GREENHOUSE 2011
THE SCIENCE OF CLIMATE CHANGE

Stepping out with climate change

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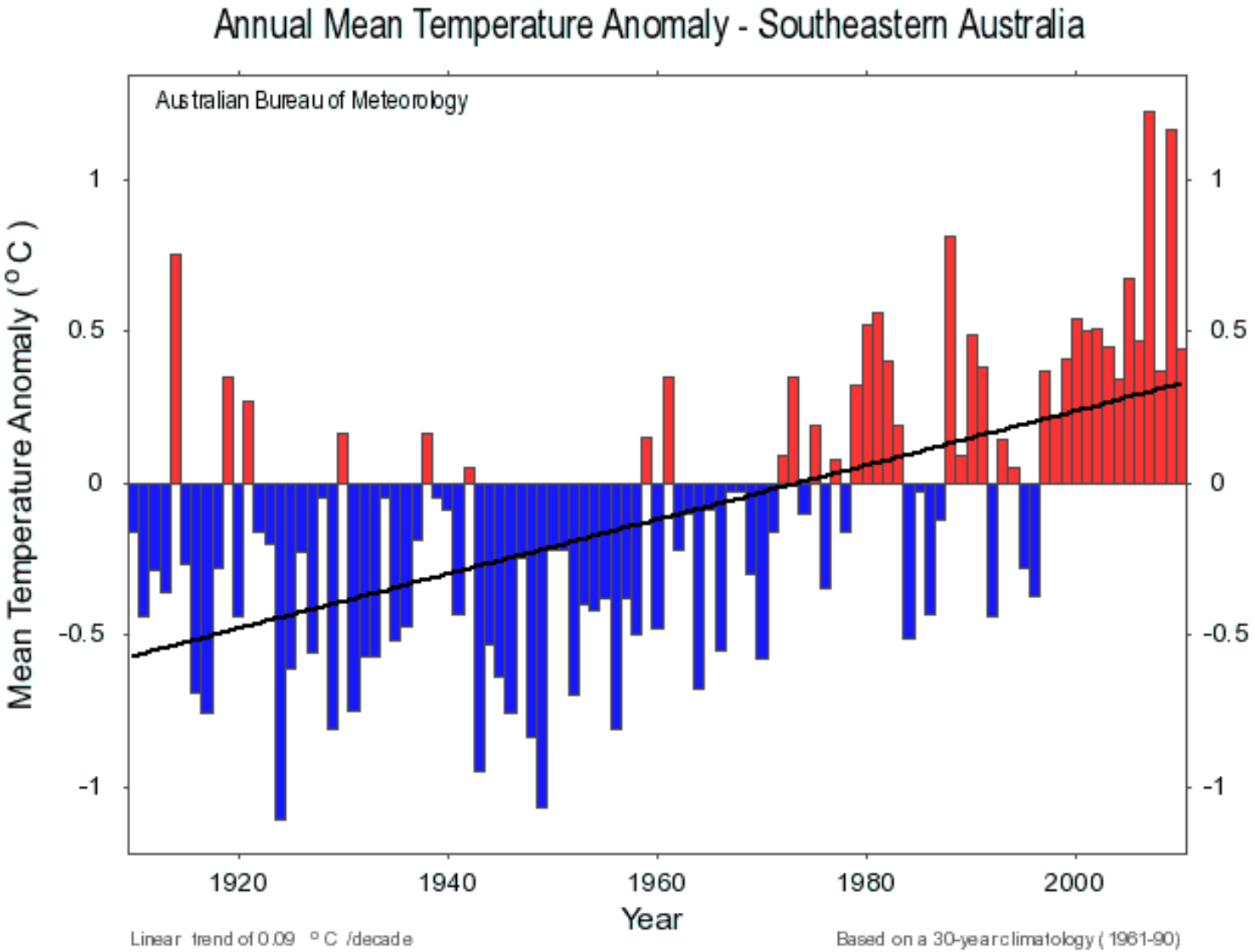
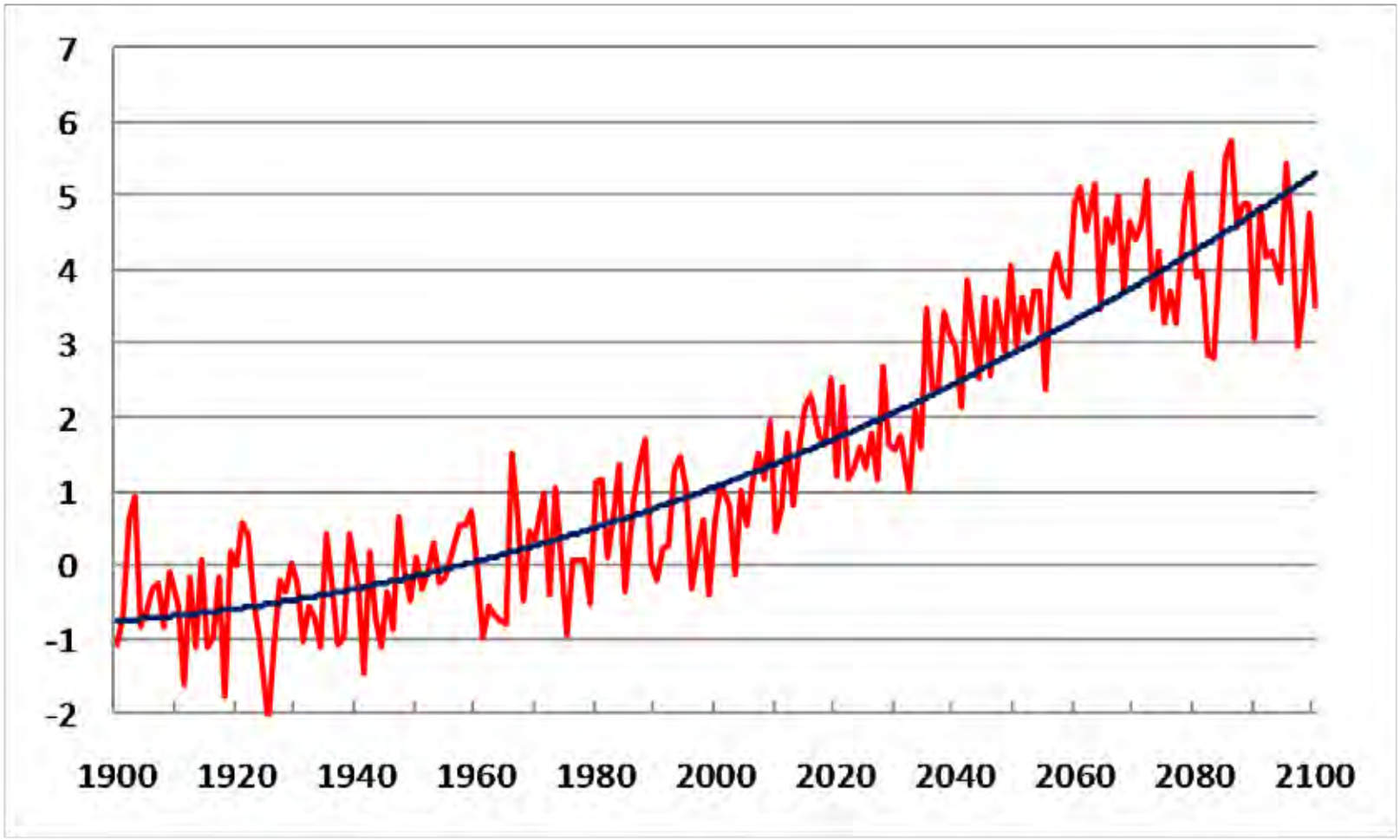
The traditional way of measuring a changing climate



The climate change signal is a monotonic curve and the surrounding noise is variability



Observed climate shifts

1967–8

Downward shift in rainfall in SW WA

Reduction in cyclone density and intensity in southern Australia

Reduction in storm generation in southern Australia

1996–7

Reduction in rainfall in SE Australia ~9% (including 2010)

Increase in Tmax in SE Australia ~0.9°C

Widespread impacts have been linked to these changes: water resources, fire danger, birds, frogs, wetlands, crops, grapes, heat stress

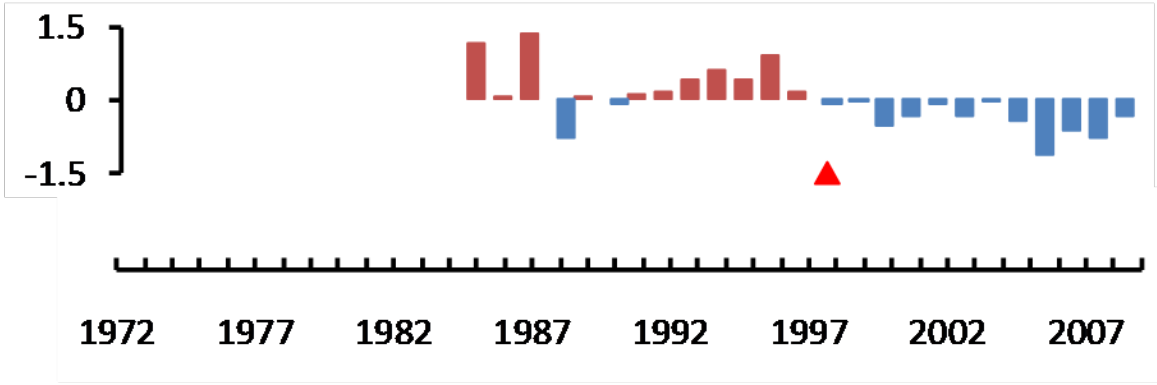
Examples of impact shifts - SEA

Vic FFDI

Vic Days High–Catastrophic Fire Danger

Mornington Pinot Noir 21° Baume

Mornington Chardonnay 21° Baume



Co-dependency between variables in the Australian region

- Tmax and P
- Tmax and Tmin

Coughlan, 1990 – observations

Power et al., 1998 – observations and BMRC climate model

Nicholls 2003, 2004 – observations, detection of change

Karoly and Braganza 2005 – attribution of change

Method

- Region is south-eastern Australia SE of 33°S, 135°E
- Identify stationary climate
- Calculate regression relationships for co-varying climate variables (Tmax/P, Tmax/Tmin/*P)
- Identify externally-driven warming using the residuals of those relationships ($Tmax_{ARW}$, $Tmin_{ARW}$)
- Analyse steps and trends in observed and simulated regional climate (11 model runs)

Analysis methods

Regime shifts

- Bivariate test – Maronna and Yohai, 1978
  - Moving window test
  - Bootstrapping
- STARS – Rodionov, 2006
  - Significance 0.05, cut-off length 15 years, Huber's weight index 3, IP4 red noise estimation, pre-whitening

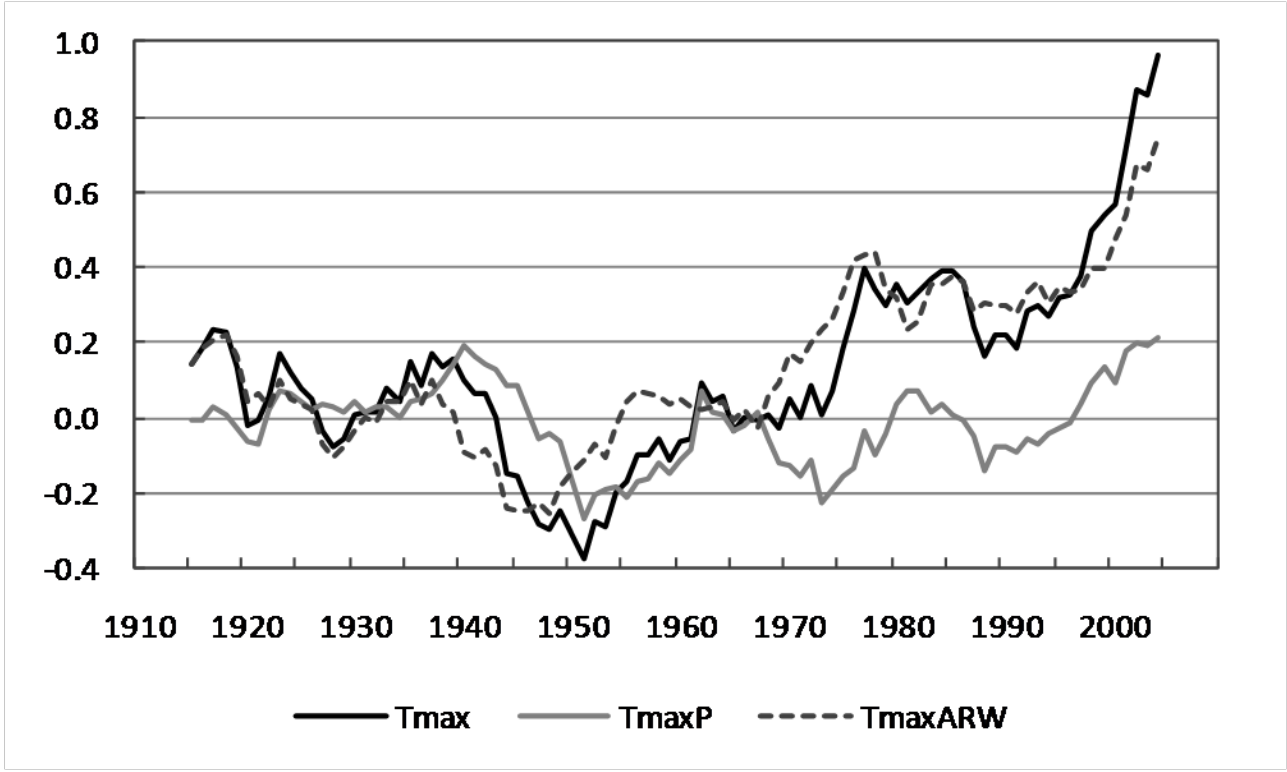
Trends

- Least squares linear regression

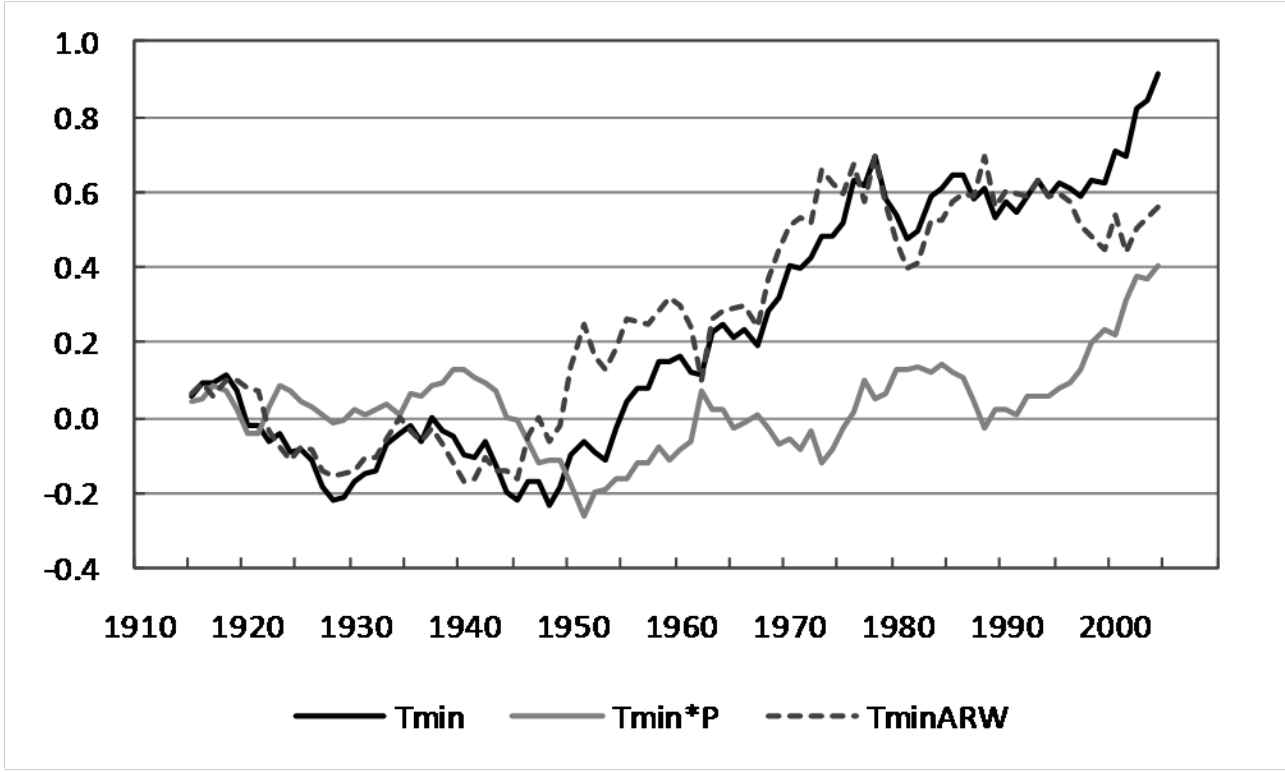
Shifts in observed climate – SEA

	Average	Standard Deviation	Ti0	Year	Change	Significance
Rain (mm)	628.6	107.9	3.8	2009	154.6	No
Tmax (°C)	20.6	0.6	24.3	1996	0.8	<0.01
Tmin (°C)	8.6	0.5	45.8	1972	0.7	<0.01
Tav (°C)	14.6	0.5	36.8	1971	0.6	<0.01
	14.9	0.4	12.9	1998	0.5	0.01
Tmax/Rain (°C)	20.6	0.6	21.2	1998	0.7	<0.01
Tmin/Tmax (°C)	8.6	0.5	36.6	1967	0.6	<0.01

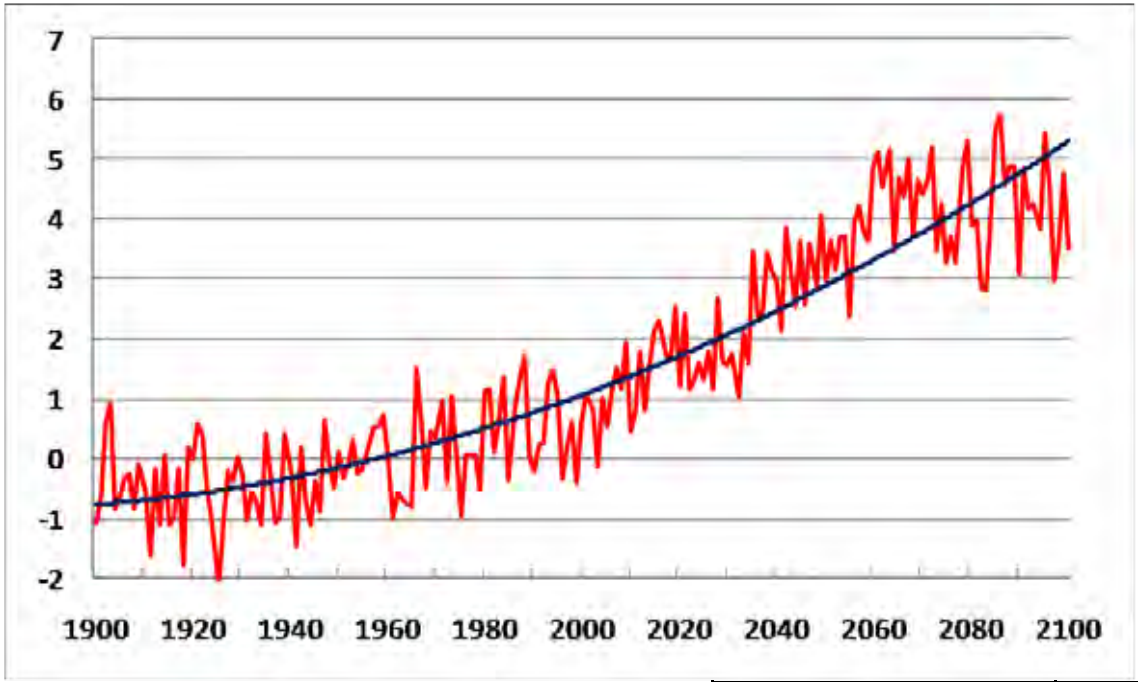
Observations – Tmax



Observations – Tmin



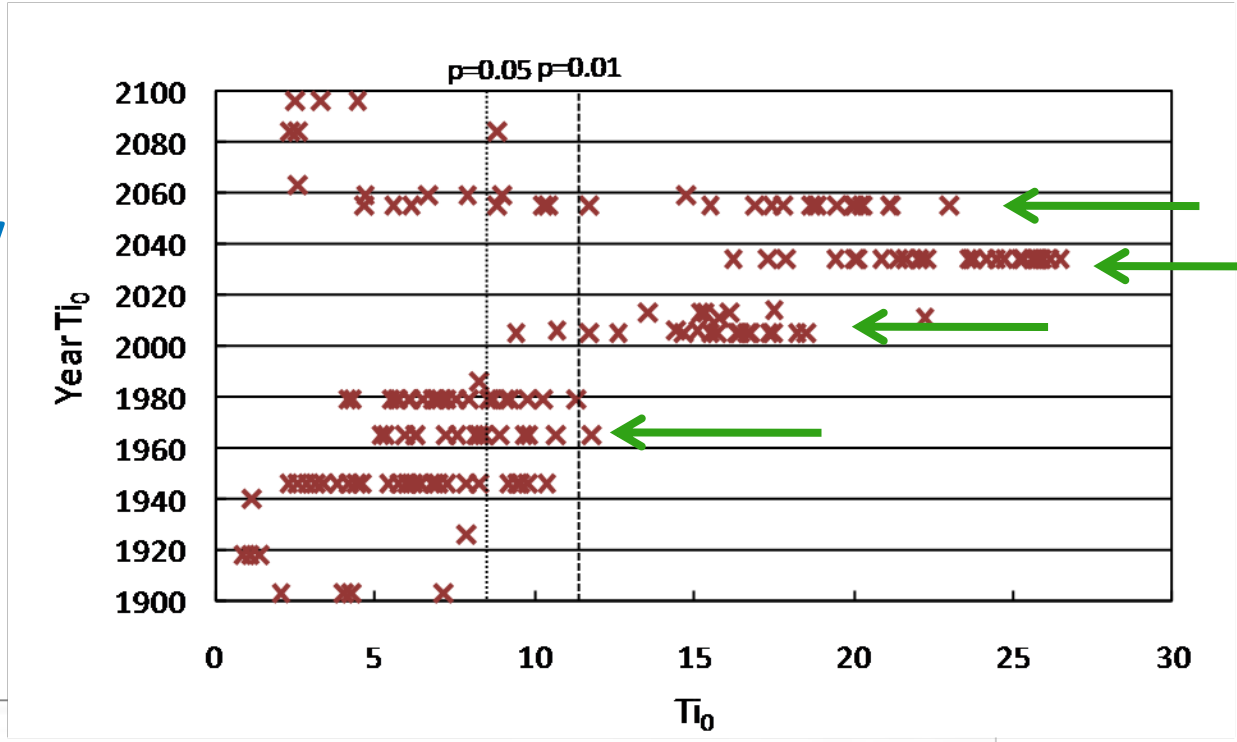
Dummy data set

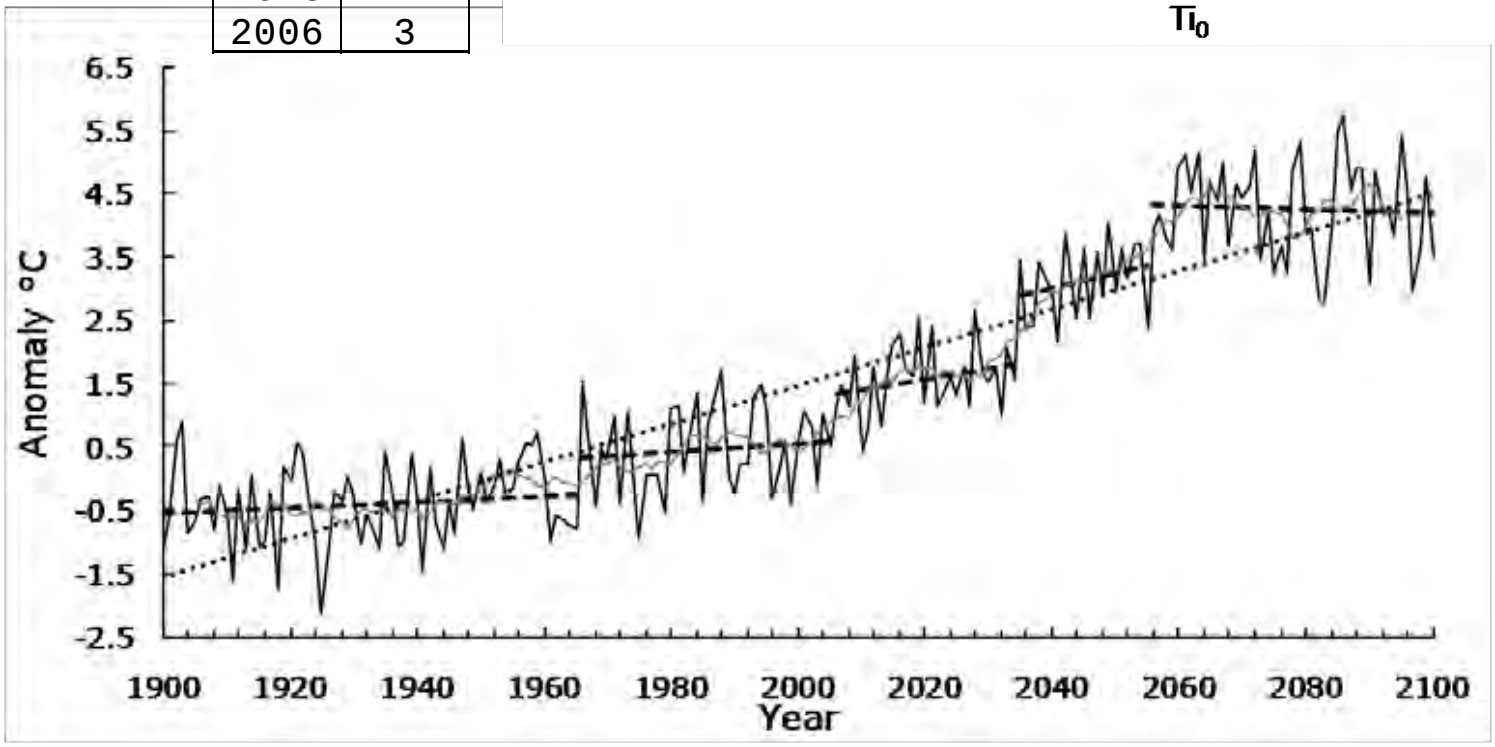


Dummy		Bivariate		STARS	
Year	Amount	Year	Amount	Year	Amount
1966	0.38	1966	0.87	1966	0.88
2006	0.78	2006	1.10	2006	1.10
2035	0.62	2035	1.55	2035	1.55
2057	0.70	2056	1.13	2056	1.15
2085	0.48				
Total	2.96		4.65		4.68

Step and trend analysis – dummy data

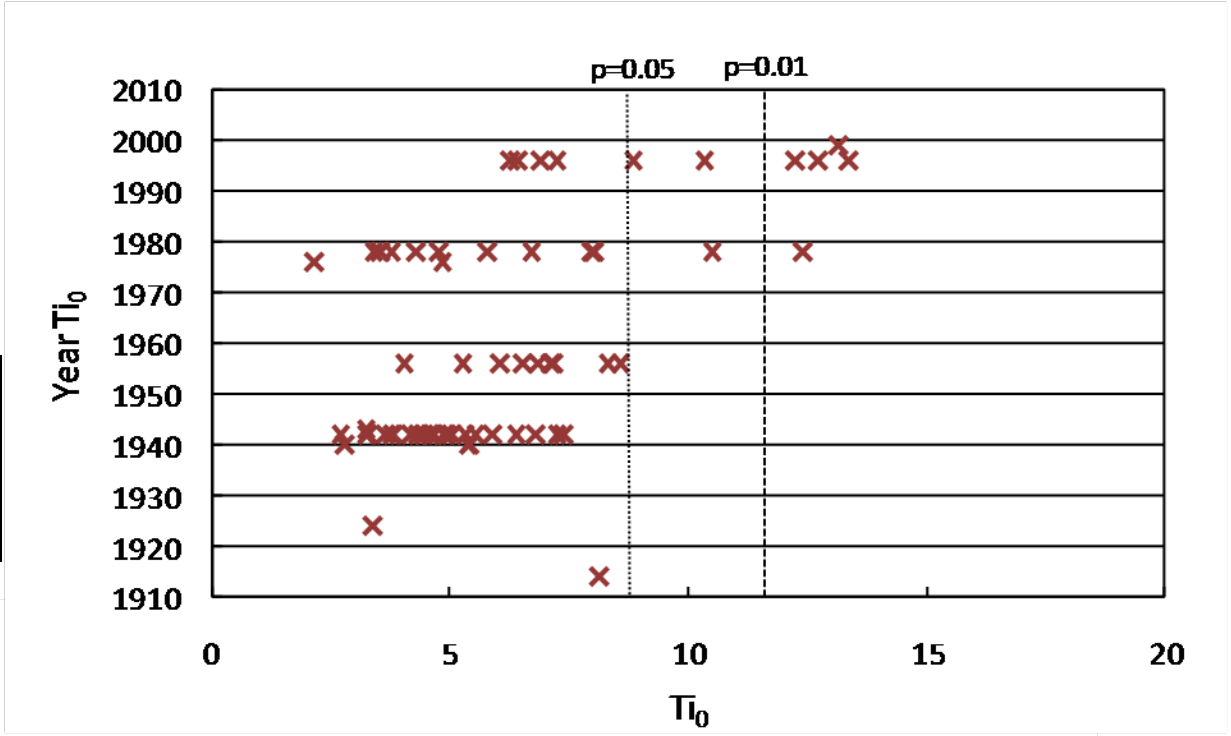
Year Ti_0	Count
2034	28
2055	19
2005	14
1946	5
1965	5
1979	5
2013	4
2006	3

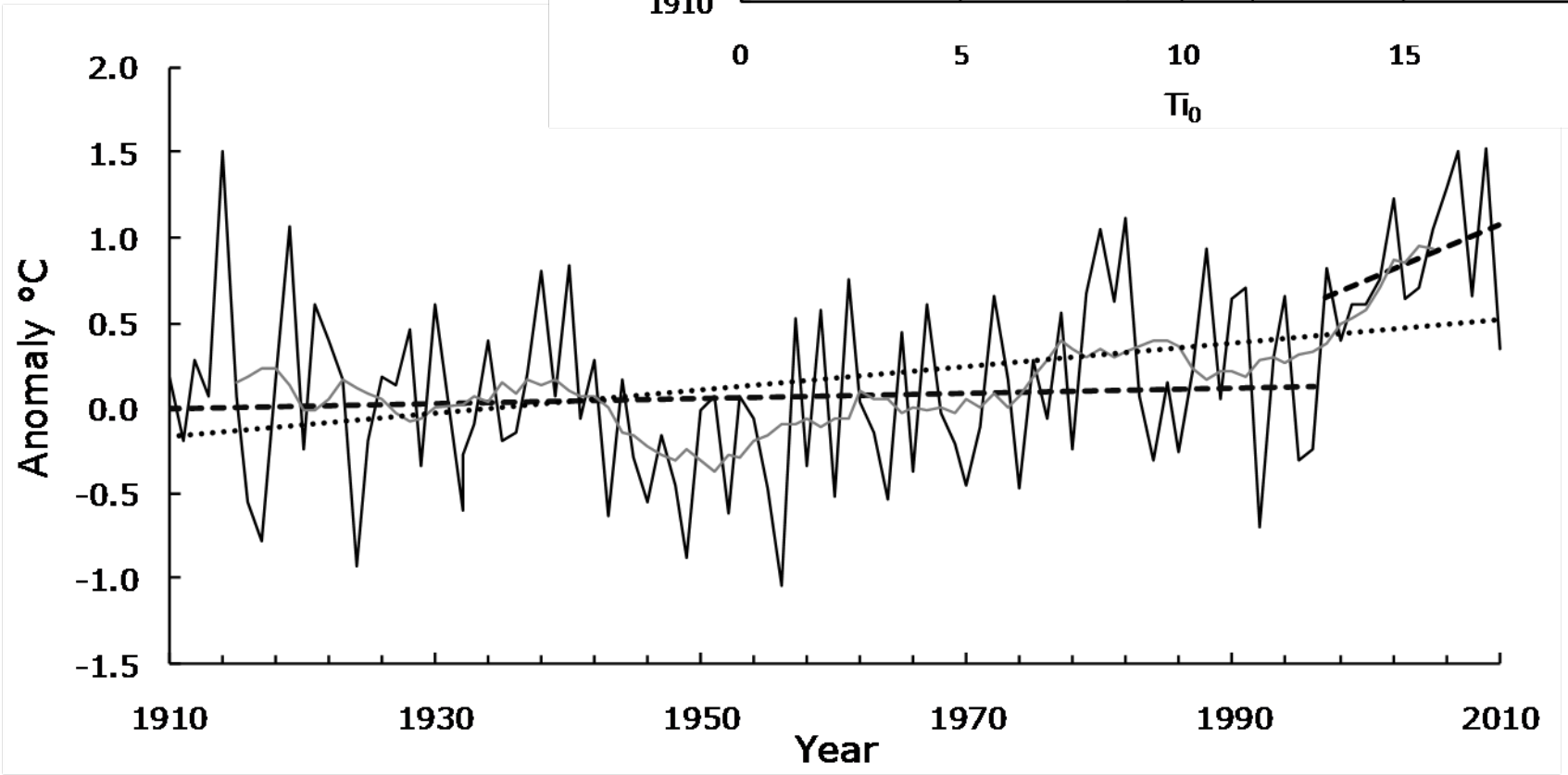




Step and trend analysis – Tmax SEA

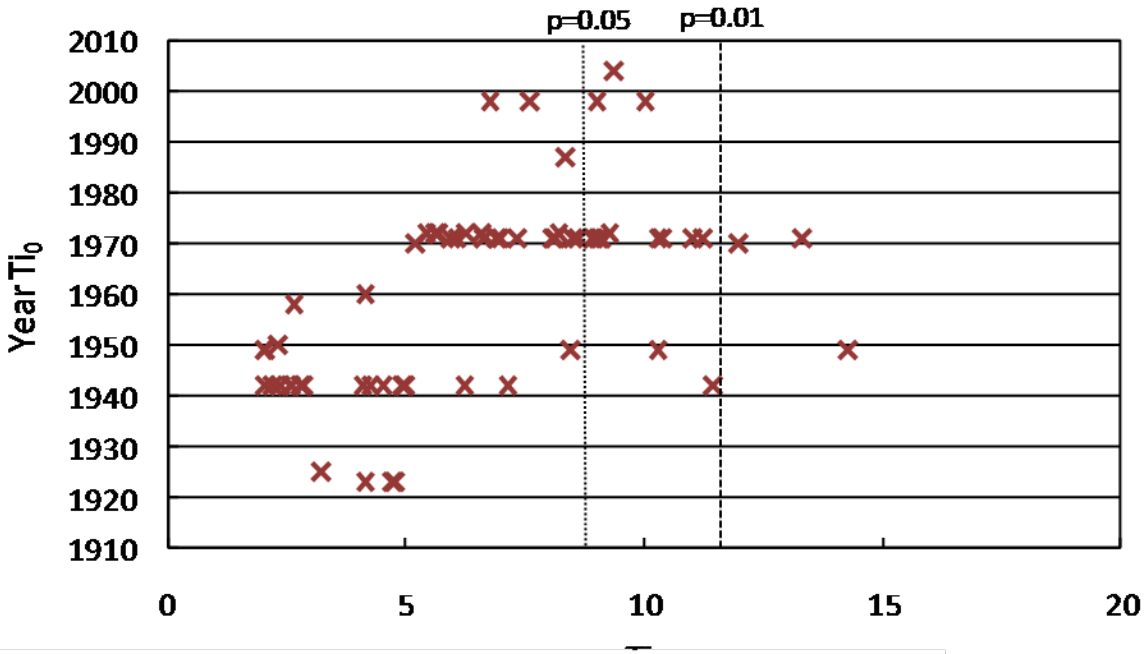
Year Ti_0	Count
1996	5
1978	2
1999	1

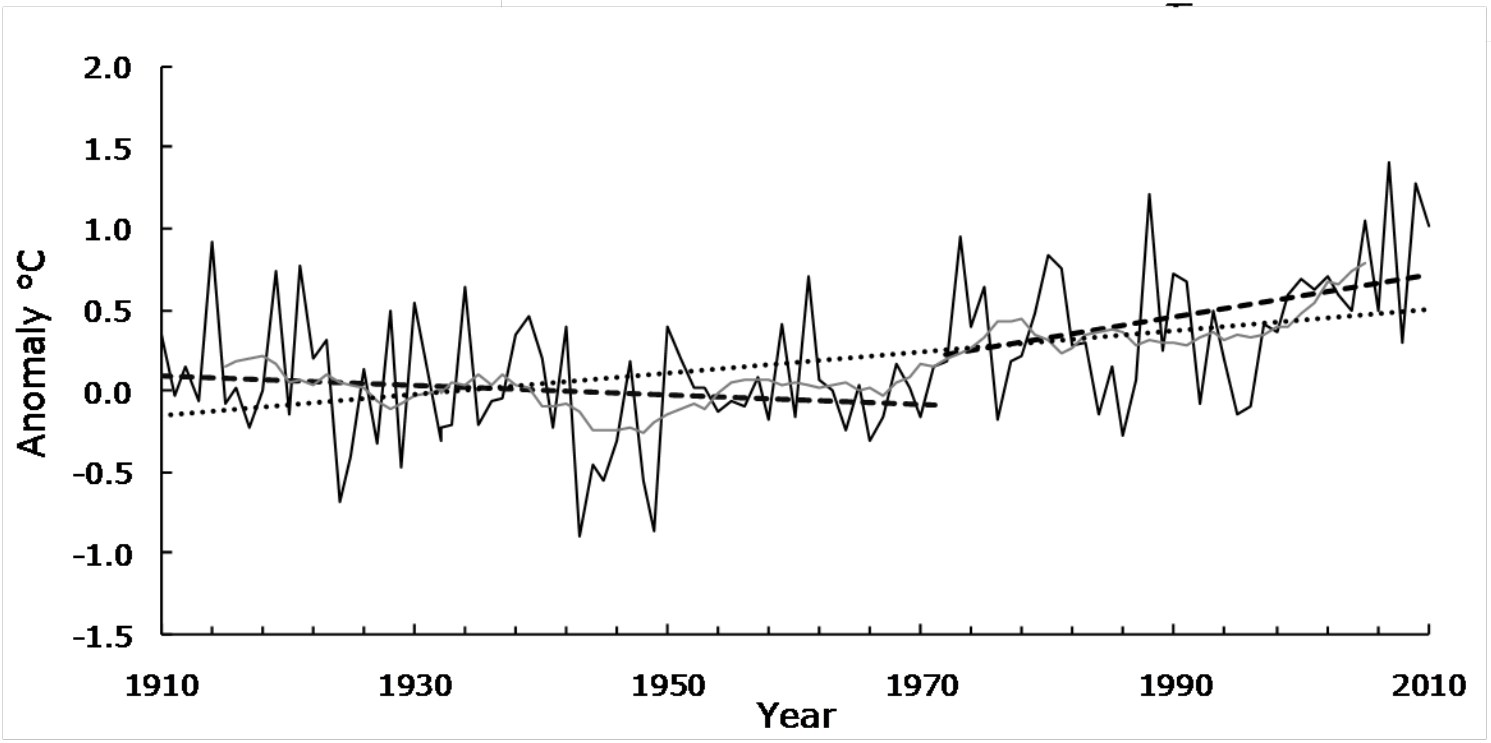




Step and trend analysis – $Tmax_{ARW}$ SEA

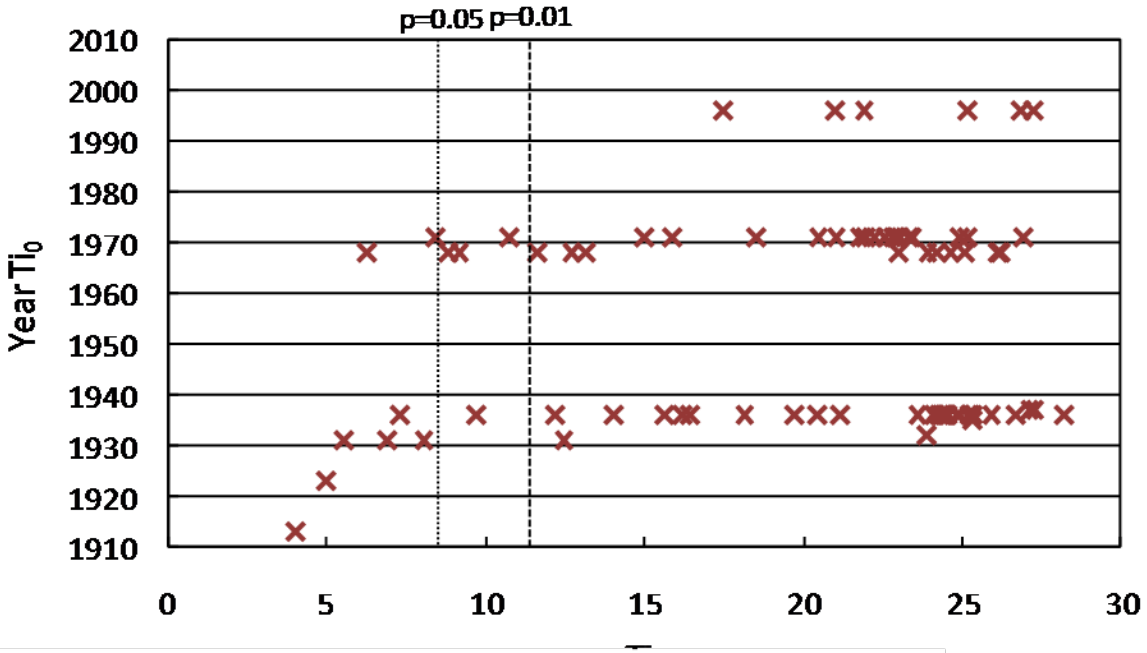
Year Ti_0	Count
1971	9
1949	2
1998	2

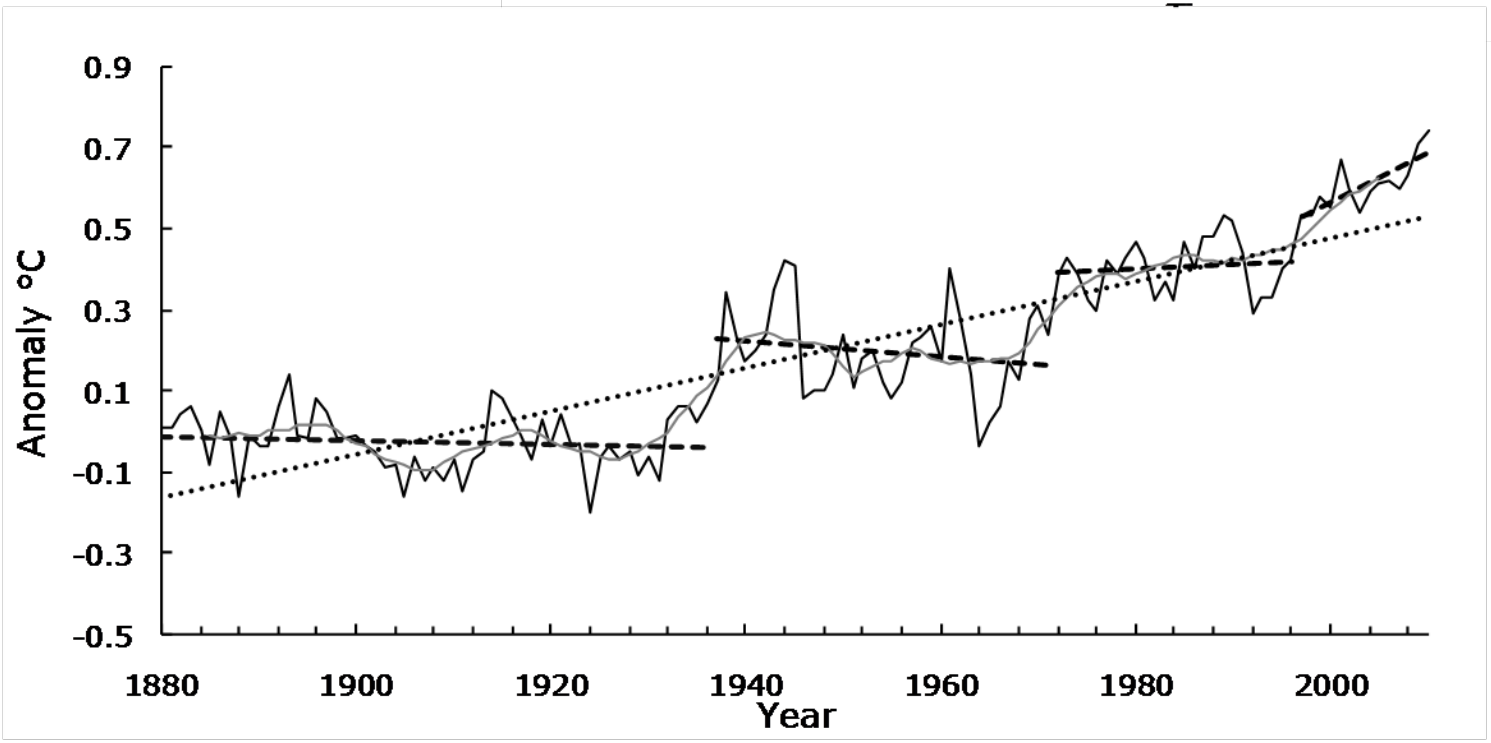




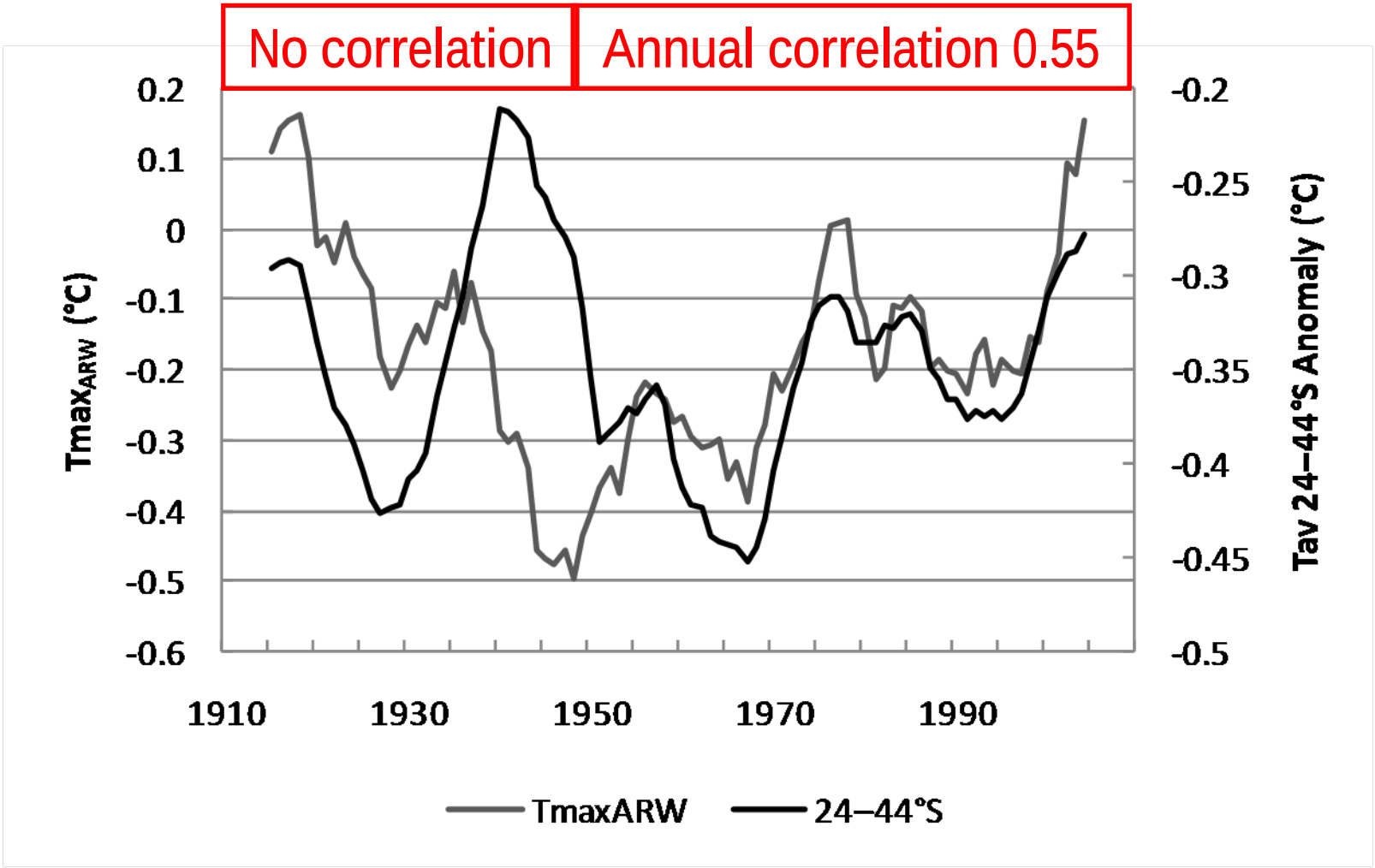
Step and trend analysis – GISStemp 24–44°S

Year Ti_0	Count
1936	29
1971	19
1968	12
1996	6



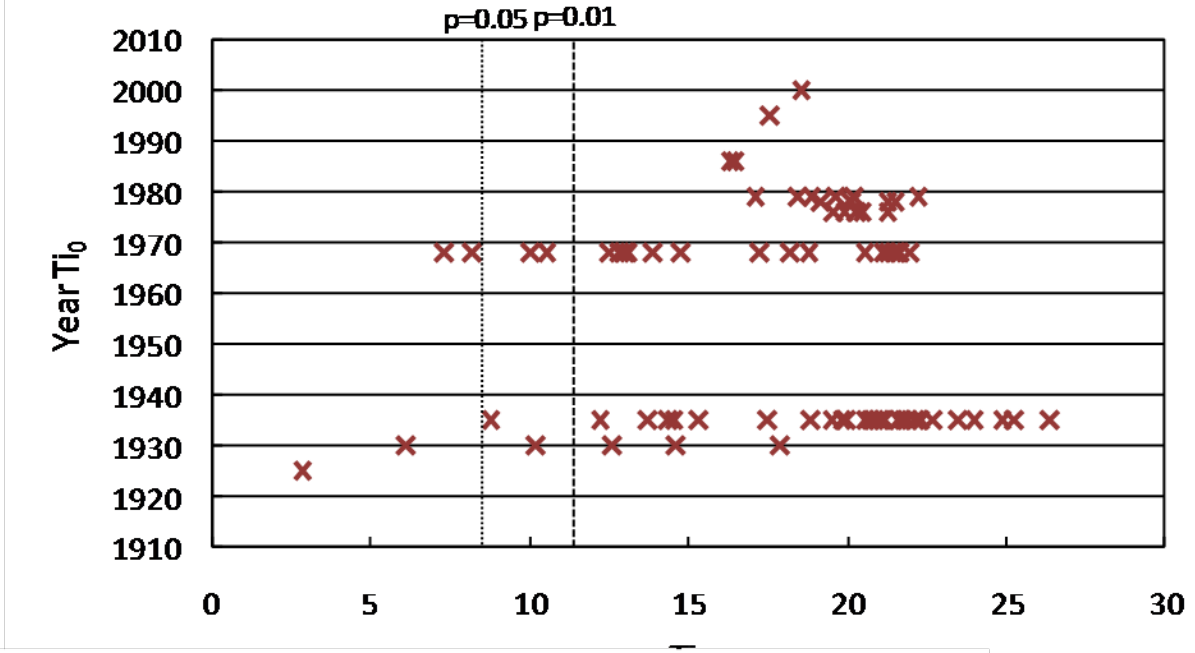


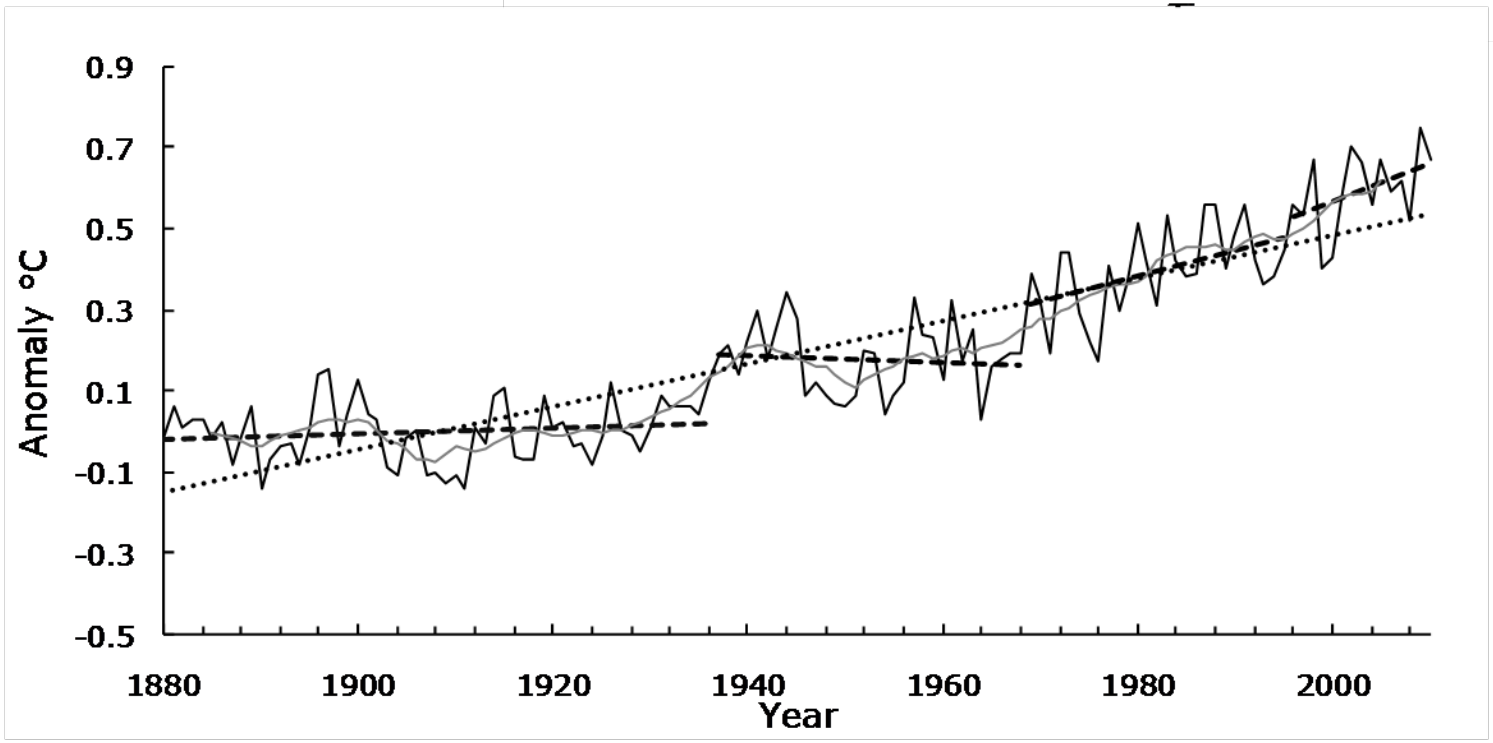
Compare 11-year running means $Tmax_{ARW}$ SEA and Tav 24–44°S



Step and trend analysis – GISStemp S Hem

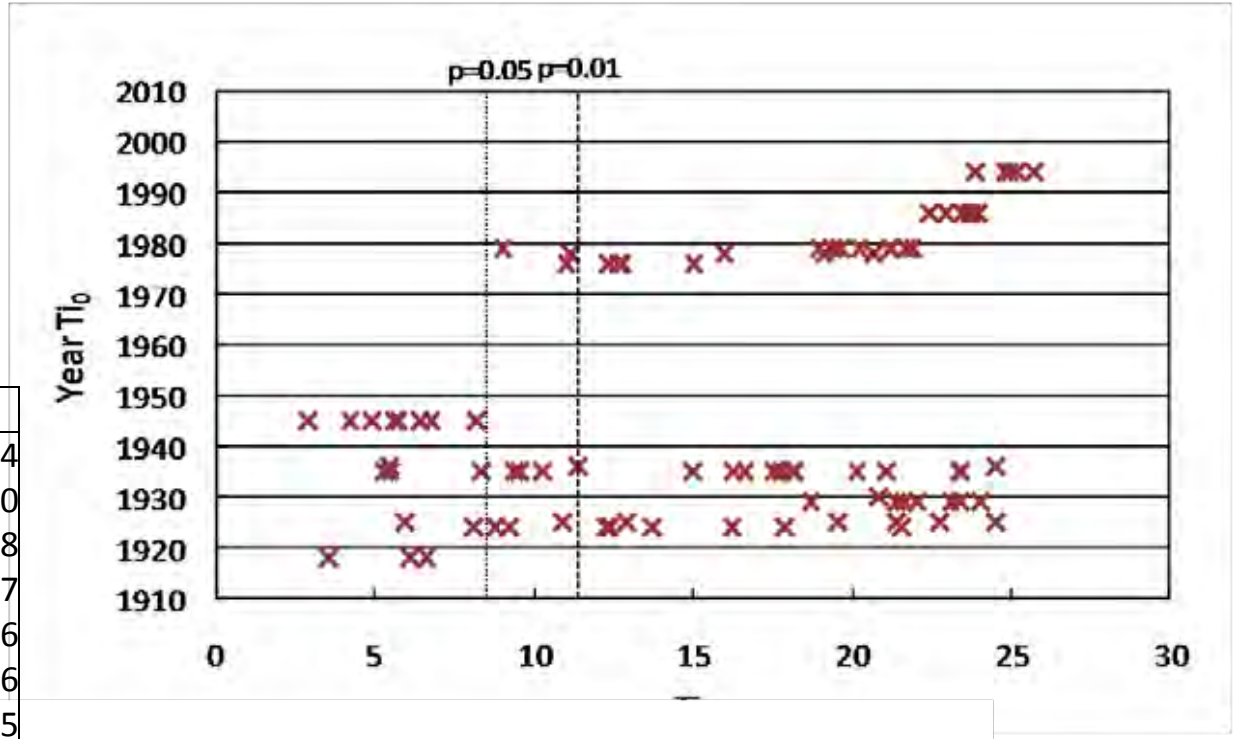
Year Ti_0	Count
1935	29
1968	20
1979	6
1976	5

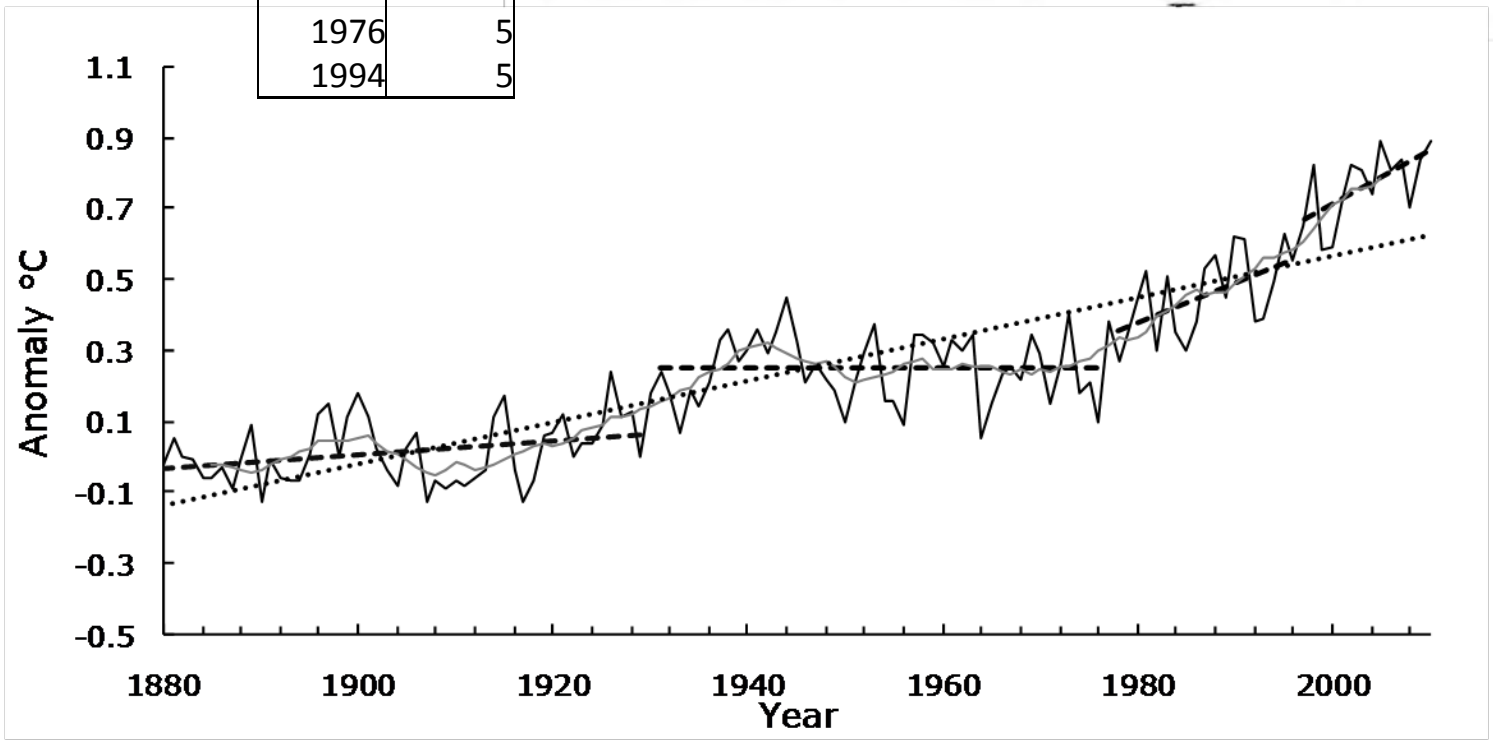




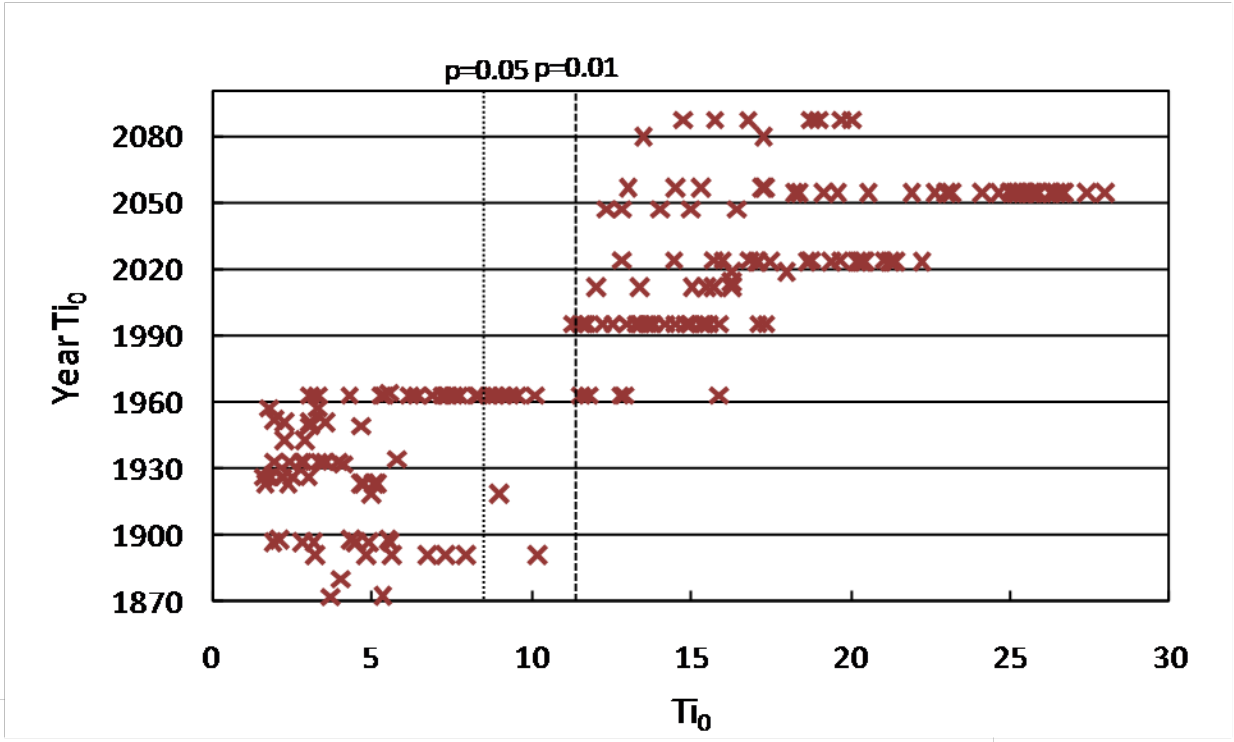
Step and trend analysis – GISStemp Global

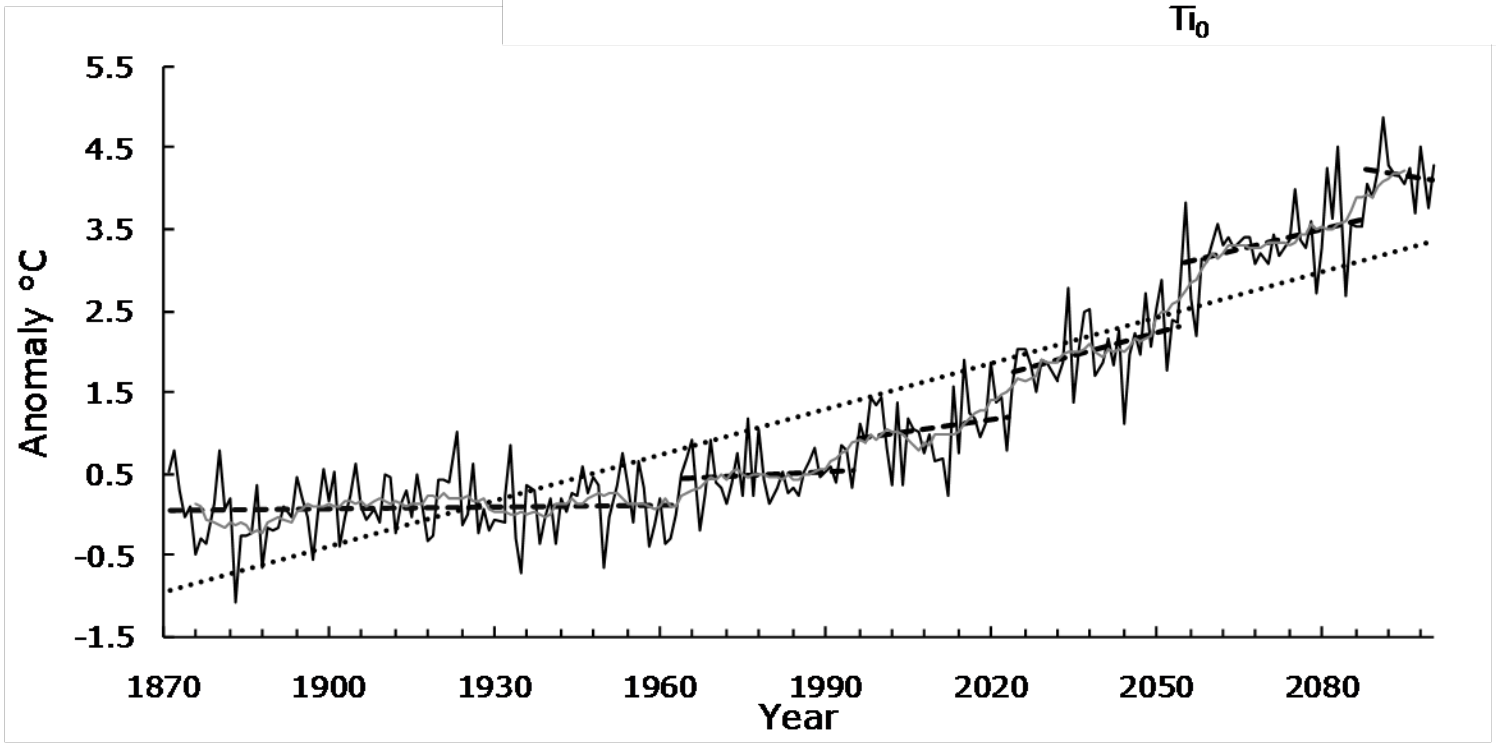
Year Ti_0	Count
1935	14
1979	10
1924	8
1929	7
1925	6
1986	6
1976	5
1994	5



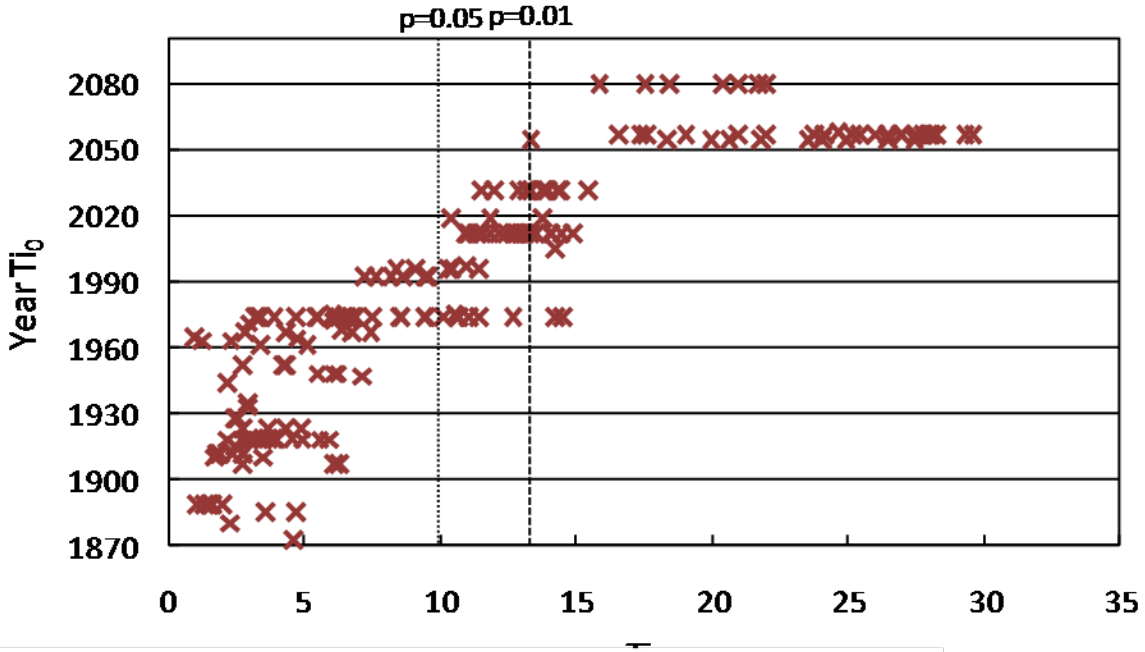


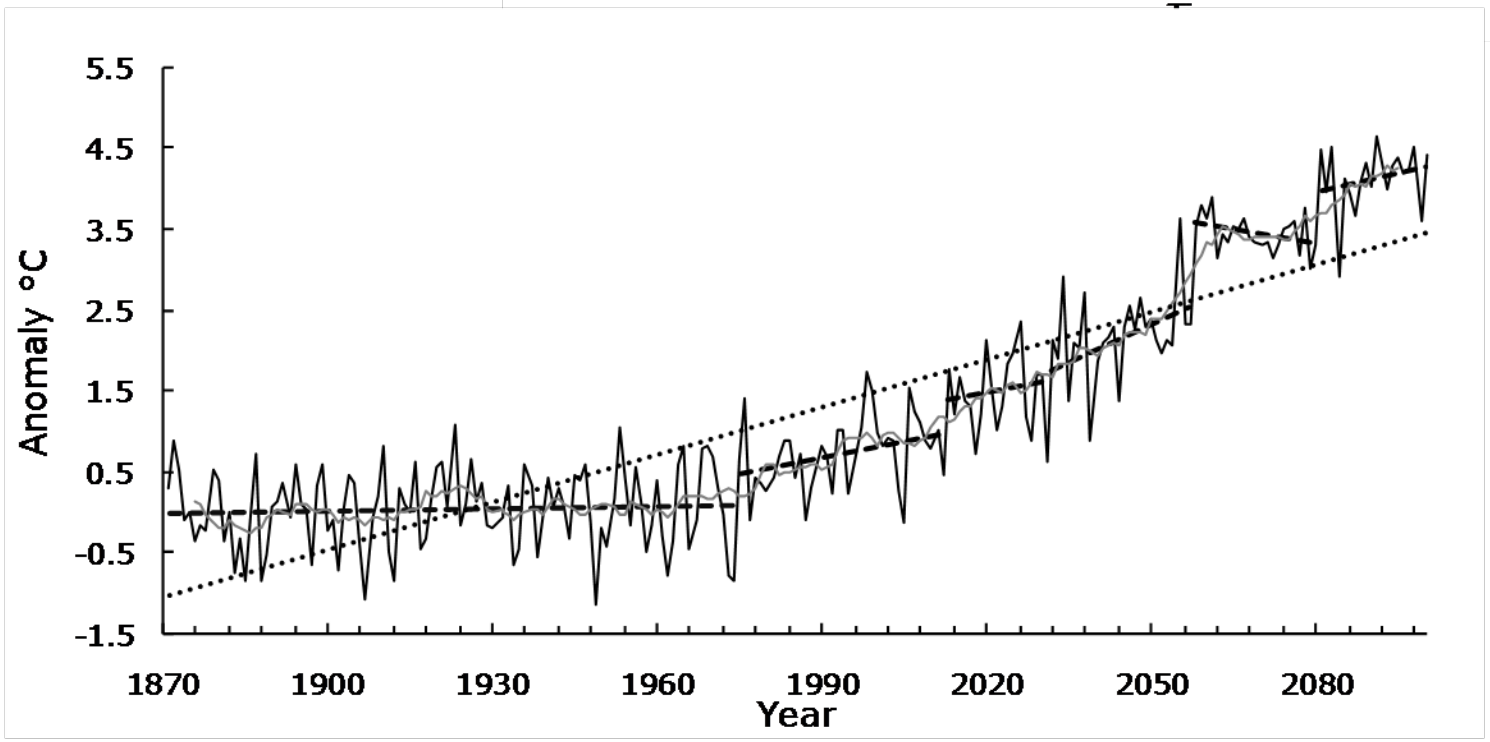
Step and trend analysis – CSIRO Mk3.5 A1B $Tmax_{ARW}$ SEA



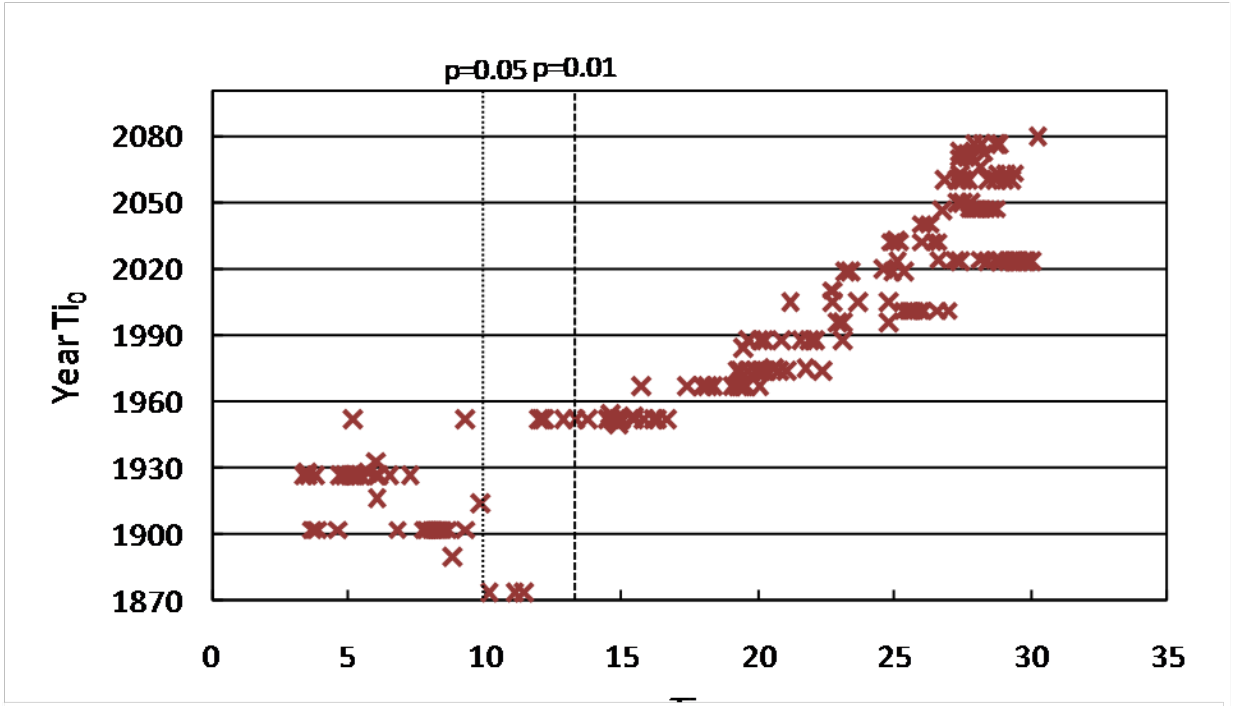


Step and trend analysis – CSIRO Mk3.5 A1B Tav SEA

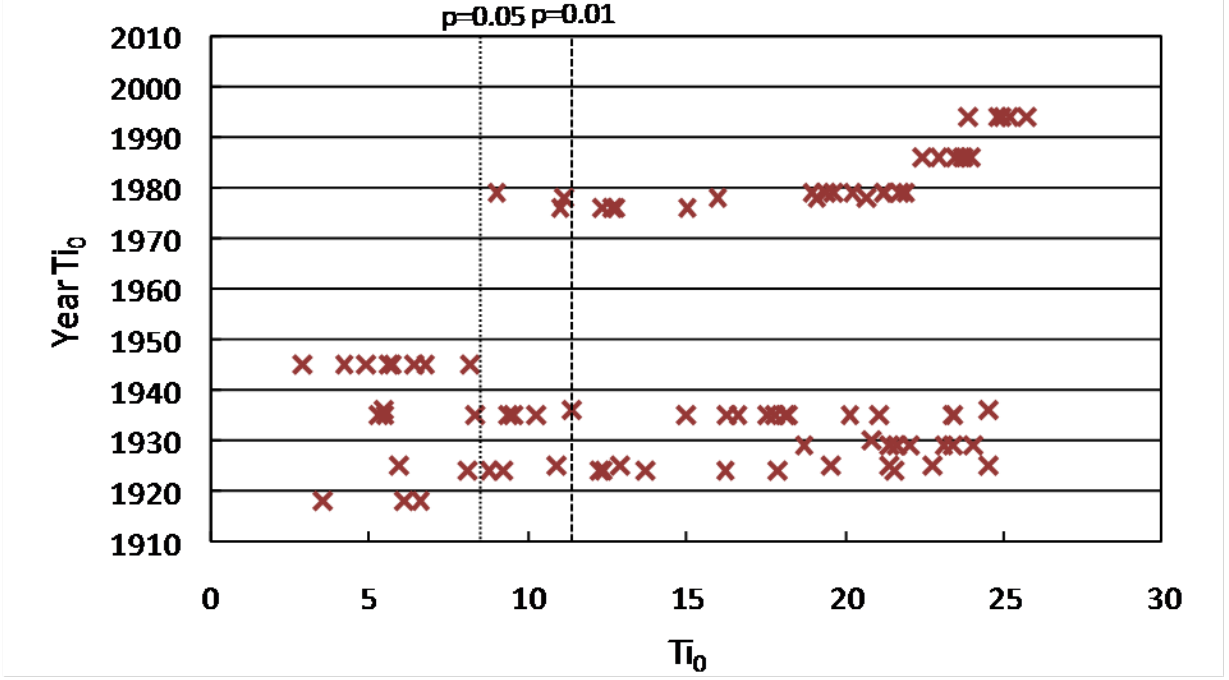




Step analysis – CSIRO Mk3.5 A1B Global Tav



Step analysis – Obs Global Tav



Conclusions – observations

- Southern Australia has experienced two step changes in 1968 and 1997
- Most of the warming in south-eastern Australia has occurred at this time
- Sustained rainfall reductions occurred in SW WA coincident with the first shift and SE Aust in the second shift
- These changes have resulted in step changes in a range of climate impacts and related risks

Conclusions – diagnosis

- Over continental regions, Tmax/P and Tmax/Tmin relationships can be used to assess the impacts of climate variability
- Historical climate can be separated into stationary and non-stationary periods using step changes in these relationships
- The residuals of these relationships can be used to estimate the anthropogenic component of regional warming on Tmax and Tmin

Conclusions – prospects

- Simulations show that 21st century regional climates will be characterised by stepping and trending behaviour
- Climate model projections will need to be updated to account for such dynamic changes
- Adaptation planning based on assumptions of gradual change may lead to under-investment in adaptation and maladaption in response to rapid change
- Mitigation of climate will probably limit the number and magnitude of step changes experienced

Acknowledgements

- Leanne Webb – grape data
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