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A shift to the new norm: riding the wave of change

Shifts to the new abnormal: riding the waves of climate change

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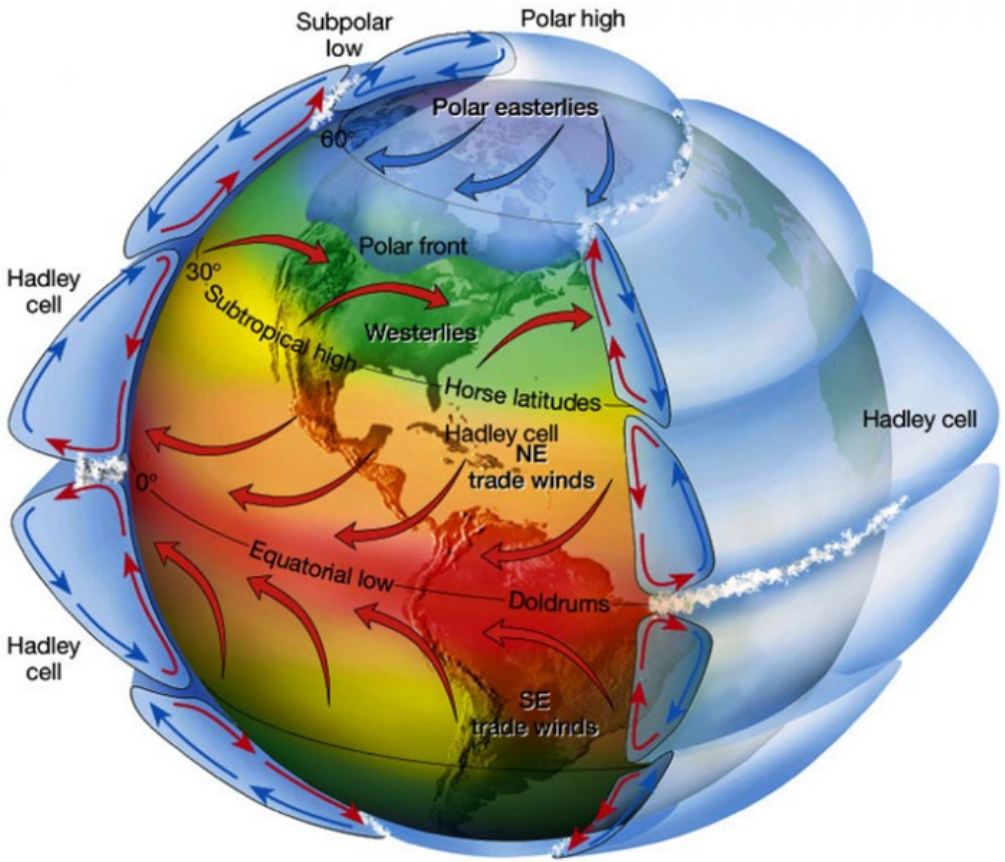
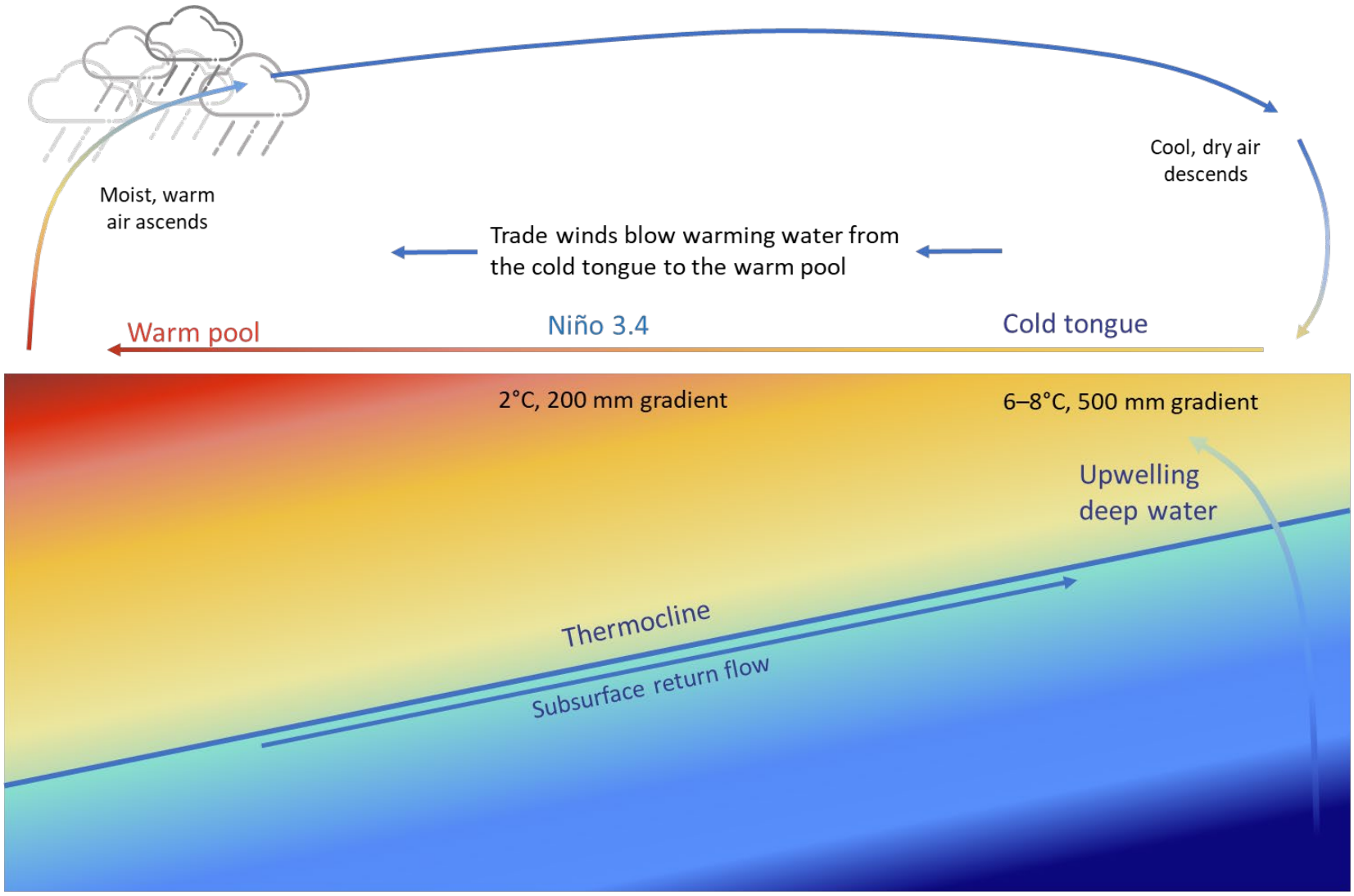
Shifts to the new abnormal

1. Climate forms a series of regimes, where steady-state conditions are separated by abrupt regime changes
2. Climate change and variability are not separate processes, all energy follows the same pathway.
3. Warming follows a step-ladder like pattern – as a series of shifts to higher energy (warmer) states, separated by periods of relative stability.
4. These are shifts to a new 'abnormal' state of heightened risk.
5. To ride the waves of change, we have to understand them

Climate as a series of heat engines

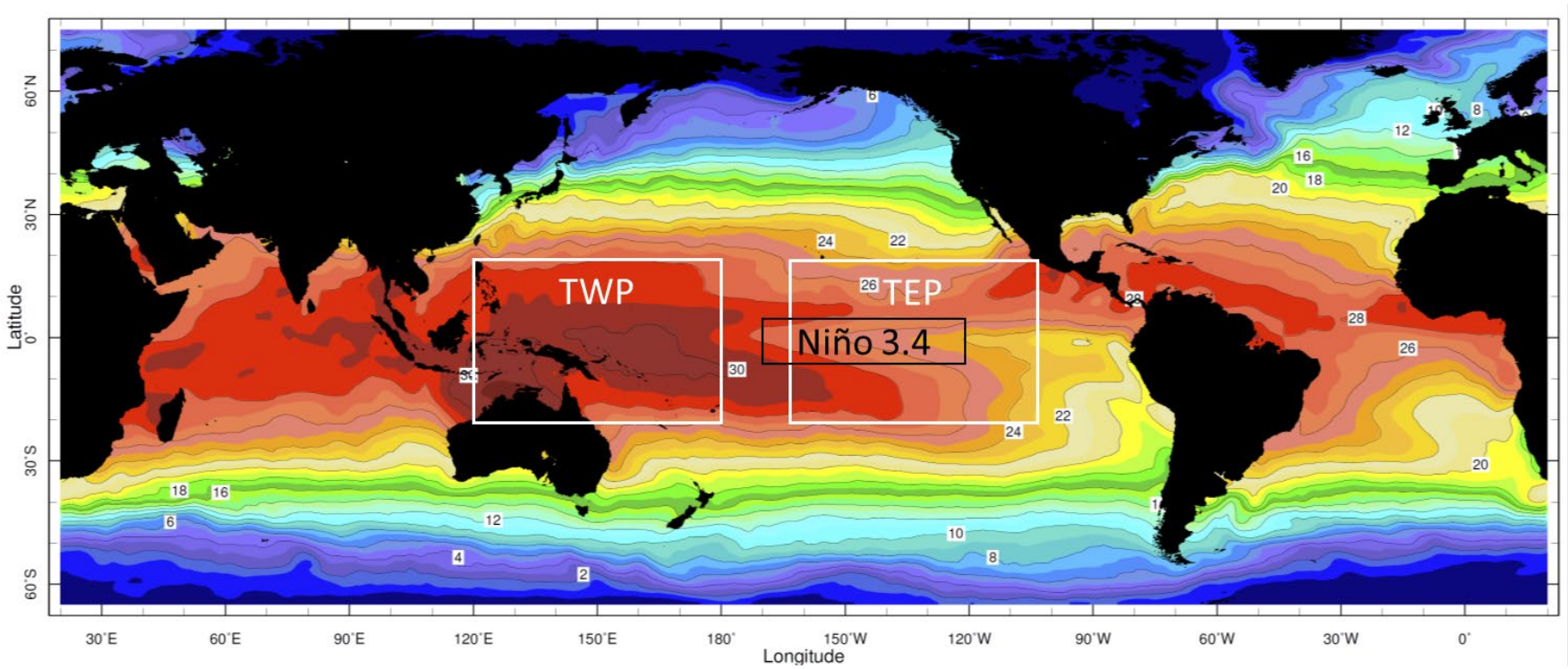


Lutgens et al. 2006

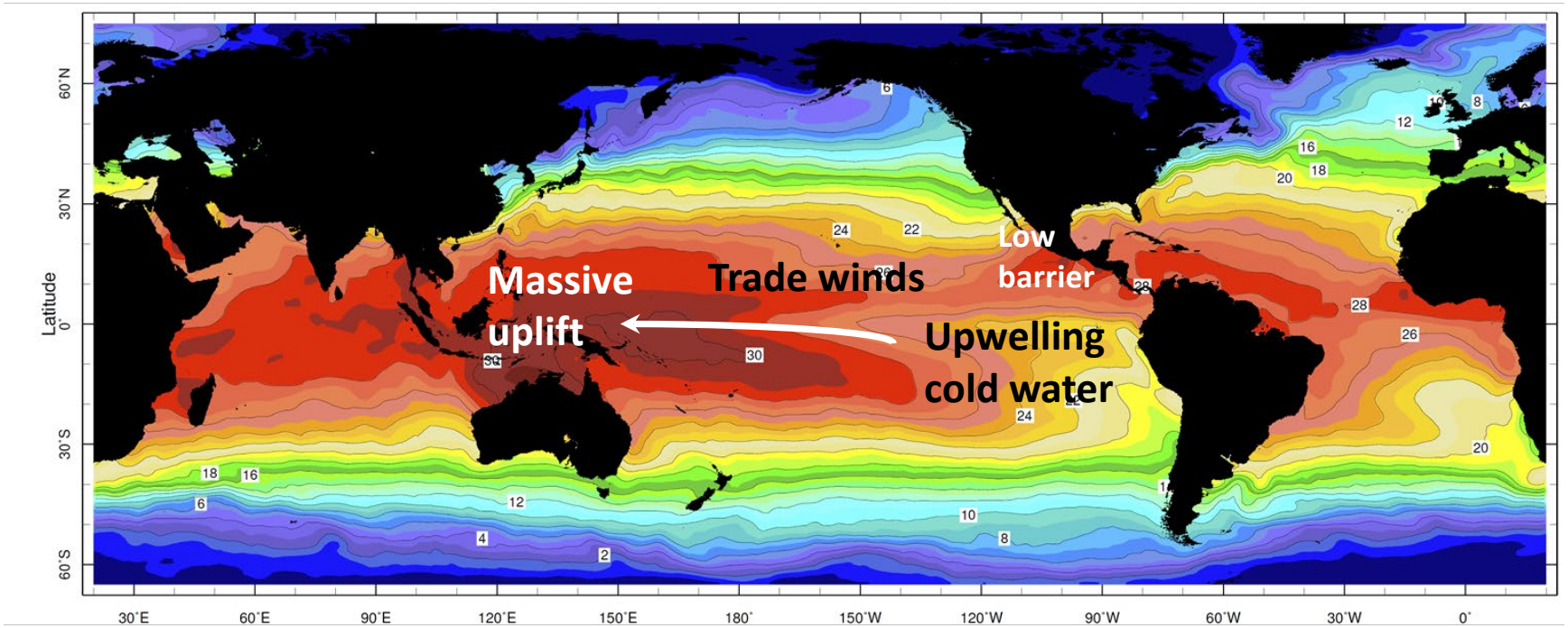


Clouds pettycon from pixabay

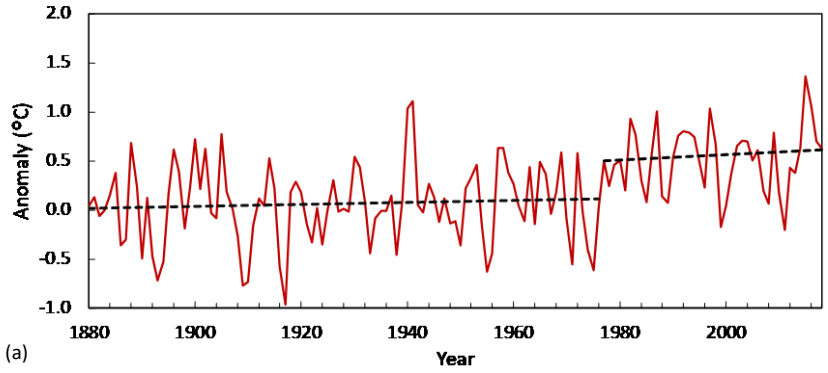
Pacific Ocean heat engine



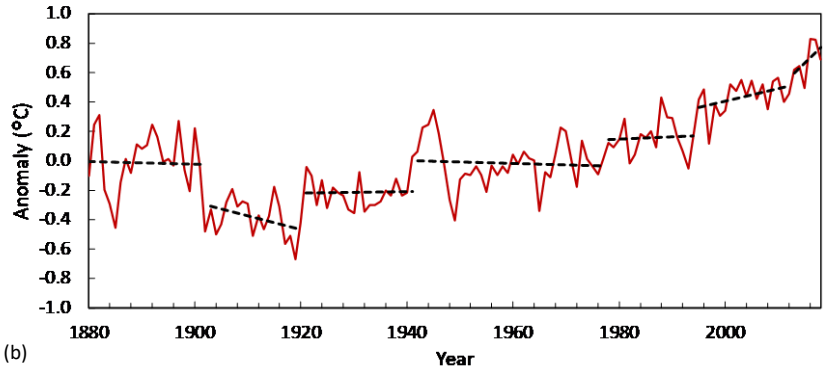
How it works

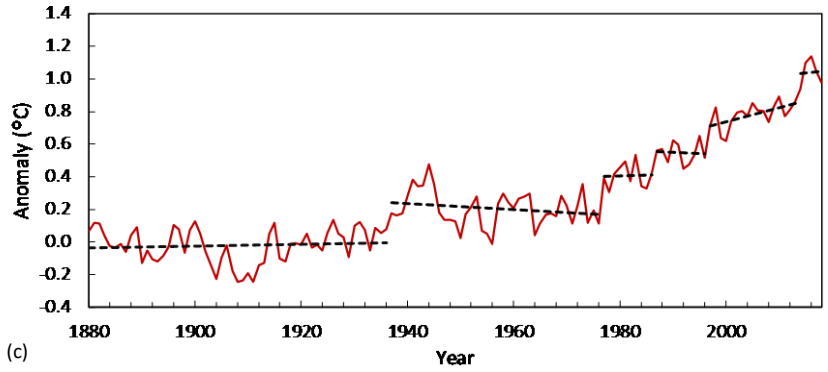

Massive uplift
Trade winds
Low barrier
Upwelling cold water
Latitude
60°N
30°N
0°
30°S
60°S
30°E
60°E
90°E
120°E
150°E
180°
150°W
120°W
90°W
60°W
30°W
0°

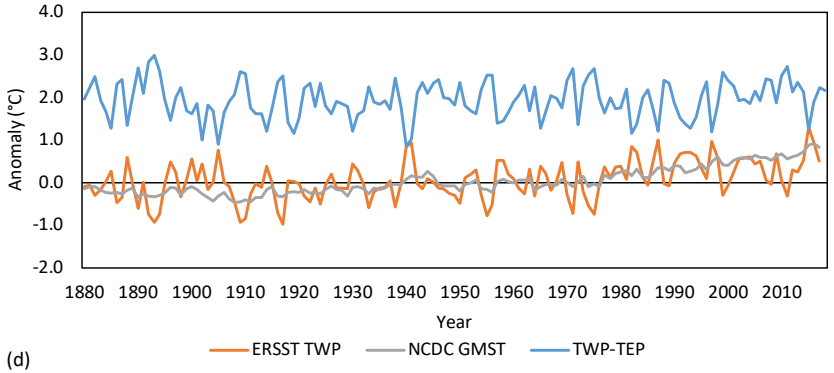
East-central Pacific



Western Pacific warm pool







Global mean surface temperature

Warm pool, GMST & east-west difference

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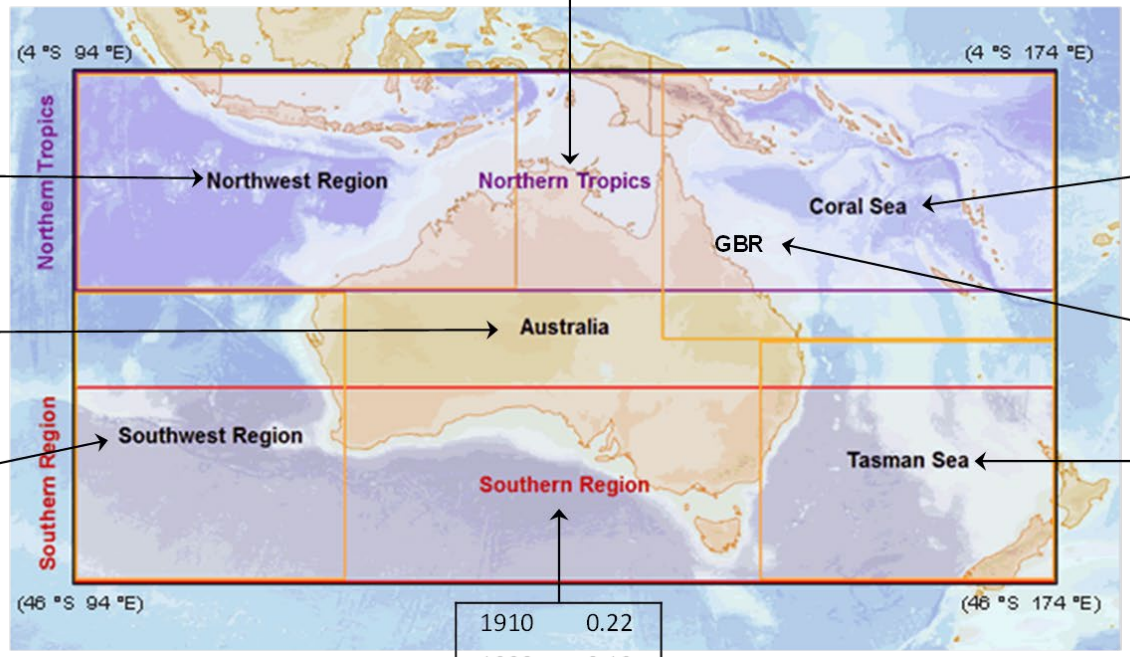
Key dates

- 1901–03 abrupt ocean cooling
- 1920–21 NH warming, land dominated
- 1925–26 NH warming ocean-dominated
- 1937–38 Ocean warming global
- 1968–69 Warm pool and SH
- 1976–79 Pacific shift, SH then NH
- 1986–89 NH some ocean, mainly land
- 1995–98 Pacific-Atlantic lock then shift, warm pool, SH then NH
- 2010 Minor shift SH
- 2012–15 Warm pool, some SH mainly NH

Heat engine in free mode

Heat engine in forced mode

Shifts in sea surface temperatures



1941	0.19
1969	0.26
1998	0.37

1940	0.14
1983	0.38
2009	0.34

1942	0.26
1968	0.24
1995	0.35
2016	0.35

1938	0.19
1968	0.32
1998	0.30
2010	0.21

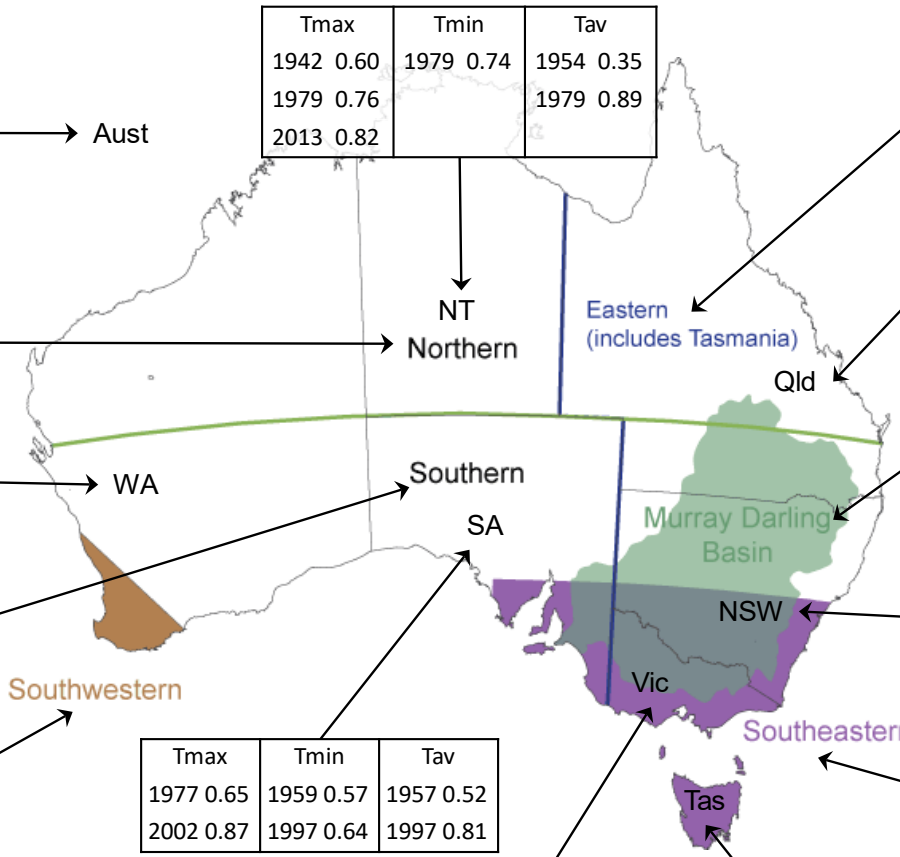
1938	0.22
1968	0.48
2015	0.59

1975	0.54
2010	0.37

1938	0.32
1970	0.36
1998	0.41

1910	0.22
1938	0.13
1970	0.44
1997	0.19
2010	0.26

Shifts in Australian regional temperature



Tmax	Tmin	Tav
1971 0.45	1950 0.39	1972 0.45
1999 0.47	1969 0.68	1999 0.49
	2009 0.40	2013 0.46

Tmax	Tmin	Tav
1942 0.60	1979 0.74	1954 0.35
1979 0.76		1979 0.89
2013 0.82		

Tmax	Tmin	Tav
1979 0.56	1958 0.43	1979 0.76
2013 0.97	1979 0.68	2013 0.88
	2013 0.77	

Tmax	Tmin	Tav
1979 0.68	1979 0.82	1979 0.71
2013 0.87		2013 0.71

Tmax	Tmin	Tav
1979 0.41	1958 0.49	1979 0.81
2013 0.99	1986 0.75	2013 0.92
	2013 0.76	

Tmax	Tmin	Tav
1976 0.43	1957 0.46	1957 0.45
2002 0.75	1988 0.36	2003 0.48

Tmax	Tmin	Tav
2000 1.18	1972 0.77	1972 0.46
	2005 0.70	1997 0.57
		2013 0.76

Tmax	Tmin	Tav
1977 0.45	1958 0.40	1977 0.57
2002 0.85	1997 0.60	2002 0.63

Tmax	Tmin	Tav
2000 1.17	1973 0.70	1979 0.50
	1998 0.57	1997 0.48
		2013 0.67

Tmax	Tmin	Tav
1972 0.39	1972 0.84	1972 0.68
1994 0.68	1994 0.48	2009 0.54

Tmax	Tmin	Tav
1977 0.65	1959 0.57	1957 0.52
2002 0.87	1997 0.64	1997 0.81

Tmax	Tmin	Tav
1997 1.01	1973 0.65	1972 0.45
	2007 0.56	1999 0.49
		2013 0.46

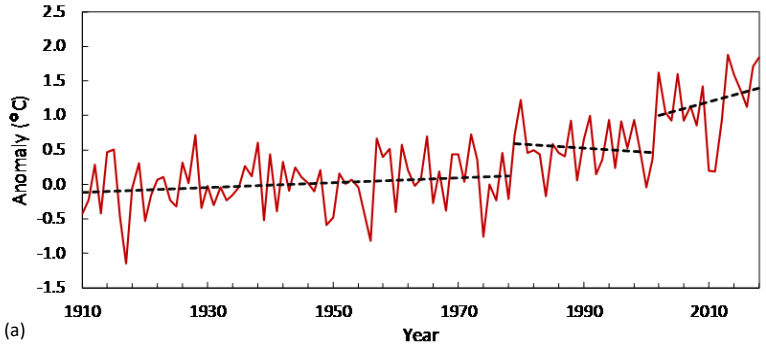
Tmax	Tmin	Tav
1997 0.94	1968 0.60	1971 0.44
	2007 0.65	1999 0.47
		2013 0.44

Tmax	Tmin	Tav
1971 0.45	1950 0.39	1959 0.47
1999 0.47	1969 0.68	1999 0.40
	2009 0.40	

Observed shifts

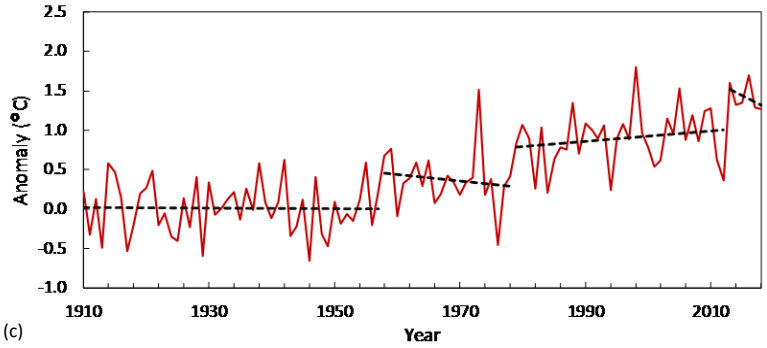
National average change

Maximum temperature



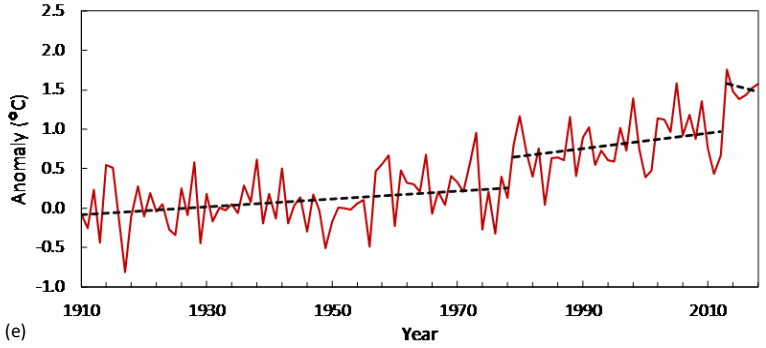
(a)

Minimum temperature



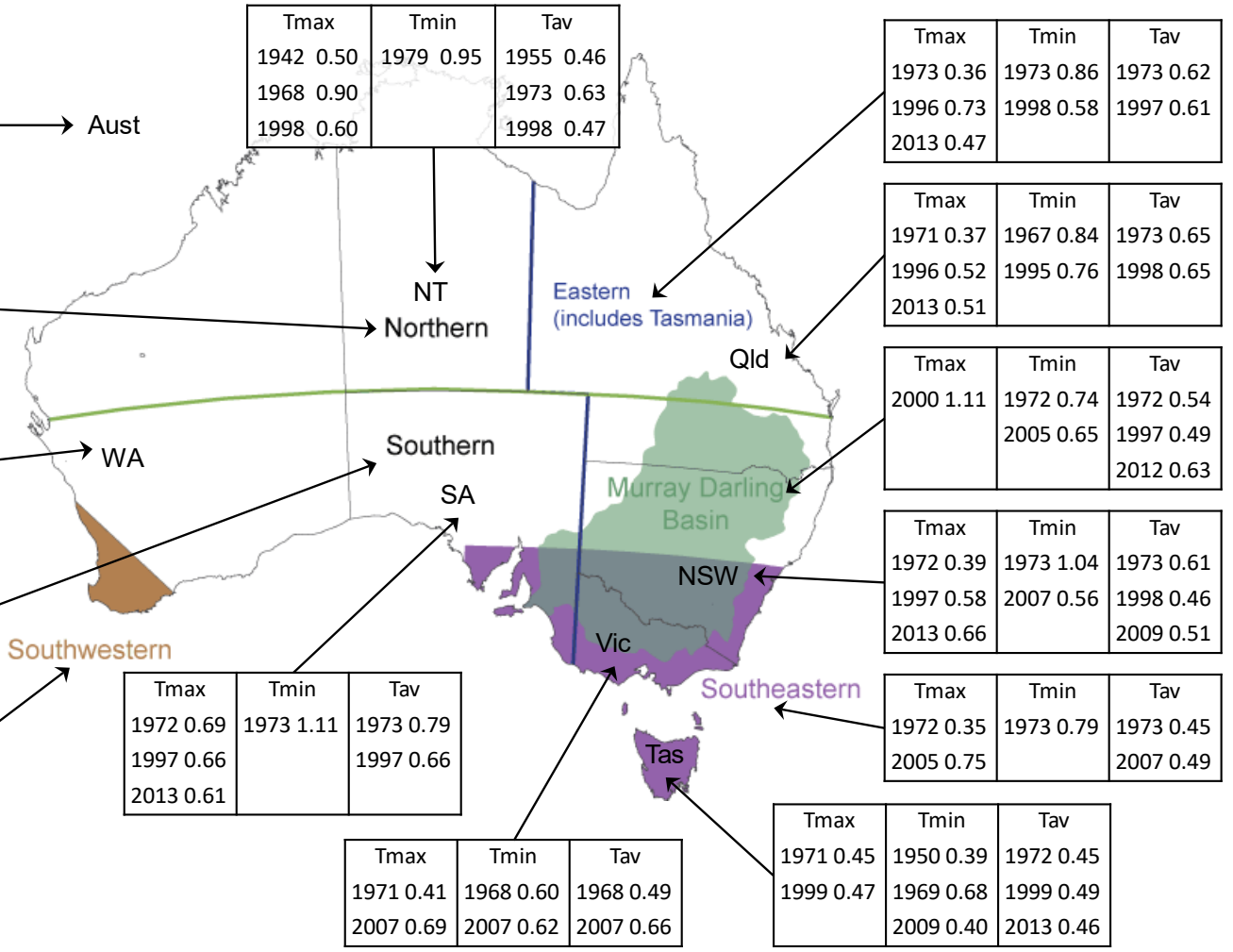
(c)

Average temperature



(e)

Shifts attributed to greenhouse gas forcing



Tmax	Tmin	Tav
1972 0.59	1973 1.07	1973 0.74
1996 0.61		1998 0.61
2013 0.56		

Tmax	Tmin	Tav
1942 0.50	1979 0.95	1955 0.46
1968 0.90		1973 0.63
1998 0.60		1998 0.47

Tmax	Tmin	Tav
1973 0.36	1973 0.86	1973 0.62
1996 0.73	1998 0.58	1997 0.61
2013 0.47		

Tmax	Tmin	Tav
1969 0.39	1979 0.82	1973 0.73
1996 0.61		1996 0.61
2013 0.55		

Tmax	Tmin	Tav
1971 0.37	1967 0.84	1973 0.65
1996 0.52	1995 0.76	1998 0.65
2013 0.51		

Tmax	Tmin	Tav
1969 0.43	1955 0.46	1949 0.45
1994 0.75	1995 0.36	1995 0.64
		2012 0.43

Tmax	Tmin	Tav
2000 1.11	1972 0.74	1972 0.54
	2005 0.65	1997 0.49
		2012 0.63

Tmax	Tmin	Tav
1972 0.48	1973 1.01	1973 0.67
1996 0.59		1998 0.59
2013 0.58		2009 0.42

Tmax	Tmin	Tav
1972 0.39	1973 1.04	1973 0.61
1997 0.58	2007 0.56	1998 0.46
2013 0.66		2009 0.51

Tmax	Tmin	Tav
1994 0.80	1961 0.64	1961 0.50
2009 0.42		2011 0.61

Tmax	Tmin	Tav
1972 0.69	1973 1.11	1973 0.79
1997 0.66		1997 0.66
2013 0.61		

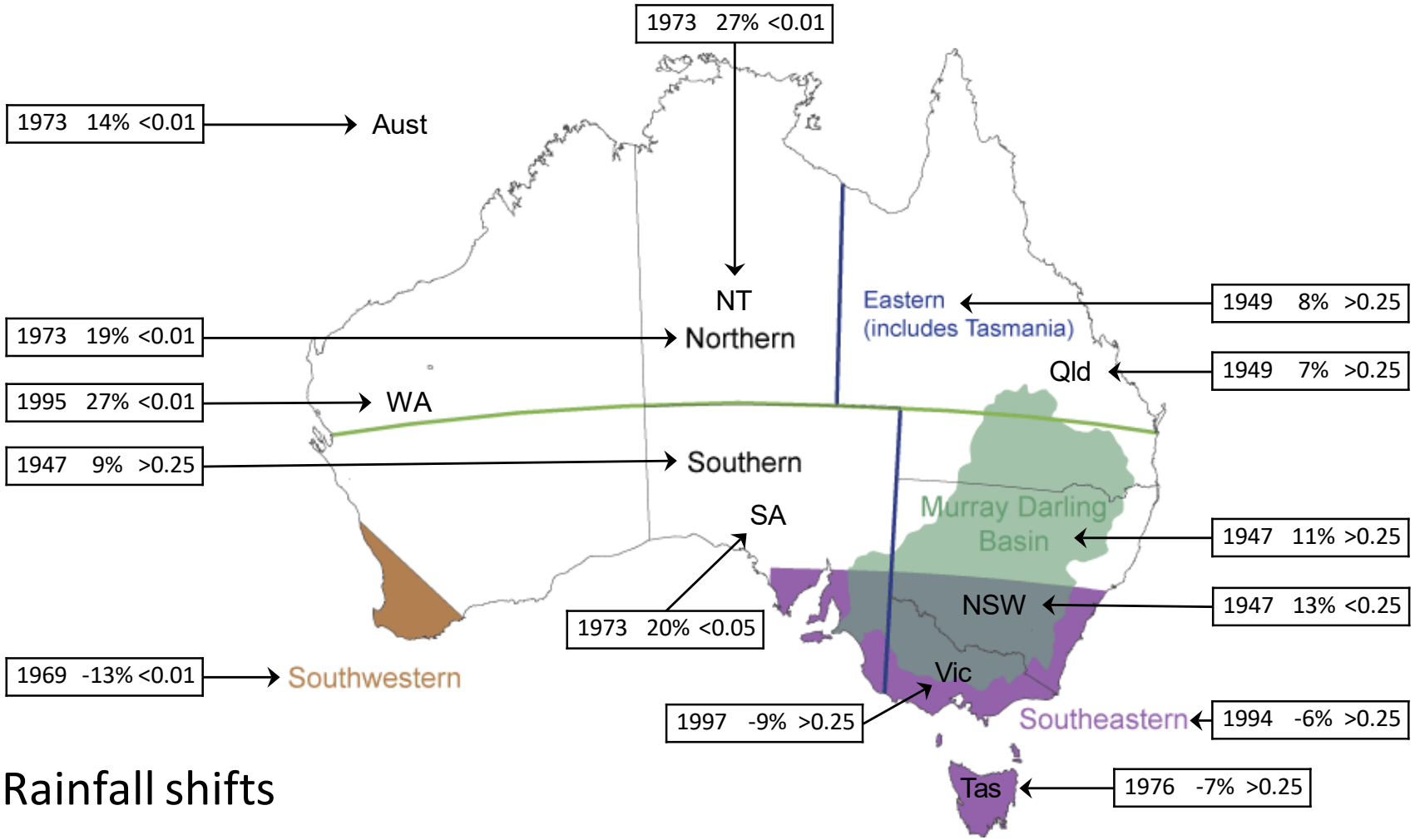
Tmax	Tmin	Tav
1972 0.35	1973 0.79	1973 0.45
2005 0.75		2007 0.49

Tmax	Tmin	Tav
1971 0.41	1968 0.60	1968 0.49
2007 0.69	2007 0.62	2007 0.66

Tmax	Tmin	Tav
1971 0.45	1950 0.39	1972 0.45
1999 0.47	1969 0.68	1999 0.49
	2009 0.40	2013 0.46

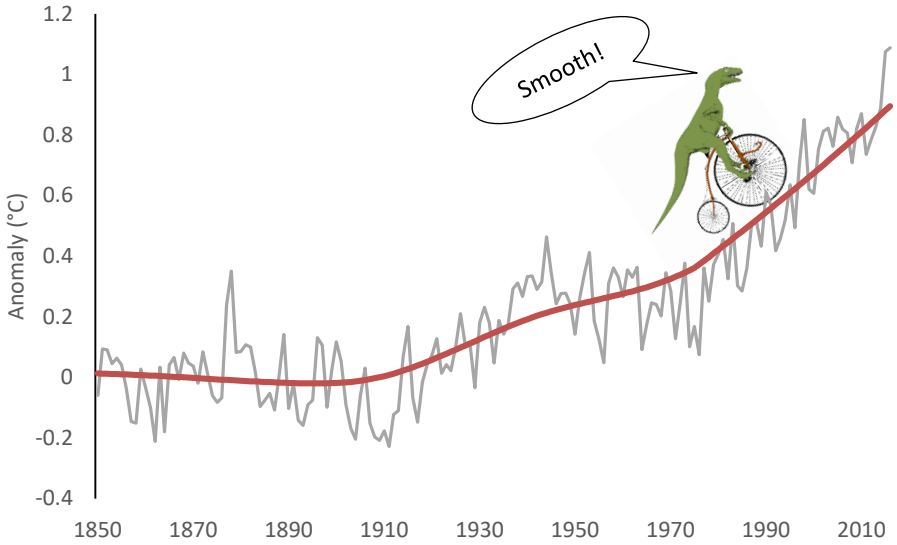
Attributed shifts

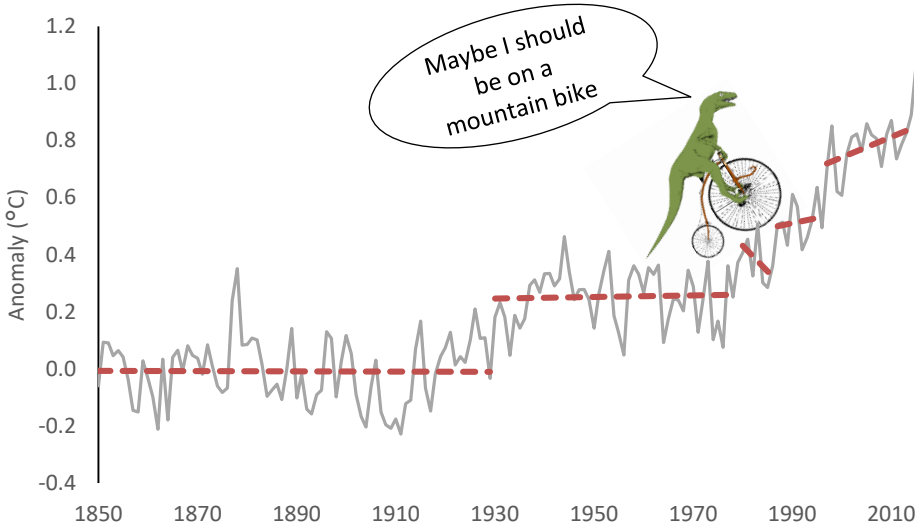
Shifts in rainfall

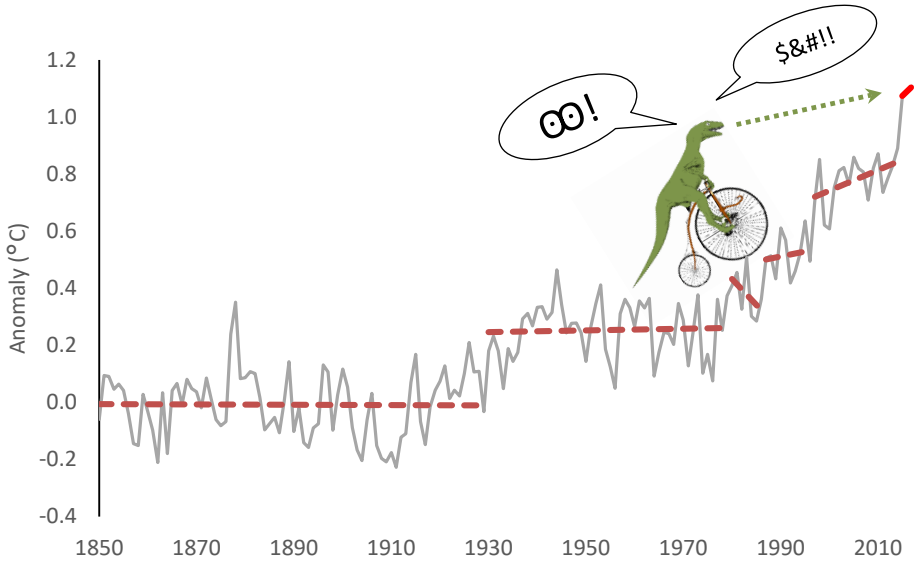


Rainfall shifts

Why does it matter? Ask the adaptoraptor







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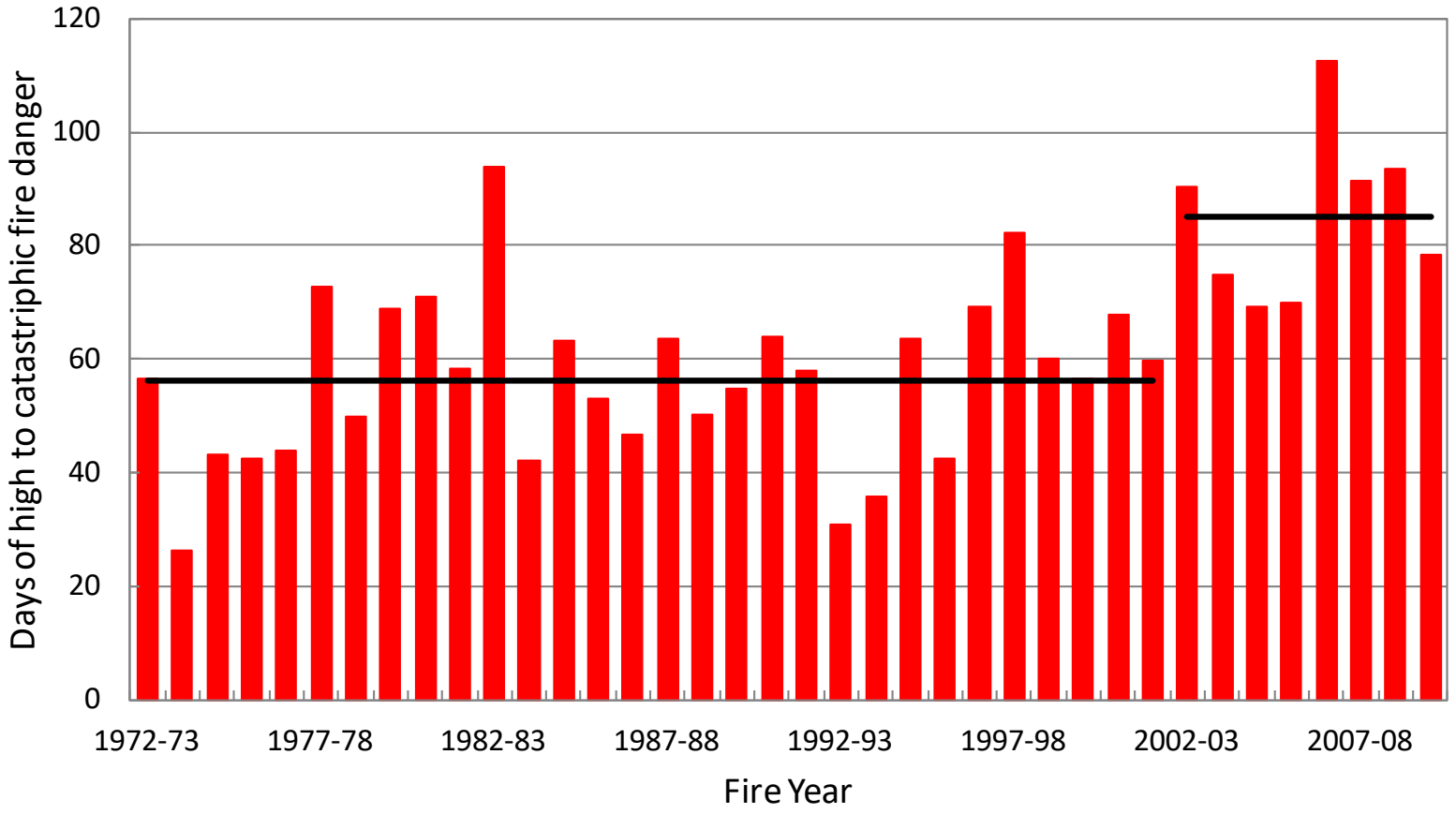
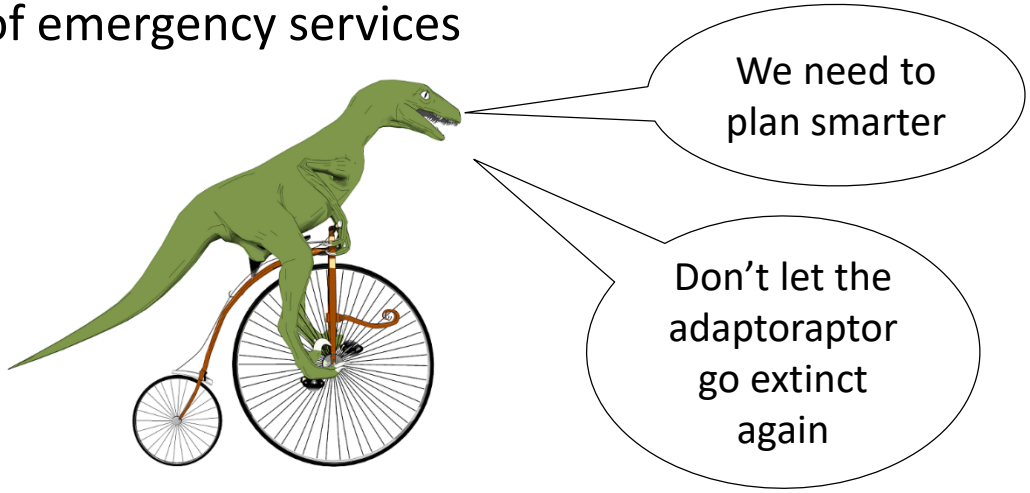
Very high FFDI or greater – 9 Vic sites



Conclusions

- Climate change is driven by a network of heat engines, governed by the one in the tropical Pacific Ocean.
- When they need to move more heat to the top of the atmosphere and the poles, they will shift to a new steady-state
- Australia is just to the south of the heat engine, so is in the first line of a shifting climate
- We need to explore what this means for the future planning and delivery of emergency services



Thank you

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Acknowledgements

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