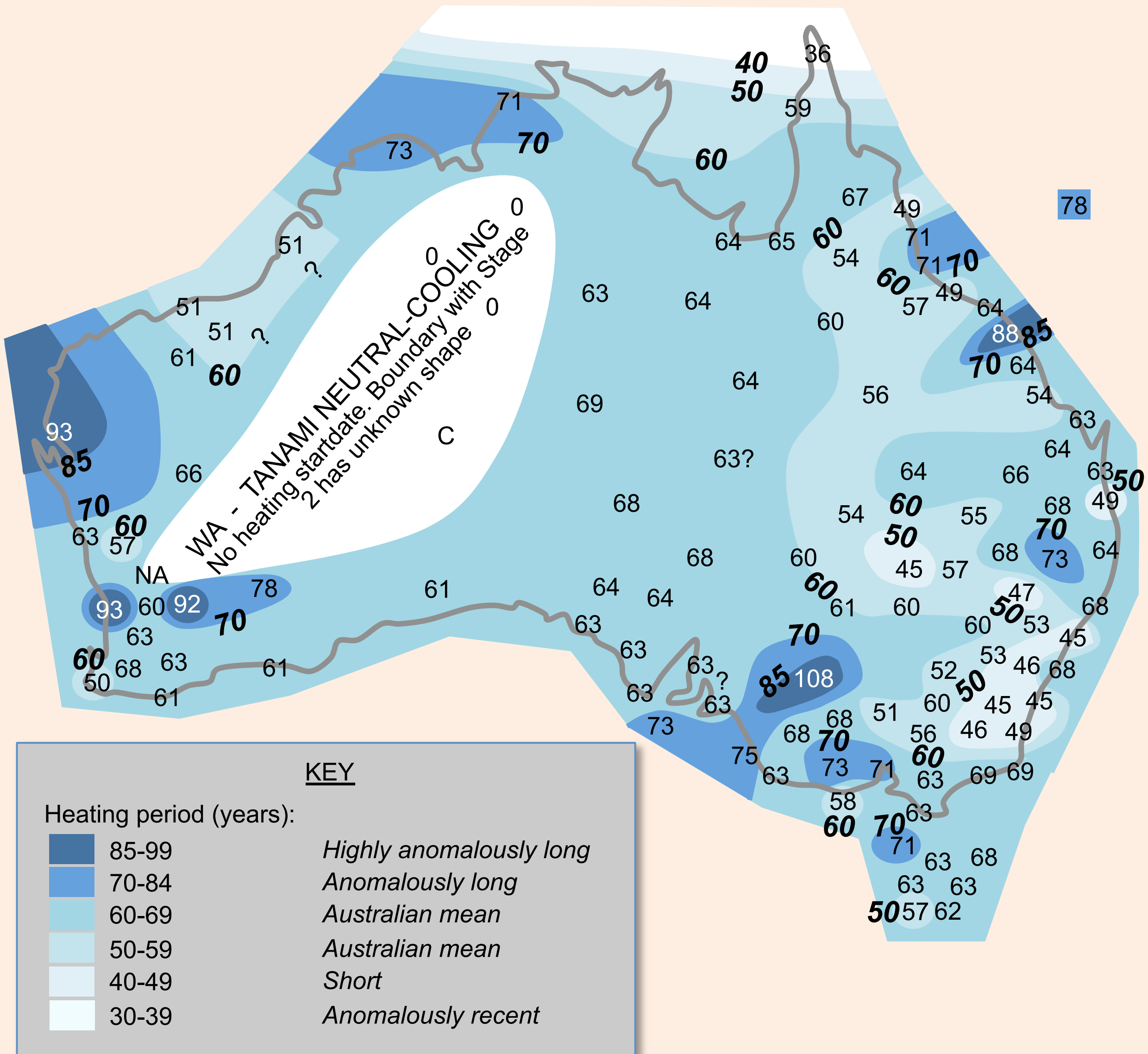
Heating rate increases

THE WORLD	**1.1º per 100y**	**1.5x** the world
AUSTRALIA	**1.6º per 100y**	**1.5x** the world
AUSTRALIA: COAST	**2.3º per 100y**	**2.1x** the world **1.4x** rest of Australia
AUSTRALIA: EAST COAST	**2.4º per 100y**	**2.1x** the world **1.5x** rest of Australia
TOWNSVILLE	**2.7º per 100y**	**2.2x** the world **1.6x** rest of Australia
MELBOURNE & SYDNEY **accelerating in past 25 yrs**	**5.3º per 100y**	**5x** the world **2.3x** rest of Australia

AUSTRALIA’S CLIMATE CHANGE ACROSS THE CONTINENT

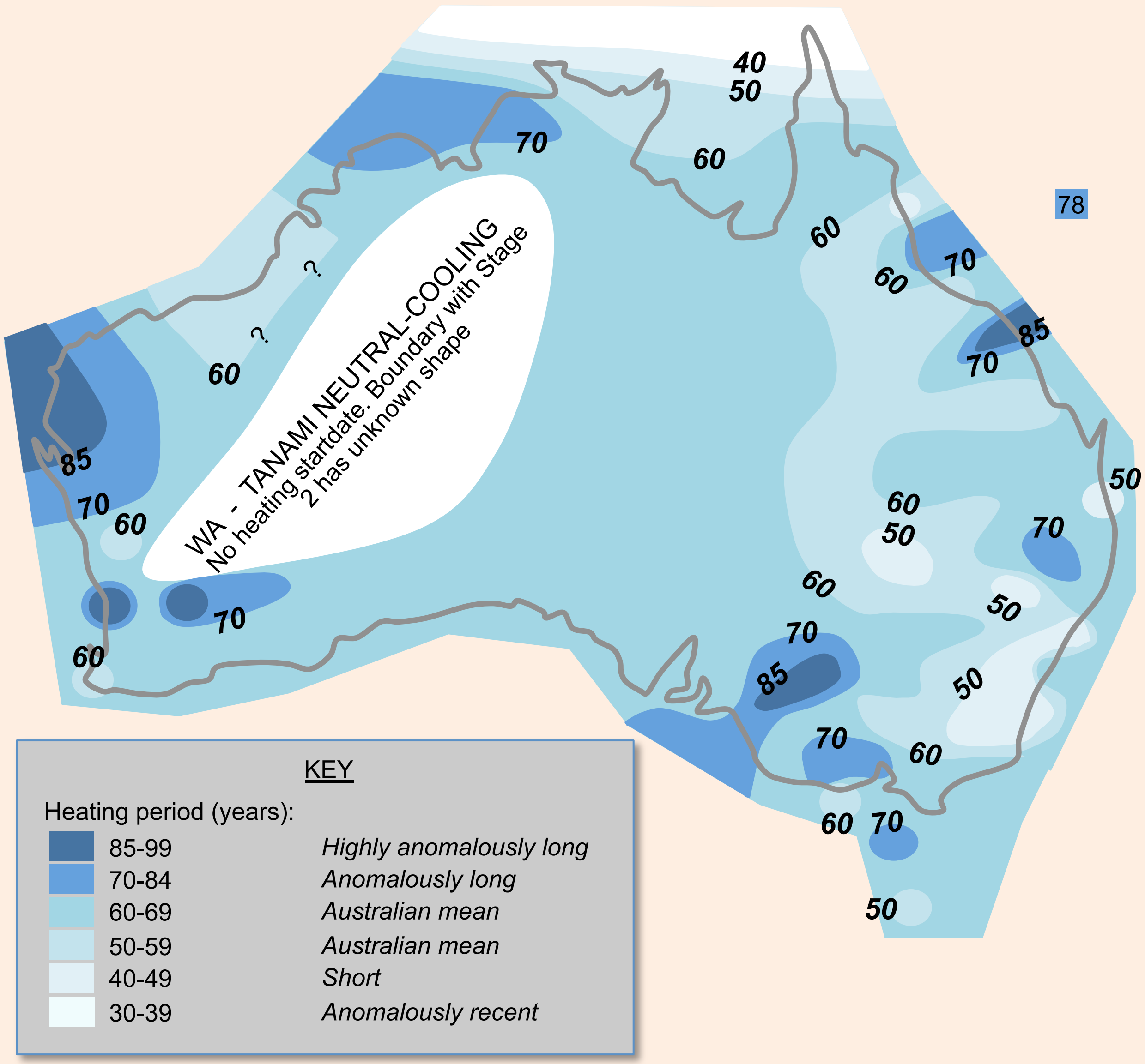
Stage 2 Heating period - Data

The climate heating period Y commences at the Startdate, and finishes end-2018.



Stage 2 Heating period - Topology

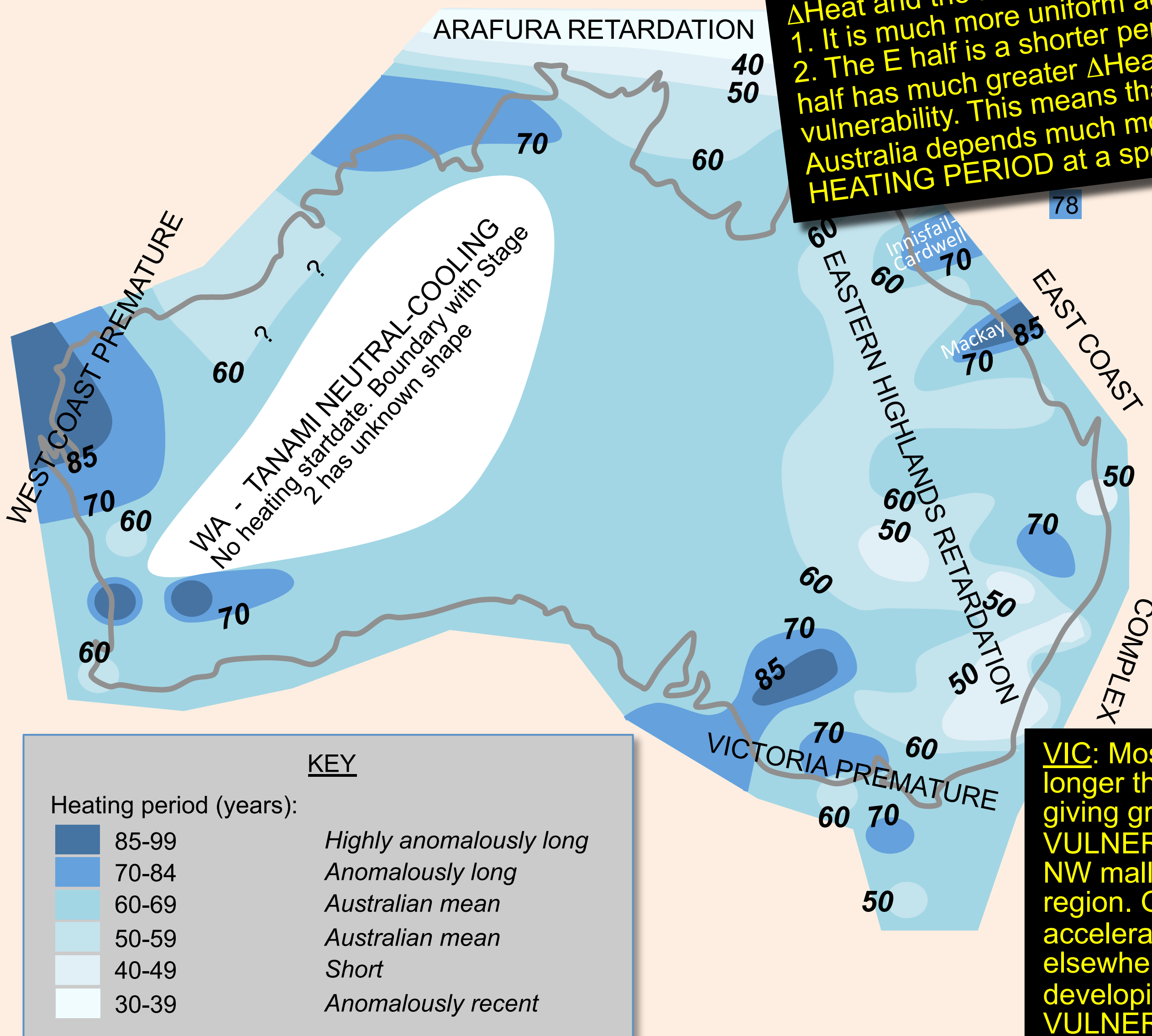
The climate heating period Y commences at the Startdate, and finishes end-2018.



Stage 2 Heating period: Topology

The climate heating period Y commences at the Startdate, and finishe

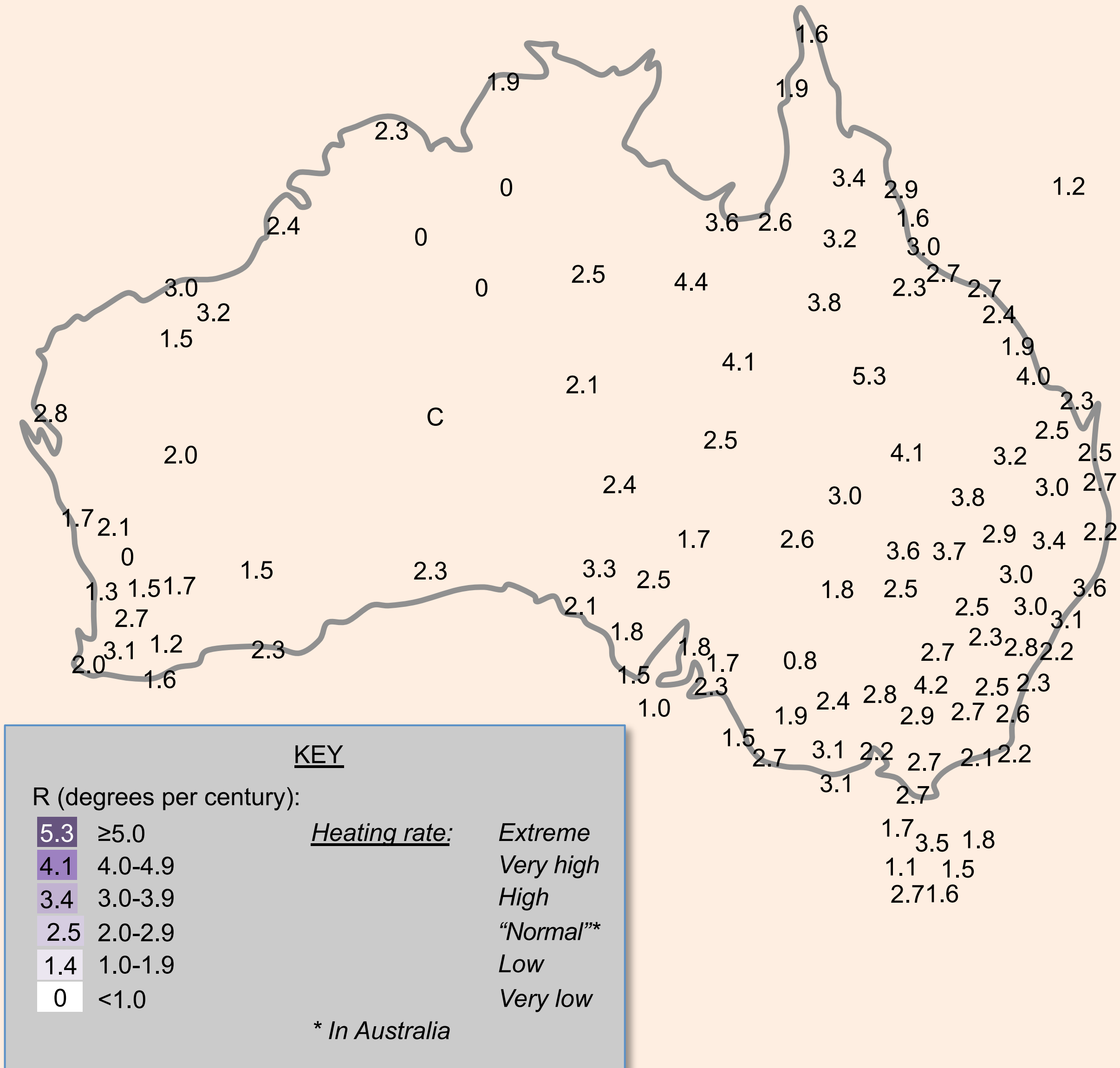
Stage 2 Heating period is strongly domained into E and W halves of the continent.
The heating period has a distinctly different distribution from ΔHeat and the Heating rate (see following pages).
1. It is much more uniform across the continent (max:min <1)
2. The E half is a shorter period than the W half. Yet the E half has much greater ΔHeat hence much greater bushfire vulnerability. This means that BUSHFIRE VULNERABILITY in Australia depends much more on HEATING RATE than on HEATING PERIOD at a specific location.



<u>VIC</u>: Most of the State has heated longer than the Australian mean, giving greater BUSHFIRE VULNERABILITY. This includes the NW mallee and the Melbourne region. Given Melbourne's accelerating Heating rate (see elsewhere) the Melbourne region is developing greater BUSHFIRE VULNERABILITY into the future.

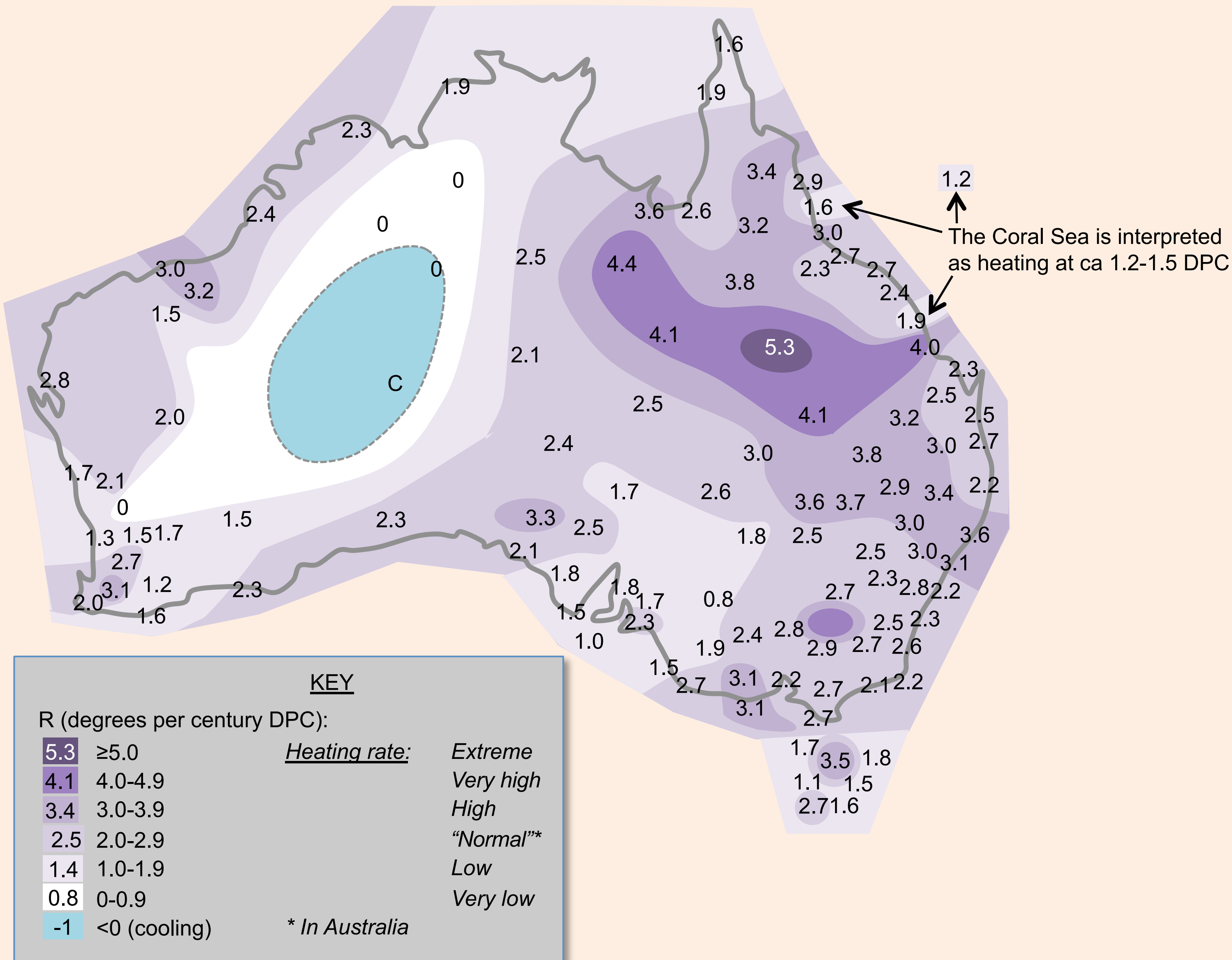
Stage 2 Heating rate R - Data

The climate heating rate R is the ratio of the increase in temperature ΔT and the heating period ΔY: **R = ΔT / ΔY**



Stage 2 Heating rate R - Topology

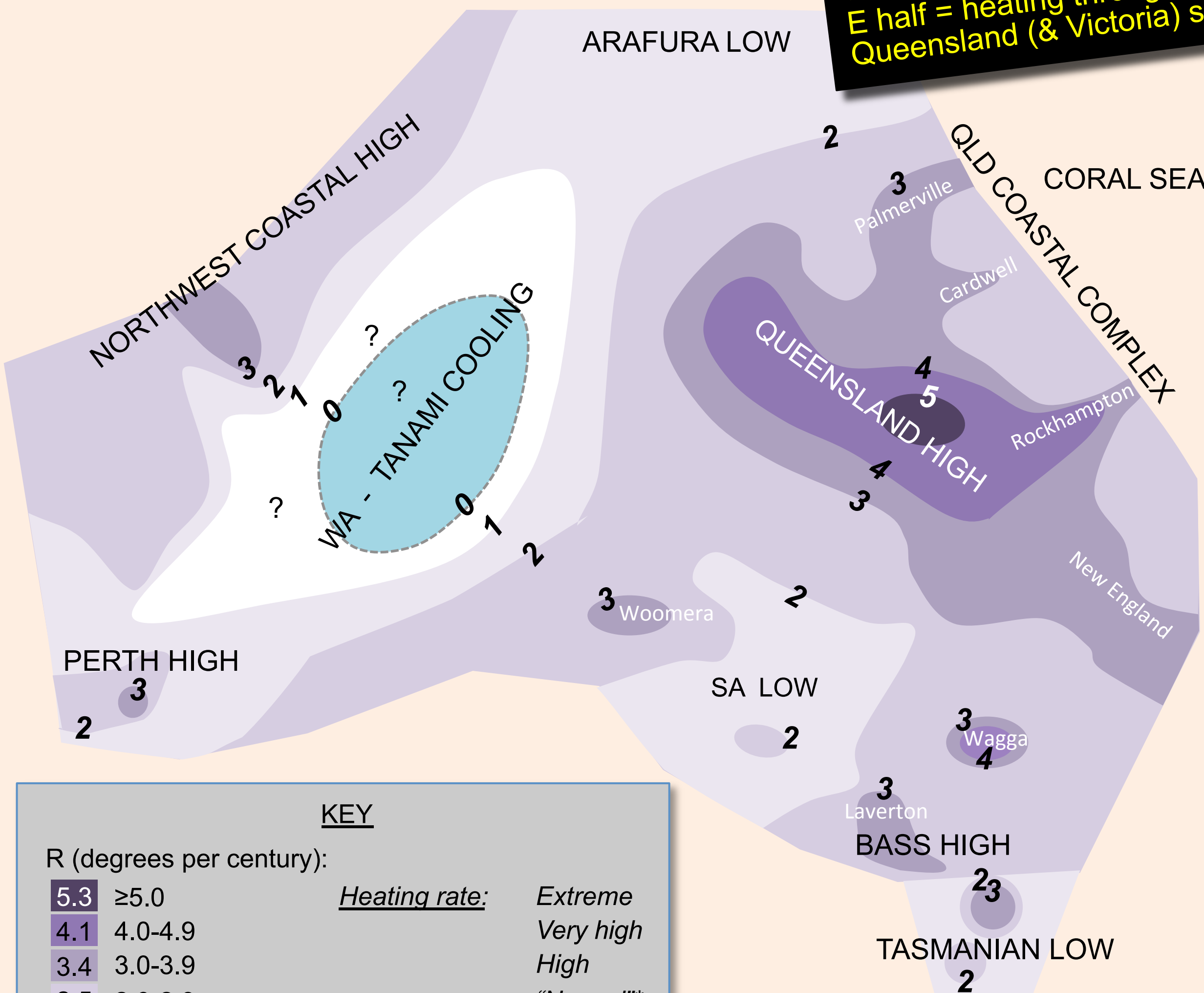
The climate heating rate R is the ratio of the increase in temperature ΔT and the heating period ΔY: **R = ΔT / ΔY**



Stage 2 Heating rate R - Topology

The climate heating rate R is the ratio of the increase in temperature ΔT and the heating period ΔY: **R = ΔT / ΔY**

Stage 2 heating rate is strongly domained into E and W halves of the continent.
W half = interior cooling + coastal heating @ Australian mean
E half = heating throughout @ greater than mean rate, and Queensland (& Victoria) significantly greater than mean.



KEY

R (degrees per century):

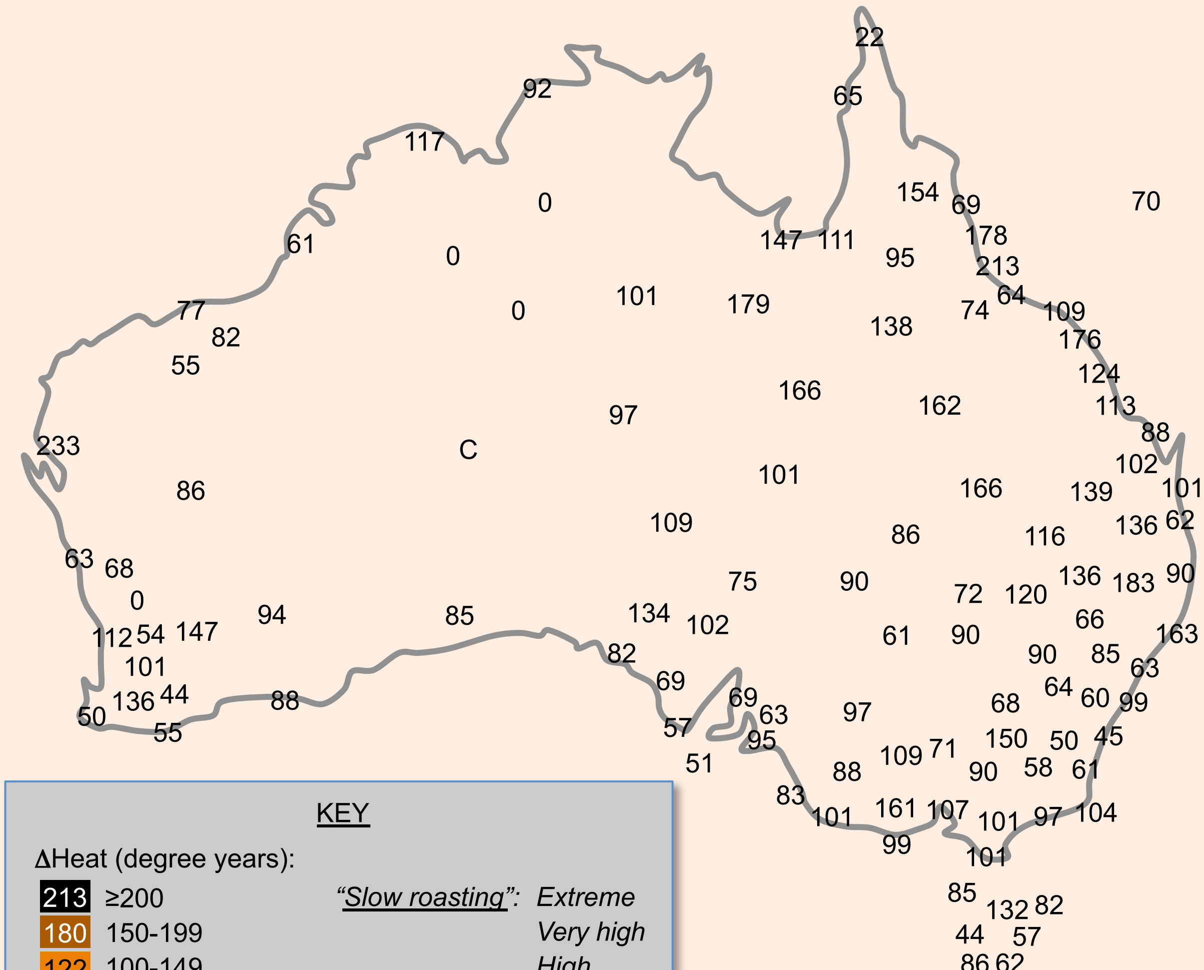
		Heating rate:
5.3	≥5.0	*Extreme*
4.1	4.0-4.9	*Very high*
3.4	3.0-3.9	*High*
2.5	2.0-2.9	*"Normal"**
1.4	1.0-1.9	*Low*
0.8	0-0.9	*Very low*
-1	<0 (cooling)	

** In Australia*

Stage 2 ΔHeat - Data

ΔHeat is the quantum of heat, at a location or over a region, that has been added by climate change.

ΔHeat = ΔTemperature** x **Length of heating period (degree years)



KEY

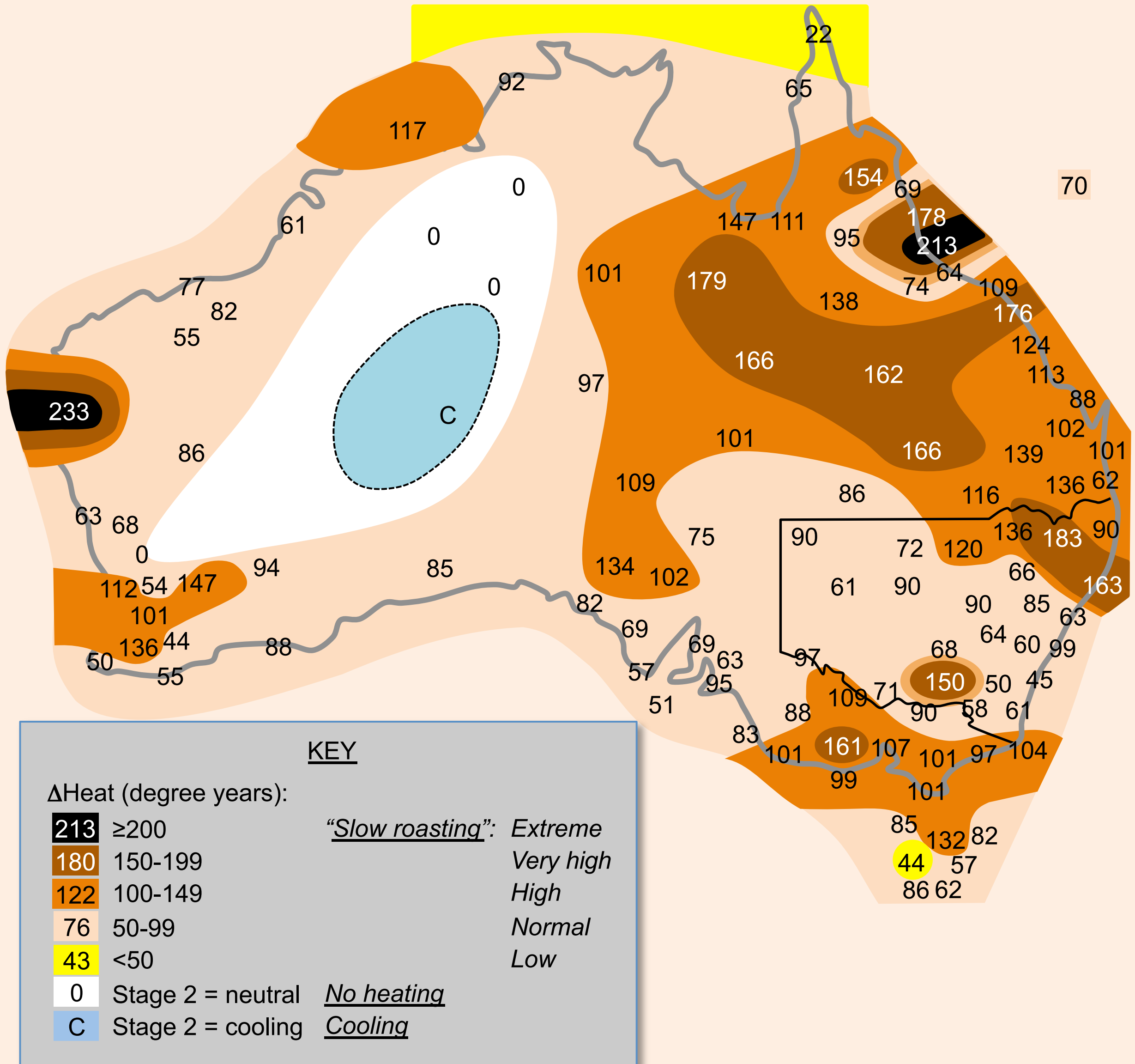
ΔHeat (degree years):

213	≥200	*"Slow roasting":*	*Extreme*
180	150-199		*Very high*
122	100-149		*High*
76	50-99		*Normal*
43	<50		*Low*
0	Stage 2 = neutral	No heating	
C	Stage 2 = cooling	Cooling	

Stage 2 ΔHeat - Data + Topology

ΔHeat is the quantum of heat, at a location or over a region, that has been added by climate change.

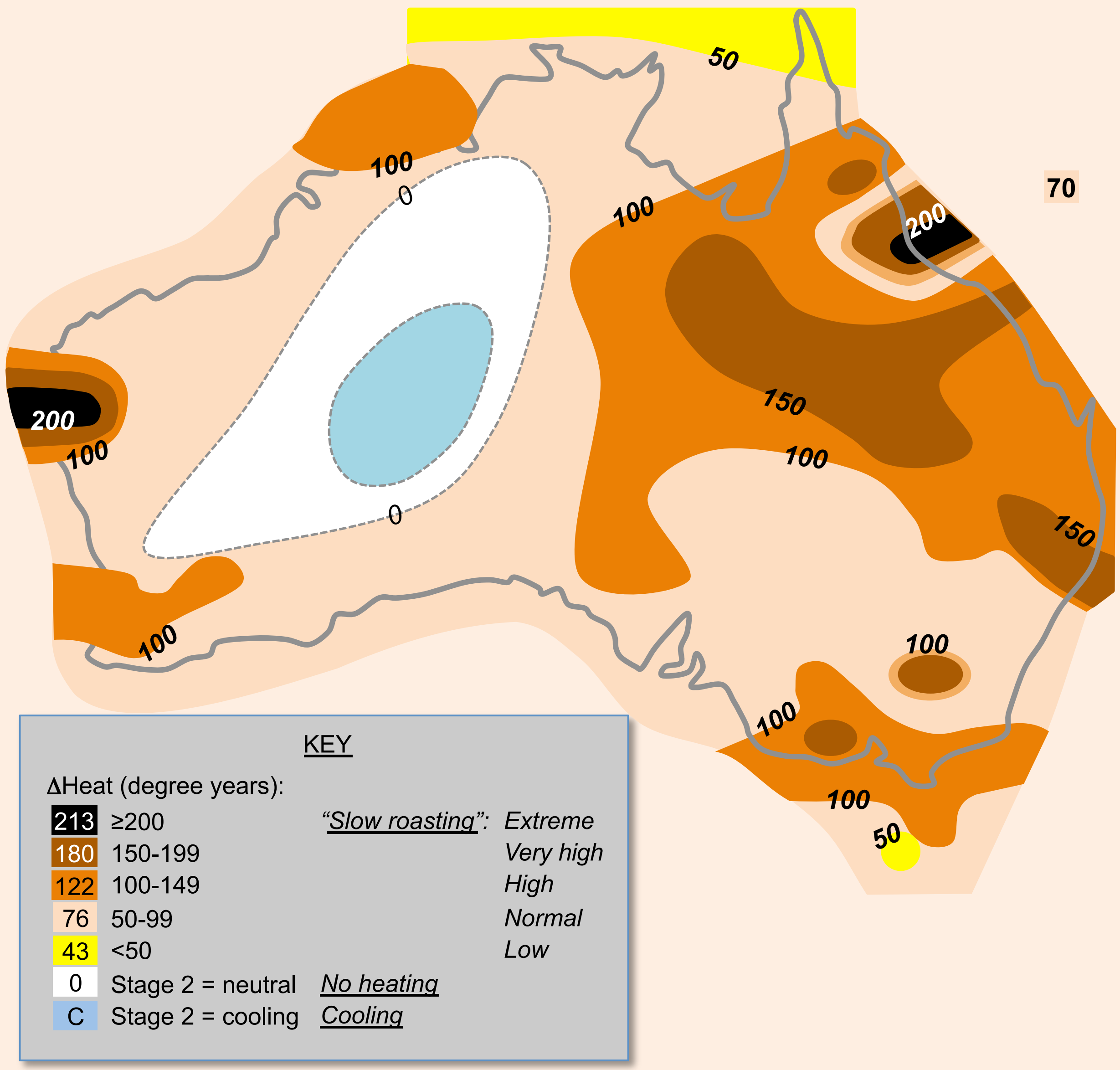
ΔHeat = ΔTemperature x Length of heating period (degree years)



Stage 2 ΔHeat - Topology

ΔHeat is the quantum of heat, at a location or over a region, that has been added by climate change.

ΔHeat = ΔTemperature** x **Length of heating period (degree years)

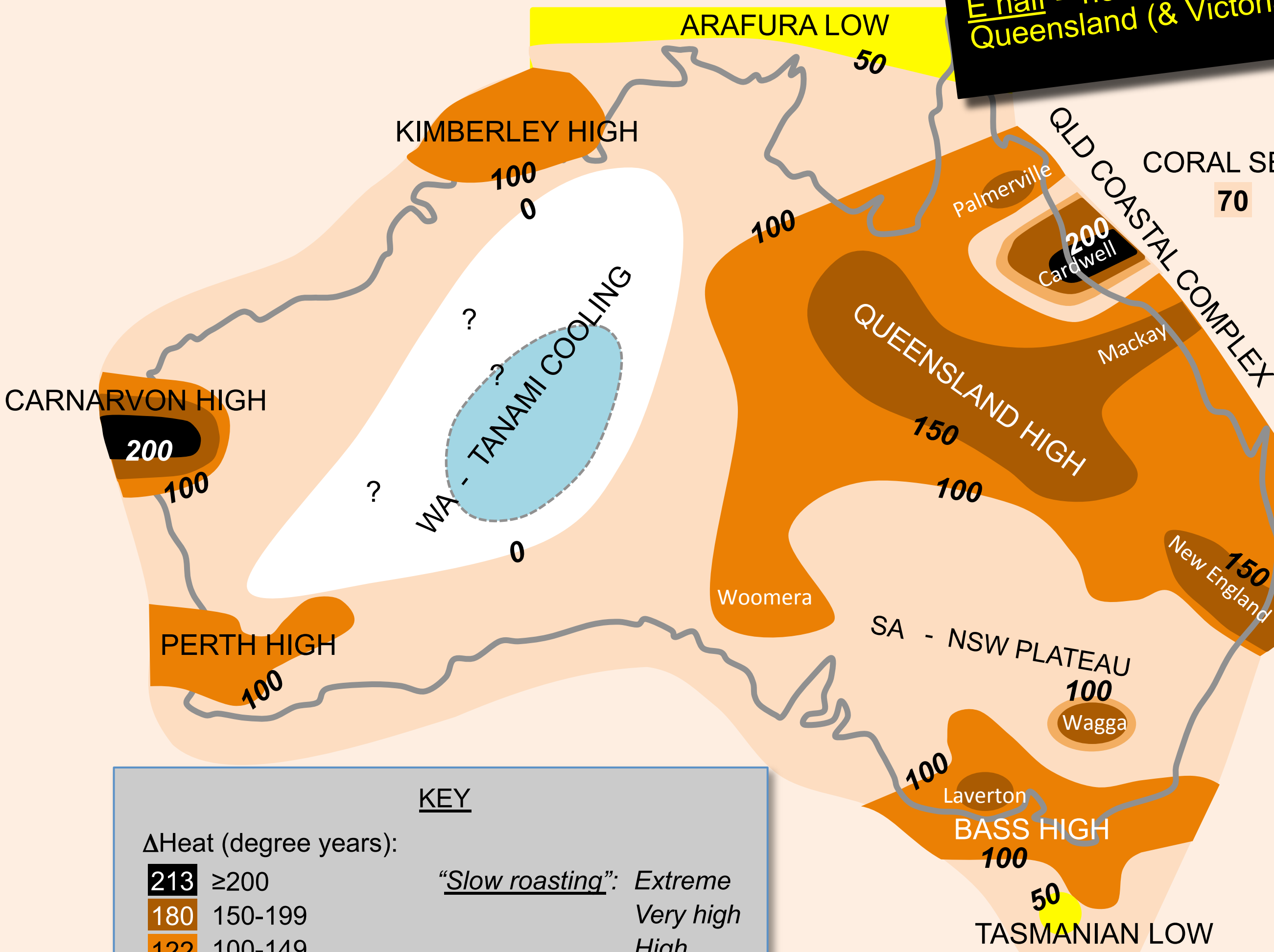


Stage 2 ΔHeat - Topology

ΔHeat is the quantum of heat, at a location or over a region, that has be

ΔHeat = ΔTemperature** x **Length of heating period (degree years)

ΔHeat is strongly domained into E and W halves of the continent.
W half = interior cooling + coastal heating @ Aust mean. The Perth high contains the tall hardwood forests of the SW.
E half = heating throughout @ greater than mean rate, and Queensland (& Victoria) significantly greater than mean.



QLD: High to extreme climate heating throughout the State. The coastal tropics have high BUSHFIRE VULNERABILITY and include all rainforest burnt in 2018-19: Japoon, Eungella, Mt Tamborine (Binnaburra). The NW-SE Queensland High includes the brigalow terrain, Pilliga Scrub, New England Plateau, and NSW coastal rainforest belt (Terania Creek).
NSW: Climate heating over most of State is at the Australian mean - which is 2x world mean. The New England High is part of the Queensland High which is Australia's strongest heating belt and the highest BUSHFIRE VULNERABILITY.
VIC: Most of the State has heated on high, well above the Australian mean. Vic has high BUSHFIRE VULNERABILITY.

KEY

ΔHeat (degree years):

213	≥200	*"Slow roasting":*	*Extreme*
180	150-199		*Very high*
122	100-149		*High*
76	50-99		*Mean*
43	<50		*Low*
0	Stage 2 = neutral	*No heating*	
C	Stage 2 = cooling	*Cooling*	

Continent-scale features shown in block letters
Local heating hotspots shown by place names

Australia's burnt rainforests are in belt of maximum climate heating

The inaugural incineration of Australia's rainforests Nov 2018 to Nov 2019:

- *for the first time in human memory*
- *for the first time in thousands of years*
- *in 4 separate areas over 11o of latitude*
- *in 4 separate extreme fire events*

Assessment of Australian State Fire Commissioners (April 2019): "*Our extreme bushfires of just the past several years, are extreme because of climate change*"

Climate heating: 2.6 DPC — ***JAPOON***

1 JAPOON *Nov 2019*
18°S, 100m, 3400 mm pa

Climate heating: 2.4 DPC — ***EUNGELLA***

2 EUNGELLA *Nov 2018*
21°S, 700m, 2200 mm pa

Climate heating: 2.5 DPC — ***MT TAMBORINE***

Sep 2019
3 MOUNT TAMBORINE
28°S, 520m, 1500 mm pa

TERANIA CREEK — **Climate heating: 3.3 DPC**

4 TERANIA CREEK
29°S, 230m, 2200 mm pa
Nov 2019

Unburnt for thousands of years; now 4 upland rainforests burnt *within a year*

These 4 rainforests have been slow-roasted by 70 years of climate heating *at 2.5x the world rate*

Stage 2 ΔHeat - Topology + Currents