Australian Government
Bureau of Meteorology

An assessment of the impact of climate change on the nature and frequency of exceptional climatic events

Supplementary Information

8 July 2008

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1 Introduction

This document accompanies *An assessment of the impact of climate change on the nature and frequency of exceptional climatic events* (Hennessy *et al.* 2008), a report prepared for the Australian Government by CSIRO and the Bureau of Meteorology. It provides additional information about observed regional changes in exceptionally[1] high (maximum, mean and minimum) temperatures, low minimum temperatures, high and low rainfall, and low soil moisture. This is principally in the form of percentage areas with exceptionally high or low values of the three climate variables, although time series graphs of area-averaged rainfall and temperatures are also given.

Tables and graphs refer to the following seven regions (Figure 1).

1. Queensland (Qld);
2. New South Wales (NSW);
3. Victoria and Tasmania (Vic&Tas);
4. The northwest (NW): all of the NT and the northern half of WA;
5. The southwest (SW): all of SA and the southern half of WA, including region 6;
6. The southwest of WA (SW WA);
7. The Murray-Darling Basin (MDB).

National results are also given for the historical rainfall (Jones and Weymouth 1997) and temperature (Torok and Nicholls 1996, Della-Marta *et al.* 2004) data.

Drought projections in the Report were based on simulations from 13 climate models judged to perform reasonably well in the Australian region, for which potential evaporation data exist. Based on the naming convention used in the Report by CSIRO and

[1]If exceptional events are defined as those occurring once every 20 years (on average), then in simple terms the probability of such an event occurring in any single year is 1 in 20, or 5%. The critical threshold value is defined as the 5th percentile for exceptionally low rainfall, minimum temperature and soil moisture, and the 95th percentile for exceptionally high maximum, mean and minimum temperatures. These thresholds are normally calculated using all years of available data (1900-2007 for rainfall, 1910-2007 for temperature, and 1957-2006 for soil moisture).

BoM (2007), the models are: MIROC-M, IPSL, CCCMA-T47, CSIRO-Mk3.5, GISS-ER, MIROC-H, MRI, CCCMA-T63, CSIRO-Mk3.0, GISS-AOM, NCAR-CCSM, IAP and INMCM. More information about these models can be found in *Climate Change in Australia* (Chapter 4, accessible at http://www.climatechangeinaustralia.gov.au/resources.php), published by CSIRO and the Bureau of Meteorology (2007).

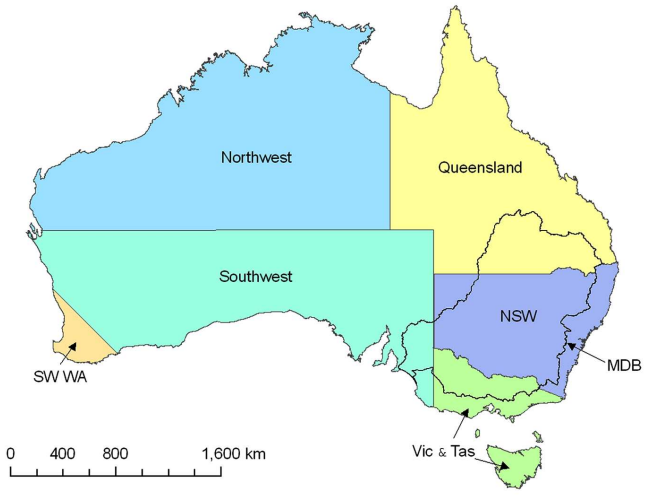

Figure 1: Map of the regions considered in the Report.

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The Report and this Supplementary Information are available on the web, at http://www.bom.gov.au/climate/droughtec/ .

2 Exceptional events

For the purposes of this study, exceptional events are defined as occurring once every 20 years, on average[2]. A 1-in-20 year event has a return period of 20 years. In simple terms, the probability of such an event occurring in any single year is then 1 in 20, or 5%. The critical threshold is defined as the 5th percentile for exceptionally low rainfall and soil moisture, and as the 95th percentile for exceptionally high temperature. These thresholds are normally based on all years of available data, which in this study is 1900-2007 for rainfall, 1910-2007 for temperature, and 1957-2006 for soil moisture.

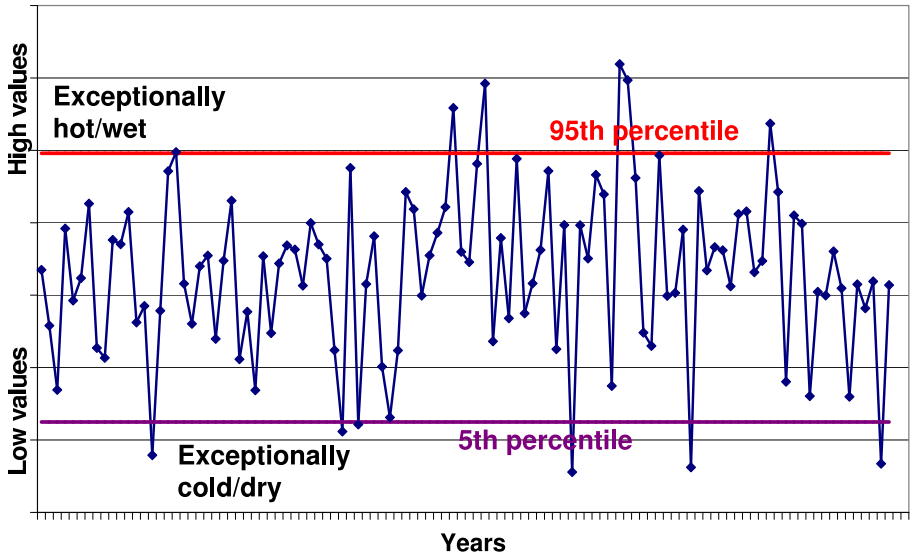


Figure 2: Schematic representation of a set of annual climate data. Approximately 5% of years are below the 5th percentile, and approximately 5% of years are above the 95th percentile. The exact percentages below the 5th percentile (or above the 95th percentile) depend on the number of years in the dataset.

If the length of the dataset is a multiple of 20 years, then exactly 5% of the values would fall below the 5th percentile (or above the 95th percentile). However, the lengths of the datasets in this study are not multiples of 20 years. For the historical rainfall data (the 108 years from 1900 to 2007), 6 out of the 108 years are below the 5th percentile, assuming no repeated values in the dataset. This implies a base rate of 5.6% and a return period of 18 years, rather than the nominal 5% and return period of 20 years. For the historical temperature data (the 98 years from 1910 to 2007), the corresponding numbers are 5 out of 98 years, a base rate of 5.1% and a return period of 19.6 years. For the historical soil moisture data (the 50 years from 1957 to 2006), the numbers are 3 out of 50 years, a base rate of 5% and a return period of 16.7 years. In datasets containing repeated values, slightly different results may be obtained.

[2]In the study, those events are defined as being of one year's duration. To encompass both the southern (April-November) and northern (October-April) wet seasons, rainfall results are given for both calendar (January-December) and financial (July-June) years. For the historical rainfall and temperature data, results for two-year events are also given.

3 Tables - Rainfall

Percentage area below the 5th percentile for calendar year (January-December) total rainfall, averaged across selected periods.

Region	1900–1939	1910–1949	1920–1959	1930–1969	1940–1979	1950–1989	1960–1999	1968–2007
Qld	9.5	6.5	5.5	4.1	3.3	3.1	2.7	2.6
NSW	5.7	6.9	5.7	6.2	5.8	4.3	4.0	3.8
Vic&Tas	5.3	6.0	4.2	6.1	5.1	5.0	5.3	5.2
SW	5.2	7.1	7.2	6.9	7.9	5.9	4.9	4.4
NW	5.8	5.6	7.2	7.7	7.4	6.6	5.6	3.1
MDB	6.1	7.2	5.8	6.4	5.7	4.1	3.5	3.5
SW WA	2.5	4.7	4.1	6.5	8.3	6.1	6.3	8.5
Aust.	6.4	6.4	6.6	6.4	6.3	5.3	4.6	3.5

Region	1958–2007	1968–2007	1978–2007	1988–2007	1998–2007
Qld	3.2	2.6	3.0	3.4	4.7
NSW	4.5	3.8	4.8	4.0	6.4
Vic&Tas	6.0	5.2	6.4	5.5	8.5
SW	4.7	4.4	2.8	2.8	3.4
NW	5.3	3.1	2.5	3.1	0.4
MDB	4.2	3.5	4.5	3.9	6.9
SW WA	6.8	8.5	6.0	7.2	8.9
Aust.	4.6	3.5	3.1	3.3	3.2

Percentage area above the 95th percentile for calendar year (January-December) total rainfall, averaged across selected periods.

Region	1900–1939	1910–1949	1920–1959	1930–1969	1940–1979	1950–1989	1960–1999	1968–2007
Qld	3.5	2.9	6.3	5.5	8.4	8.8	5.0	6.1
NSW	1.9	2.0	6.3	6.6	10.1	10.8	7.3	7.4
Vic&Tas	3.1	3.6	5.1	6.5	10.2	9.5	7.7	6.4
SW	2.9	3.6	3.6	4.3	7.6	7.2	7.7	8.5
NW	2.2	2.4	2.5	2.0	5.3	5.3	6.8	11.1
MDB	3.1	2.7	6.2	5.8	8.9	9.7	6.6	6.9
SW WA	8.0	9.2	8.4	7.6	6.6	4.4	2.1	0.8
Aust.	2.7	2.9	4.2	4.1	7.4	7.3	6.8	8.7

Region	1958–2007	1968–2007	1978–2007	1988–2007	1998–2007
Qld	5.0	6.1	4.3	4.7	6.9
NSW	6.5	7.4	4.8	4.7	4.6
Vic&Tas	6.4	6.4	2.8	3.1	0.4
SW	7.6	8.5	6.3	8.4	8.5
NW	9.2	11.1	10.2	13.2	21.7
MDB	5.7	6.9	4.6	4.5	3.7
SW WA	1.9	0.8	0.7	0.7	1.3
Aust.	7.4	8.7	6.9	8.6	12.0

Percentage area below the 5th percentile for financial year (July-June) total rainfall, averaged across selected periods.

Region	1900/01–1939/40	1910/11–1949/50	1920/21–1959/60	1930/31–1969/70	1940/41–1979/80	1950/51–1989/90	1960/61–1999/00	1967/68–2006/07
Qld	9.1	6.7	5.5	5.0	3.8	3.8	3.9	3.4
NSW	9.7	8.5	6.5	4.8	3.6	2.3	2.0	2.0
Vic&Tas	8.4	9.8	6.1	4.0	3.4	2.4	2.4	3.6
SW	6.8	7.7	7.5	7.3	6.7	5.3	4.4	3.3
NW	6.3	5.3	6.5	7.5	6.5	6.1	4.7	3.5
MDB	9.3	9.0	6.3	4.4	3.6	2.1	2.1	2.6
SW WA	4.6	4.5	5.0	5.0	5.2	5.0	3.0	6.2
Aust.	7.5	6.8	6.6	6.4	5.5	4.8	4.1	3.3

Region	1957/58–2006/07	1967/68–2006/07	1977/78–2006/07	1987/88–2006/07	1997/98–2006/07
Qld	3.8	3.4	3.0	3.6	2.3
NSW	2.6	2.0	2.5	2.6	4.4
Vic&Tas	3.5	3.6	4.8	4.3	8.0
SW	4.5	3.3	2.1	1.8	2.5
NW	4.7	3.5	3.0	4.2	3.3
MDB	2.9	2.6	3.3	3.2	4.8
SW WA	6.7	6.2	7.2	8.1	12.7
Aust.	4.1	3.3	2.8	3.2	3.1

Percentage area above the 95th percentile for financial year (July-June) total rainfall, averaged across selected periods.

Region	1900/01–1939/40	1910/11–1949/50	1920/21–1959/60	1930/31–1969/70	1940/41–1979/80	1950/51–1989/90	1960/61–1999/00	1967/68–2006/07
Qld	4.5	5.1	5.3	4.6	8.2	7.2	5.9	6.3
NSW	2.6	4.0	6.7	6.3	9.3	9.1	7.3	6.8
Vic&Tas	7.1	7.5	6.6	5.9	6.4	6.3	4.5	4.4
SW	4.4	5.4	4.1	3.7	6.1	5.6	7.3	7.5
NW	2.9	2.8	2.6	1.9	4.6	4.6	7.7	10.7
MDB	3.9	4.9	6.6	5.7	8.1	8.0	6.3	6.1
SW WA	9.1	9.8	8.1	5.3	5.2	3.3	1.7	1.1
Aust.	3.8	4.4	4.2	3.6	6.4	6.0	7.0	8.1

Region	1957/58–2006/07	1967/68–2006/07	1977/78–2006/07	1987/88–2006/07	1997/98–2006/07
Qld	5.2	6.3	3.7	4.4	5.3
NSW	5.9	6.8	4.3	5.3	4.7
Vic&Tas	3.7	4.4	2.2	2.3	0.6
SW	6.6	7.5	6.4	8.0	9.4
NW	8.8	10.7	10.2	13.5	23.8
MDB	5.1	6.1	4.0	5.0	3.8
SW WA	1.7	1.1	0.9	1.3	0.1
Aust.	6.9	8.1	6.7	8.6	12.6

Percentage area below the 5th percentile for biennial (January-December) total rainfall, averaged across selected periods.

Region	1900/01–1939/40	1910/11–1949/50	1920/21–1959/60	1930/31–1969/70	1940/41–1979/80	1950/51–1989/90	1960/61–1999/00	1967/68–2006/07
Qld	8.4	6.3	5.7	4.8	3.3	2.9	3.6	3.8
NSW	8.0	8.5	6.4	5.8	5.0	2.0	2.2	2.8
Vic&Tas	6.5	7.9	5.3	6.1	4.9	2.5	2.9	4.3
SW	6.8	8.8	8.2	6.7	7.0	4.8	4.4	3.5
NW	6.2	6.1	8.2	8.9	7.6	7.5	4.8	2.0
MDB	7.3	8.5	6.4	6.1	5.4	2.0	2.1	2.9
SW WA	3.0	3.6	3.4	4.4	5.7	5.5	5.6	8.8
Aust.	7.1	7.2	7.3	6.9	6.1	4.9	4.0	3.0

Region	1957/58–2006/07	1967/68–2006/07	1977/78–2006/07	1987/88–2006/07	1997/98–2006/07
Qld	4.4	3.8	4.6	5.8	7.2
NSW	3.0	2.8	3.5	3.6	6.2
Vic&Tas	4.2	4.3	5.0	5.7	10.9
SW	3.9	3.5	1.8	1.5	1.7
NW	4.6	2.0	1.6	1.8	0.4
MDB	3.2	2.9	3.6	4.2	7.7
SW WA	7.1	8.8	9.3	9.3	12.5
Aust.	4.2	3.0	2.6	2.9	3.3

Percentage area above the 95th percentile for biennial (January-December) total rainfall, averaged across selected periods.

Region	1900/01–1939/40	1910/11–1949/50	1920/21–1959/60	1930/31–1969/70	1940/41–1979/80	1950/51–1989/90	1960/61–1999/00	1967/68–2006/07
Qld	2.7	4.1	6.2	5.5	9.7	8.4	6.7	6.9
NSW	1.2	2.8	6.0	6.1	10.1	10.0	8.2	7.9
Vic&Tas	3.1	3.9	5.2	5.4	9.9	8.7	7.3	7.3
SW	2.7	3.3	2.5	3.2	7.1	6.4	8.8	9.6
NW	1.5	1.8	1.8	1.4	5.6	5.5	9.0	12.4
MDB	2.2	3.4	5.8	5.4	9.0	9.0	7.7	7.6
SW WA	8.2	8.0	5.5	6.5	6.6	4.2	2.8	0.5
Aust.	2.1	2.9	3.5	3.5	7.6	7.0	8.3	9.7

Region	1957/58–2006/07	1967/68–2006/07	1977/78–2006/07	1987/88–2006/07	1997/98–2006/07
Qld	5.6	6.9	3.5	4.3	7.1
NSW	6.6	7.9	5.0	5.6	5.6
Vic&Tas	6.0	7.3	2.8	4.0	0.4
SW	8.3	9.6	7.2	10.1	11.9
NW	10.1	12.4	10.8	14.5	27.8
MDB	6.2	7.6	5.2	5.6	5.2
SW WA	2.2	0.5	0.5	0.4	0.0
Aust.	8.1	9.7	7.2	9.6	15.2

4 Tables - Calendar Year Temperatures

Percentage area above the 95th percentile for calendar year maximum temperature, averaged across selected periods.

Region	1910–1949	1920–1959	1930–1969	1940–1979	1950–1989	1960–1999	1968–2007
Qld	5.3	3.5	2.5	2.0	2.1	1.7	6.4
NSW	5.0	2.1	1.9	1.6	1.3	1.1	7.3
Vic&Tas	2.4	0.5	1.5	2.1	4.7	5.0	9.2
SW	0.8	0.2	0.3	1.1	2.1	5.9	11.6
NW	1.3	1.8	1.4	1.8	3.6	7.1	10.6
MDB	4.6	1.4	1.4	1.2	1.5	1.3	7.4
SW WA	0.8	0.9	2.0	4.4	4.6	8.9	10.7
Aust.	2.5	1.7	1.4	1.6	2.6	4.8	9.5

Percentage area above the 95th percentile for calendar year mean temperature, averaged across selected periods.

Region	1910–1949	1920–1959	1930–1969	1940–1979	1950–1989	1960–1999	1968–2007
Qld	1.3	0.7	0.5	1.0	2.9	5.3	11.2
NSW	3.0	0.8	0.8	0.9	2.5	3.1	9.6
Vic&Tas	1.4	0.3	1.4	1.4	5.6	6.5	10.2
SW	0.6	0.1	0.4	0.8	2.4	6.7	11.7
NW	0.7	1.3	0.9	1.4	3.0	8.8	11.3
MDB	2.5	0.4	0.5	0.9	2.9	3.5	10.0
SW WA	0.0	0.0	0.0	2.4	5.1	11.3	12.7
Aust.	1.1	0.7	0.7	1.1	2.8	6.7	11.2

Percentage area above the 95th percentile for calendar year minimum temperature, averaged across selected periods.

Region	1910–1949	1920–1959	1930–1969	1940–1979	1950–1989	1960–1999	1968–2007
Qld	0.2	0.1	0.1	2.4	5.0	8.7	12.4
NSW	1.3	0.9	0.9	2.9	6.3	7.5	10.8
Vic&Tas	0.4	0.4	0.5	2.8	7.4	8.1	12.1
SW	0.3	0.3	1.1	2.8	4.6	8.9	11.3
NW	0.2	1.1	1.0	2.2	3.9	9.5	11.4
MDB	0.8	0.5	0.4	2.8	6.2	7.7	11.5
SW WA	0.2	0.5	2.3	3.1	6.2	10.8	10.4
Aust.	0.4	0.6	0.8	2.5	4.7	8.9	11.6

Percentage area below the 5th percentile for calendar year minimum temperature, averaged across selected periods.

Region	1910–1949	1920–1959	1930–1969	1940–1979	1950–1989	1960–1999	1968–2007
Qld	9.8	6.4	4.4	4.6	2.8	0.7	0.5
NSW	9.8	10.2	6.3	5.7	2.7	0.8	0.5
Vic&Tas	11.9	11.5	9.0	8.3	0.7	0.3	0.1
SW	9.2	9.2	7.2	6.9	3.5	1.9	1.2
NW	9.5	7.2	6.0	7.7	2.9	3.1	2.7
MDB	10.0	9.7	5.8	5.6	2.5	0.7	0.6
SW WA	9.2	6.9	4.2	3.5	3.5	2.7	1.1
Aust.	9.6	8.0	6.1	6.6	2.9	1.9	1.4

5 Tables - Biennial Temperatures

Percentage area above the 95th percentile for biennial maximum temperature, averaged across selected periods.

Region	1910/11–1949/50	1920/21–1959/60	1930/31–1969/70	1940/41–1979/80	1950/51–1989/90	1960/61–1999/00	1967/68–2006/07
Qld	2.9	2.0	1.8	1.6	1.7	1.4	9.1
NSW	1.8	0.6	0.5	0.9	0.8	0.8	10.8
Vic&Tas	1.0	0.2	0.3	1.4	4.4	5.6	11.3
SW	0.1	0.1	0.3	1.3	1.9	3.9	12.2
NW	0.9	1.2	1.2	2.3	4.3	6.7	11.2
MDB	1.7	0.4	0.2	0.7	1.0	1.0	10.7
SW WA	0.5	0.5	1.7	1.8	1.5	8.3	10.9
Aust.	1.2	1.0	1.0	1.7	2.7	4.0	11.0

Percentage area above the 95th percentile for biennial mean temperature, averaged across selected periods.

Region	1910/11–1949/50	1920/21–1959/60	1930/31–1969/70	1940/41–1979/80	1950/51–1989/90	1960/61–1999/00	1967/68–2006/07
Qld	0.4	0.0	0.0	0.2	2.5	4.2	12.2
NSW	1.1	0.2	0.2	1.0	2.2	3.1	11.5
Vic&Tas	0.0	0.0	0.0	0.0	4.6	6.9	12.7
SW	0.0	0.0	0.0	1.3	2.2	5.4	12.6
NW	0.0	0.7	0.7	1.7	4.4	9.1	11.9
MDB	0.9	0.0	0.0	0.6	2.2	2.8	11.7
SW WA	0.0	0.0	0.3	0.9	1.0	10.1	12.6
Aust.	0.2	0.3	0.3	1.1	3.1	6.2	12.2

Percentage area above the 95th percentile for biennial minimum temperature, averaged across selected periods.

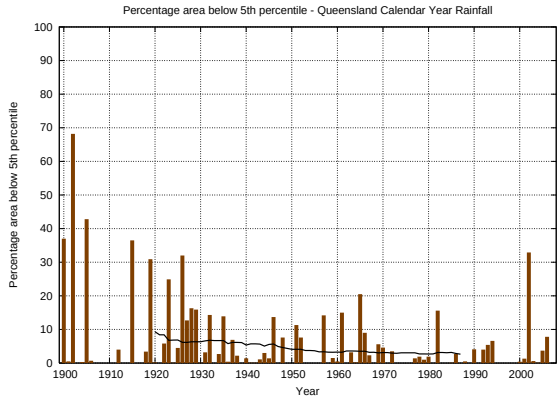
Region	1910/11–1949/50	1920/21–1959/60	1930/31–1969/70	1940/41–1979/80	1950/51–1989/90	1960/61–1999/00	1967/68–2006/07
Qld	0.1	0.0	0.0	0.3	3.4	7.4	12.5
NSW	0.4	0.2	0.1	1.6	5.7	9.0	12.2
Vic&Tas	0.2	0.2	0.2	4.0	8.2	9.9	12.3
SW	0.0	0.0	0.4	2.2	3.1	8.9	12.3
NW	0.1	0.8	0.8	2.0	3.8	10.4	11.8
MDB	0.3	0.1	0.1	2.1	6.1	8.5	12.3
SW WA	0.1	0.4	2.3	3.5	4.3	12.2	10.3
Aust.	0.1	0.3	0.4	1.7	3.9	9.1	12.1

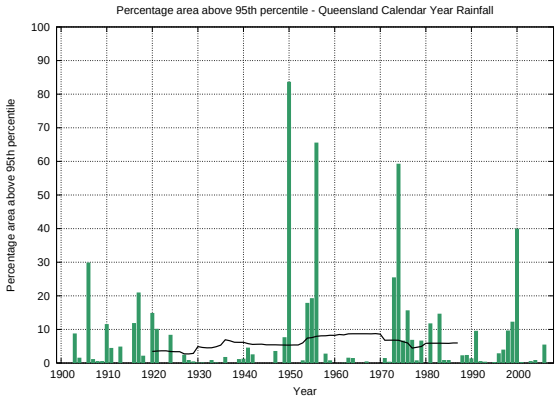
Percentage area below the 5th percentile for biennial minimum temperature, averaged across selected periods.

Region	1910/11–1949/50	1920/21–1959/60	1930/31–1969/70	1940/41–1979/80	1950/51–1989/90	1960/61–1999/00	1967/68–2006/07
Qld	9.9	6.5	4.6	4.5	2.7	0.7	0.3
NSW	9.9	10.0	7.6	6.1	2.7	0.4	0.1
Vic&Tas	12.3	11.8	10.1	9.0	0.3	0.1	0.0
SW	11.0	10.3	6.1	5.6	1.7	0.5	0.5
NW	9.7	8.0	5.9	7.3	2.8	2.7	2.4
MDB	10.2	9.5	7.0	6.0	2.5	0.6	0.3
SW WA	10.7	6.3	2.1	2.1	2.0	0.9	0.9
Aust.	10.2	8.7	6.0	6.1	2.4	1.3	1.1

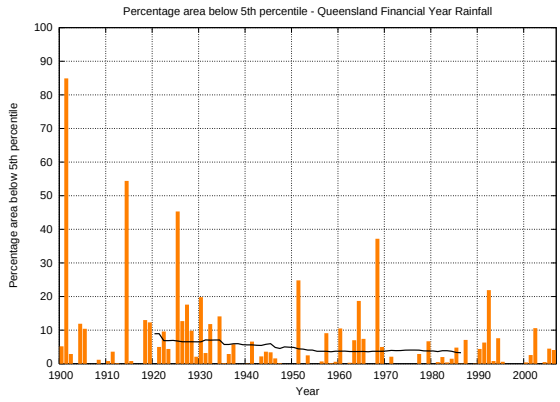
6 Graphs - Queensland region

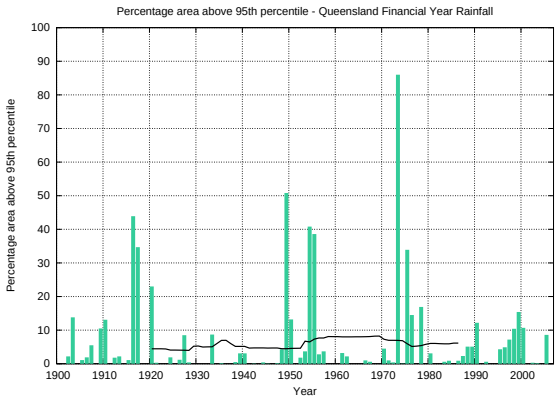
Percentage area below the 5th percentile (left) and above the 95th percentile (right) for calendar year rainfall, together with a 41-year moving average (black line).



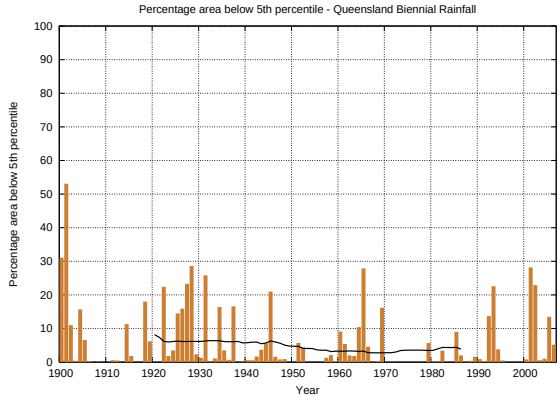


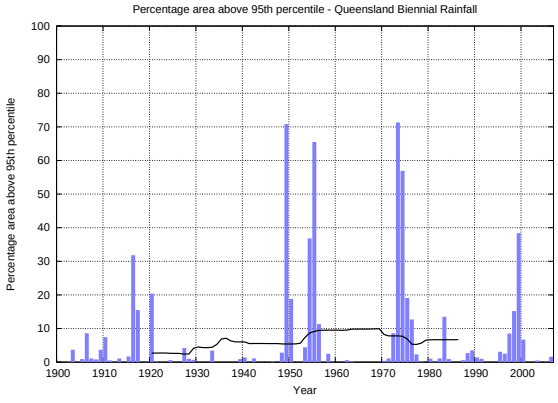
Percentage area below the 5th percentile (left) and above the 95th percentile (right) for financial year rainfall, together with a 41-year moving average (black line).



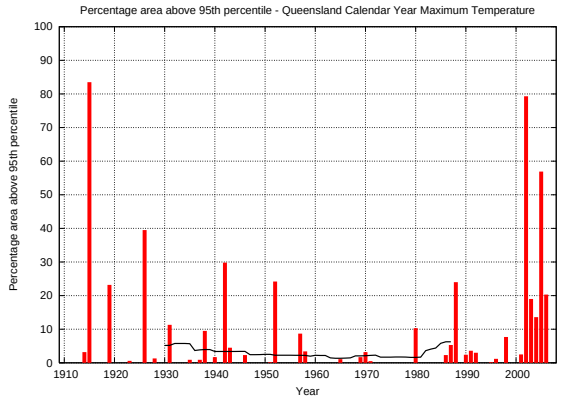


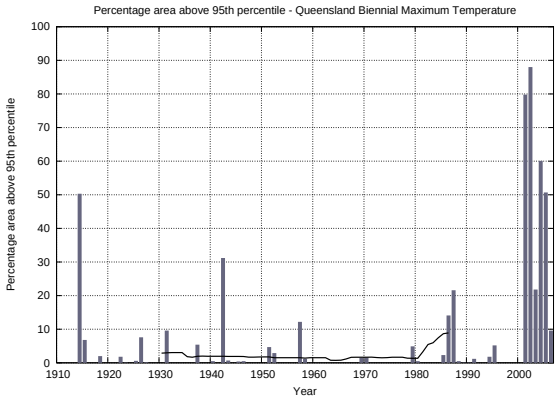
Percentage area below the 5th percentile (left) and above the 95th percentile (right) for biennial rainfall, together with a 41-year moving average (black line).



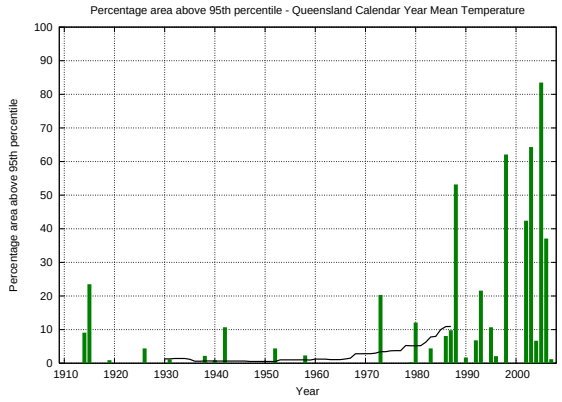


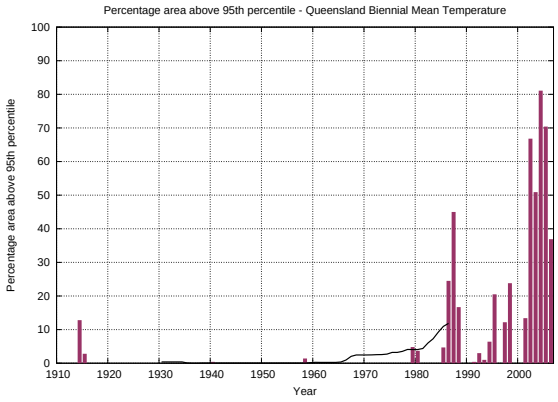
Percentage area above the 95th percentile for calendar year (left) and biennial (right) maximum temperature, together with a 41-year moving average (black line).



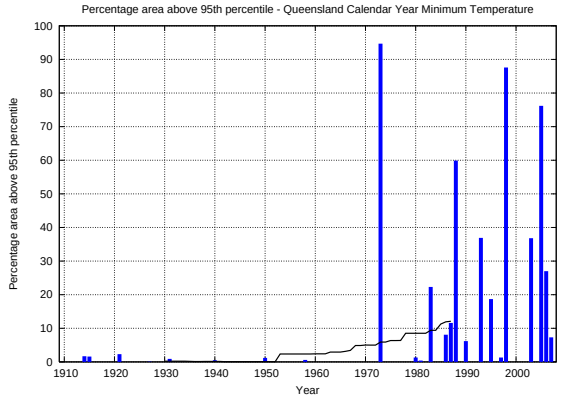


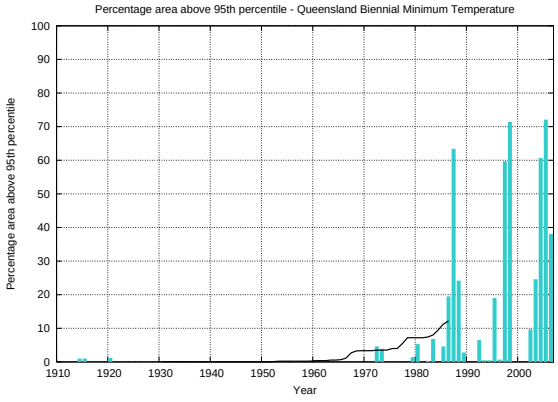
Percentage area above the 95th percentile for calendar year (left) and biennial (right) mean temperature, together with a 41-year moving average (black line).



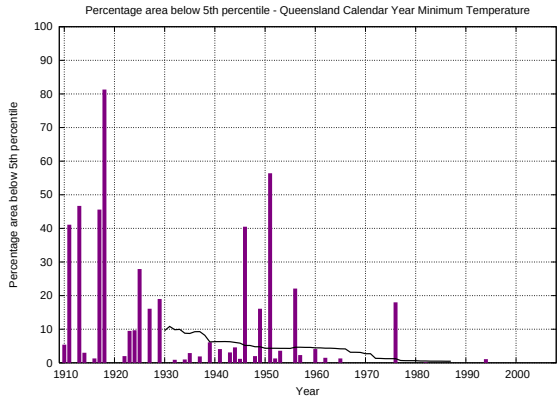


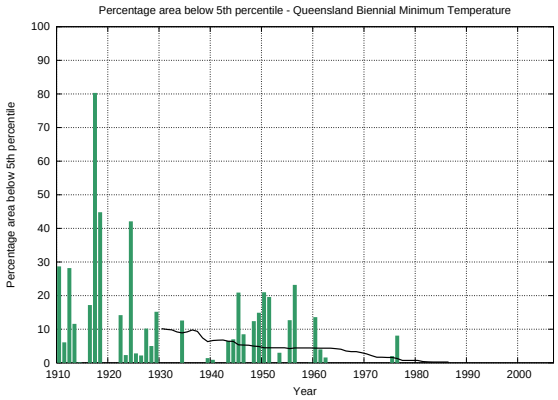
Percentage area above the 95th percentile for calendar year (left) and biennial (right) minimum temperature, together with a 41-year moving average (black line).



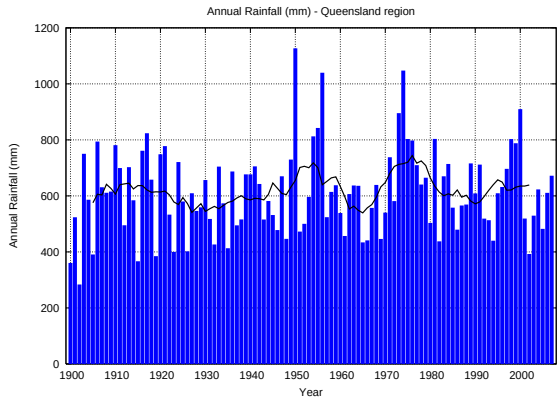


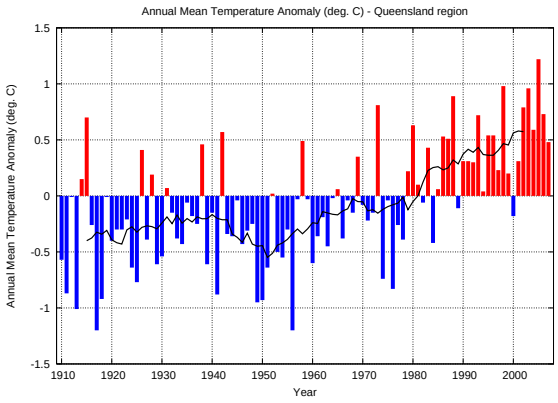
Percentage area below the 5th percentile for calendar year (left) and biennial (right) minimum temperature, together with a 41-year moving average (black line).



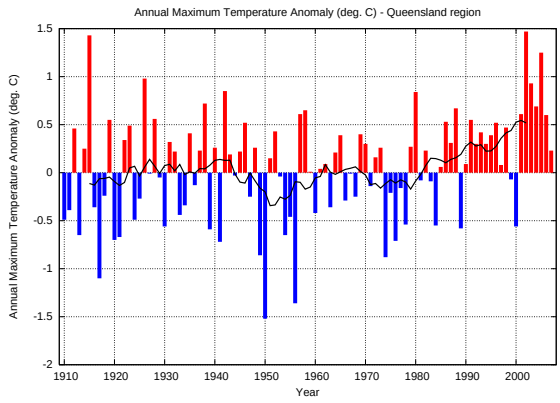


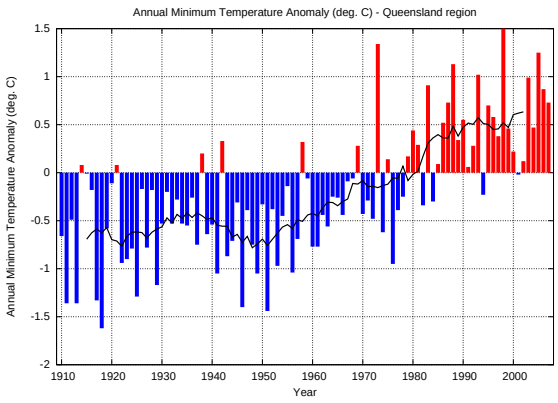
Annual rainfall totals (mm; left) and mean temperature anomalies (deg. C; right), together with an 11-year moving average (black line). The temperature anomalies are calculated with respect to the base period 1961-1990.





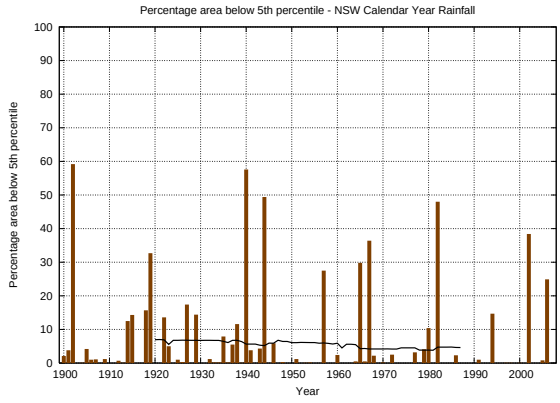
Annual maximum temperature anomalies (deg. C; left) and minimum temperature anomalies (deg. C; right), together with an 11-year moving average (black line). The temperature anomalies are calculated with respect to the base period 1961-1990.

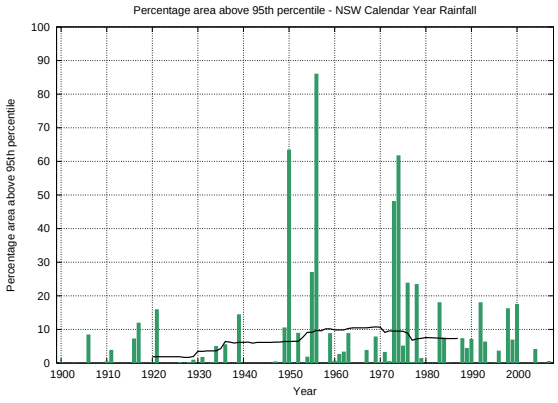




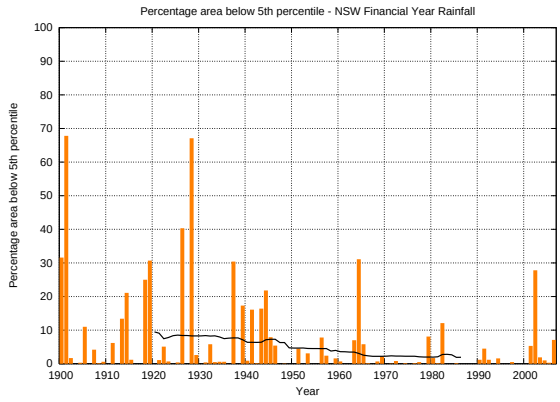
7 Graphs - New South Wales region

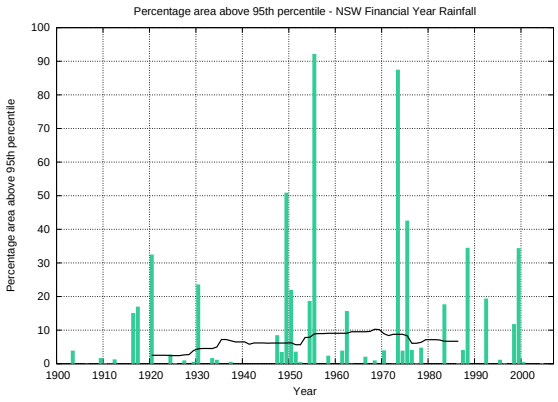
Percentage area below the 5th percentile (left) and above the 95th percentile (right) for calendar year rainfall, together with a 41-year moving average (black line).



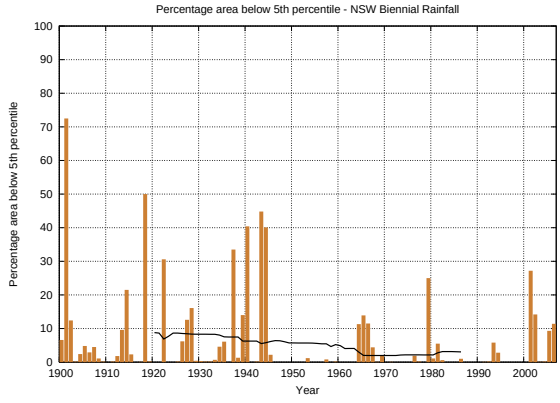


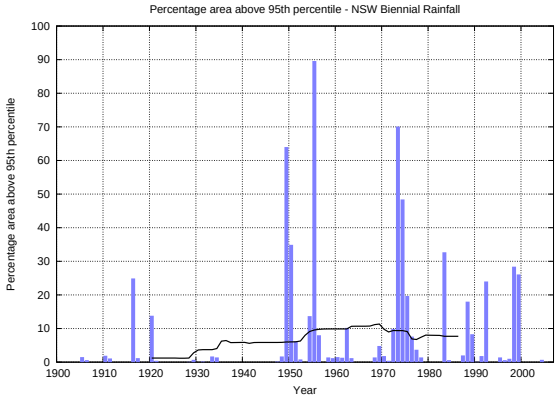
Percentage area below the 5th percentile (left) and above the 95th percentile (right) for financial year rainfall, together with a 41-year moving average (black line).



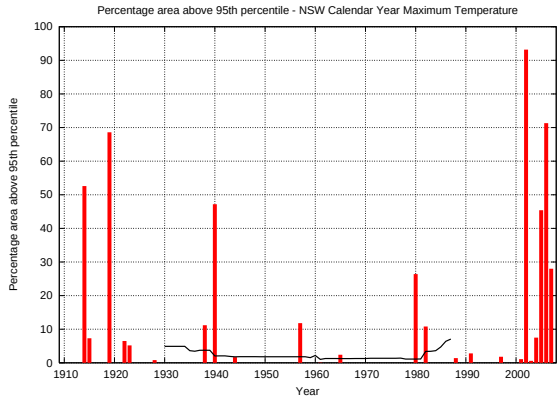


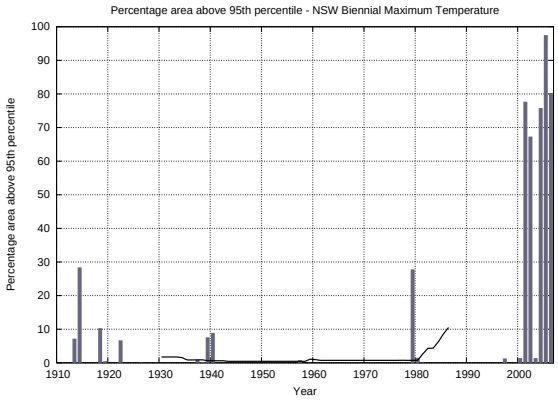
Percentage area below the 5th percentile (left) and above the 95th percentile (right) for biennial rainfall, together with a 41-year moving average (black line).



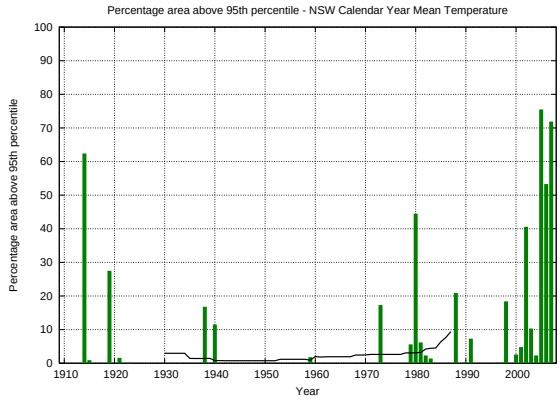


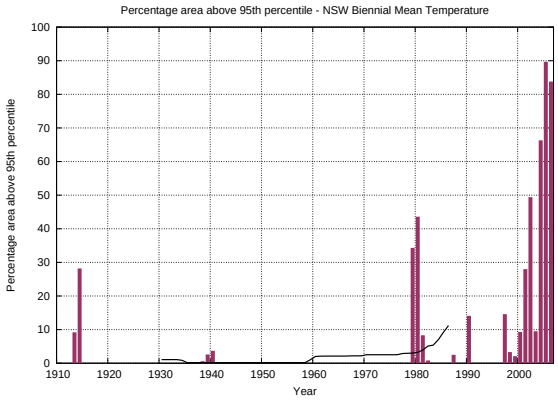
Percentage area above the 95th percentile for calendar year (left) and biennial (right) maximum temperature, together with a 41-year moving average (black line).



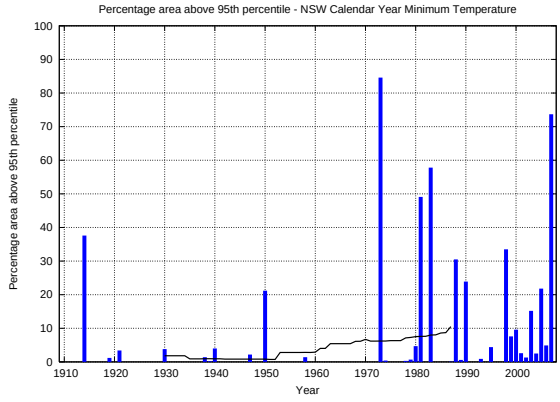


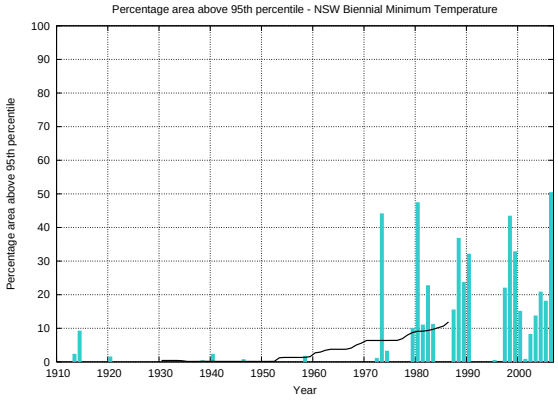
Percentage area above the 95th percentile for calendar year (left) and biennial (right) mean temperature, together with a 41-year moving average (black line).



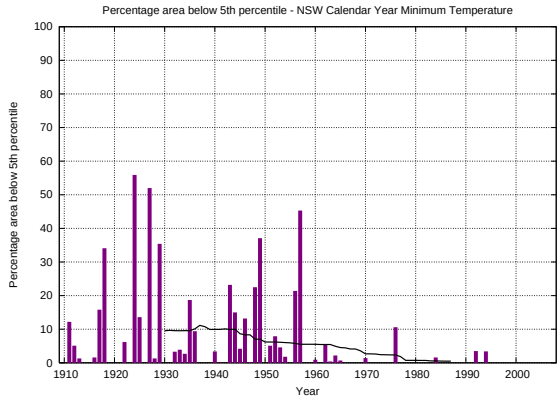


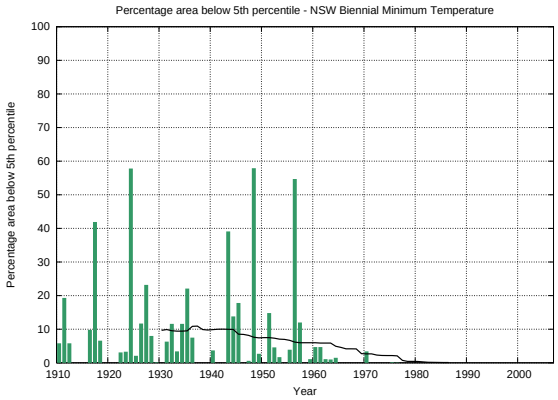
Percentage area above the 95th percentile for calendar year (left) and biennial (right) minimum temperature, together with a 41-year moving average (black line).



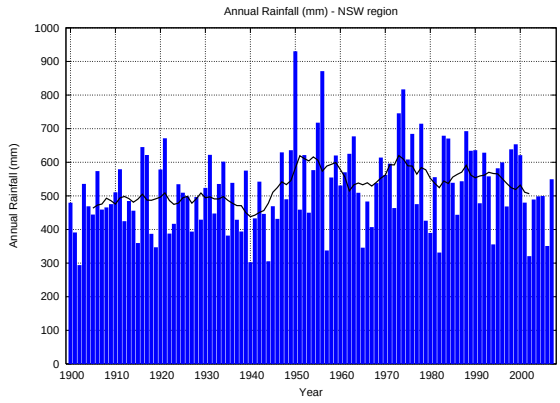


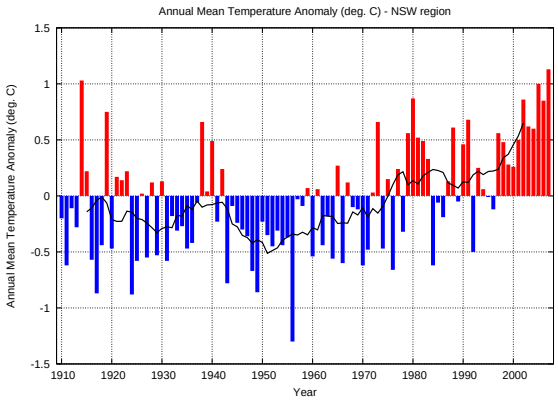
Percentage area below the 5th percentile for calendar year (left) and biennial (right) minimum temperature, together with a 41-year moving average (black line).



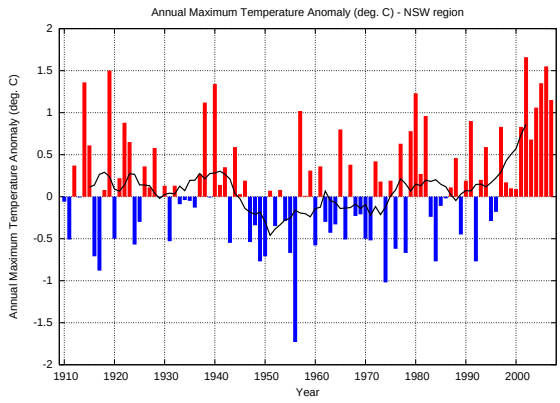


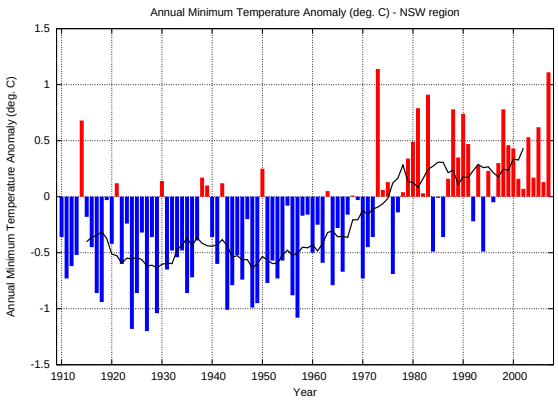
Annual rainfall totals (mm; left) and mean temperature anomalies (deg. C; right), together with an 11-year moving average (black line). The temperature anomalies are calculated with respect to the base period 1961-1990.





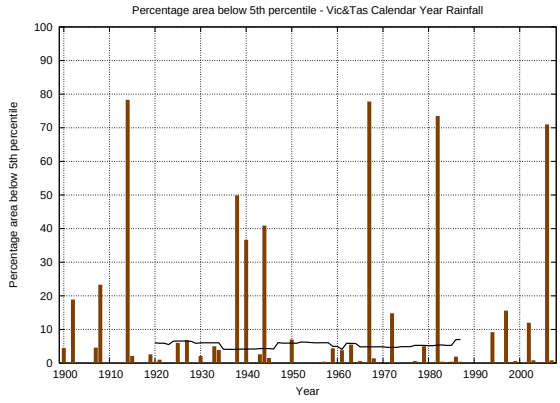
Annual maximum temperature anomalies (deg. C; left) and minimum temperature anomalies (deg. C; right), together with an 11-year moving average (black line). The temperature anomalies are calculated with respect to the base period 1961-1990.

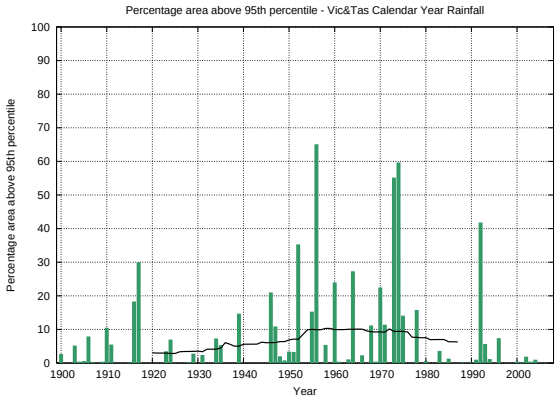




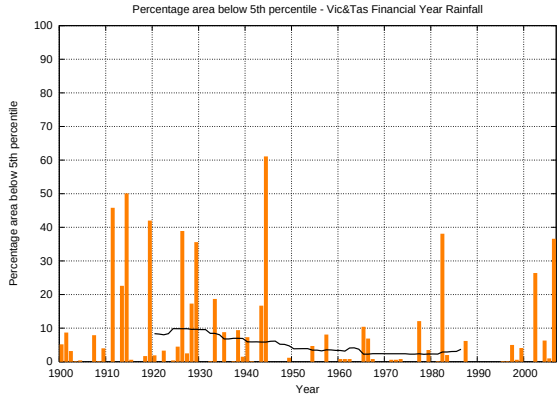
8 Graphs - Victoria & Tasmania region

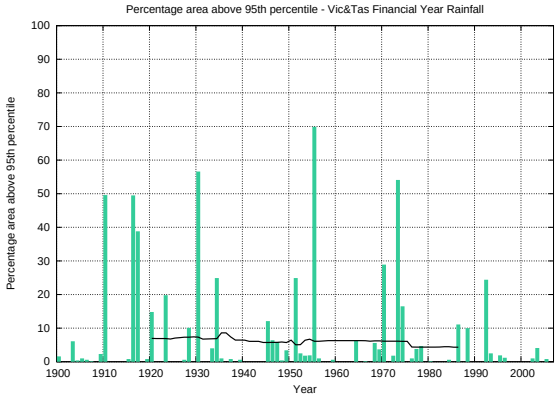
Percentage area below the 5th percentile (left) and above the 95th percentile (right) for calendar year rainfall, together with a 41-year moving average (black line).



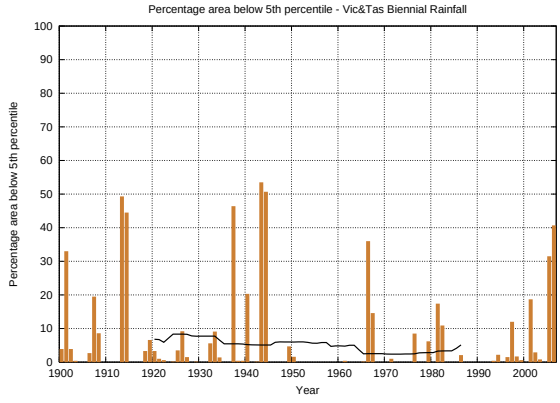


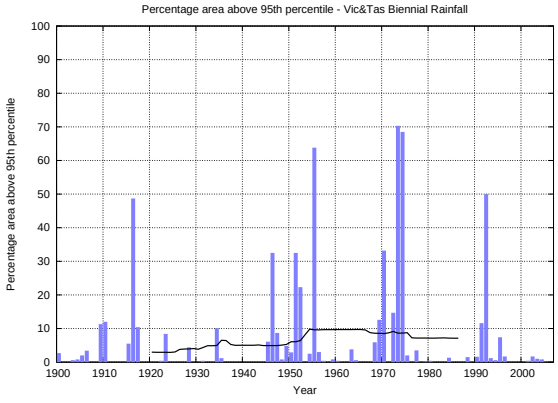
Percentage area below the 5th percentile (left) and above the 95th percentile (right) for financial year rainfall, together with a 41-year moving average (black line).



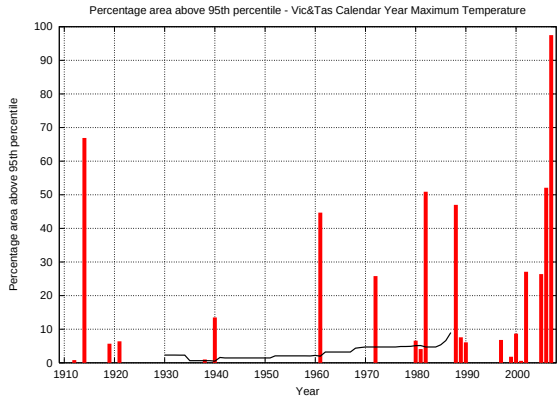


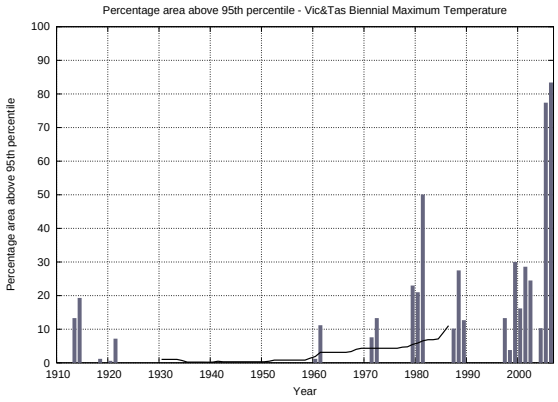
Percentage area below the 5th percentile (left) and above the 95th percentile (right) for biennial rainfall, together with a 41-year moving average (black line).



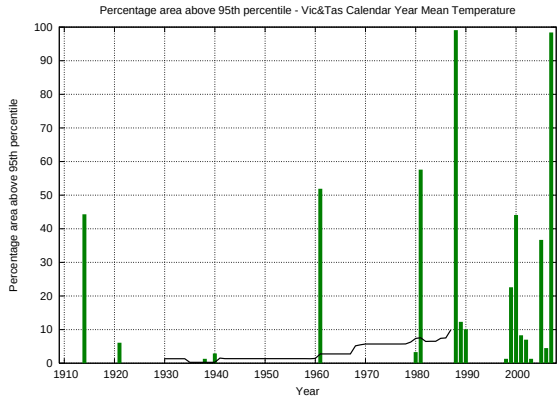


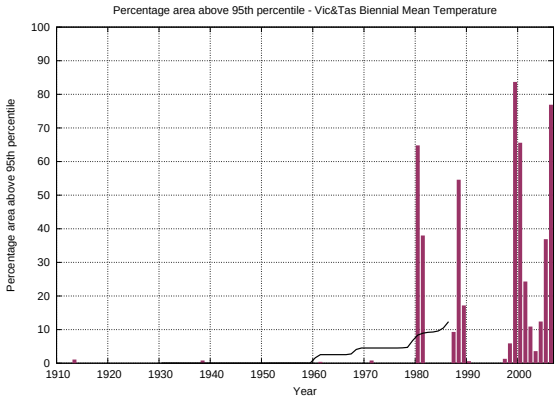
Percentage area above the 95th percentile for calendar year (left) and biennial (right) maximum temperature, together with a 41-year moving average (black line).



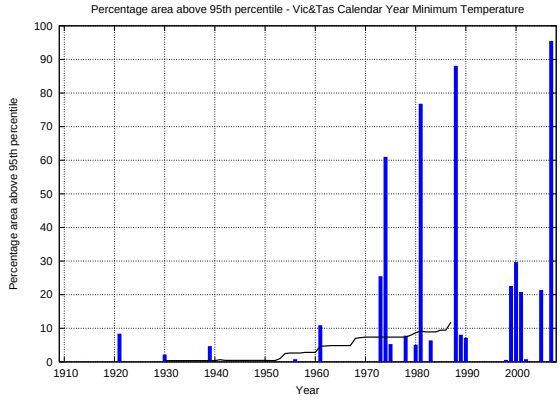


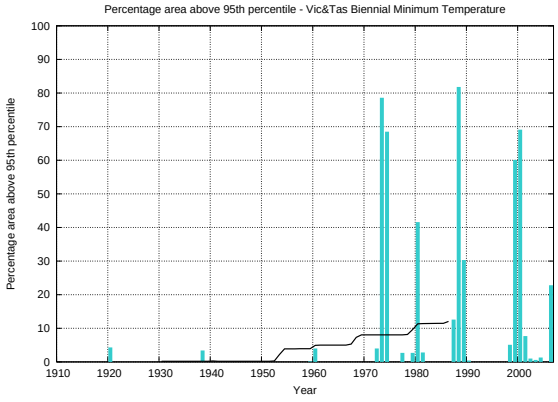
Percentage area above the 95th percentile for calendar year (left) and biennial (right) mean temperature, together with a 41-year moving average (black line).



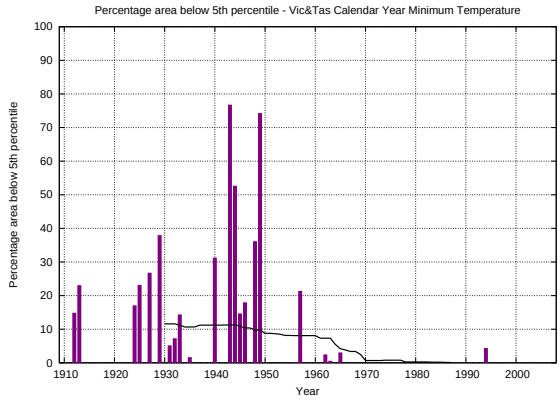


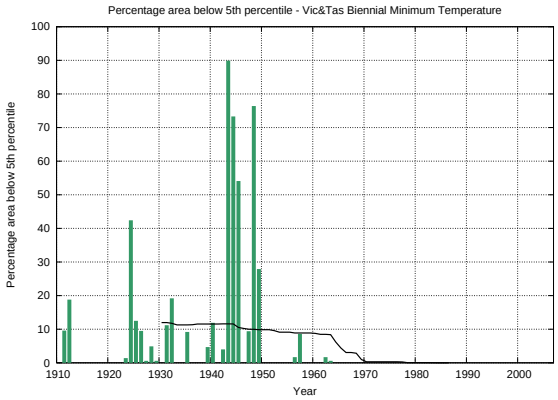
Percentage area above the 95th percentile for calendar year (left) and biennial (right) minimum temperature, together with a 41-year moving average (black line).



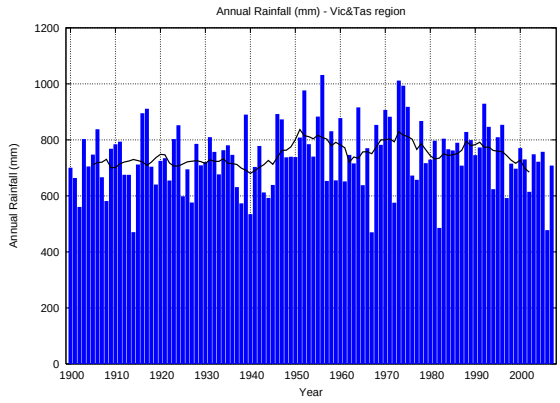


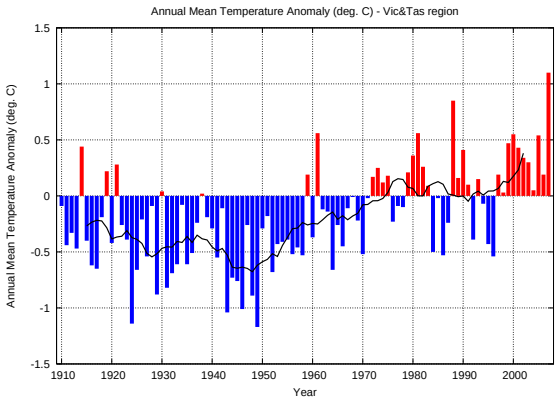
Percentage area below the 5th percentile for calendar year (left) and biennial (right) minimum temperature, together with a 41-year moving average (black line).



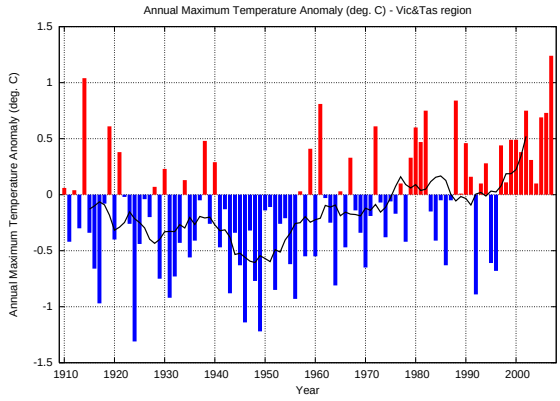


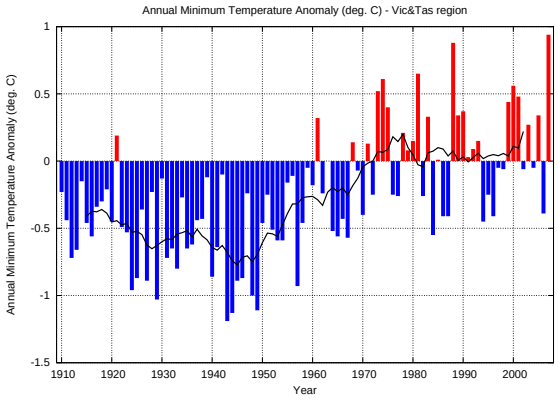
Annual rainfall totals (mm; left) and mean temperature anomalies (deg. C; right), together with an 11-year moving average (black line). The temperature anomalies are calculated with respect to the base period 1961-1990.





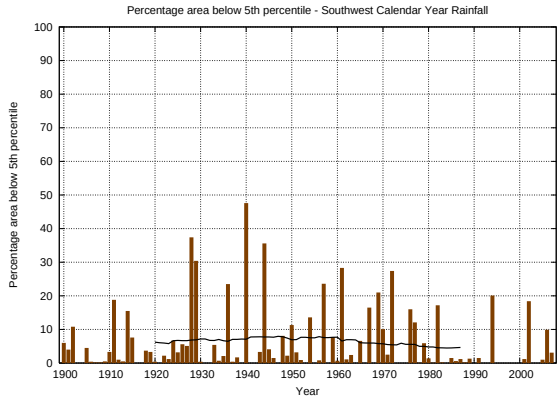
Annual maximum temperature anomalies (deg. C; left) and minimum temperature anomalies (deg. C; right), together with an 11-year moving average (black line). The temperature anomalies are calculated with respect to the base period 1961-1990.

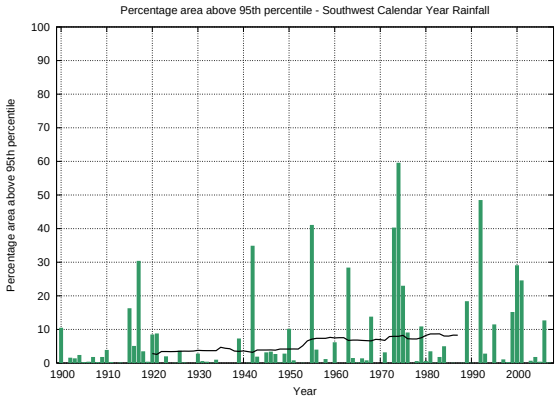




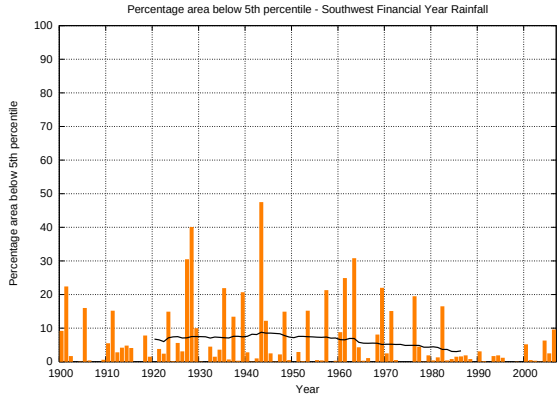
9 Graphs - Southwest region

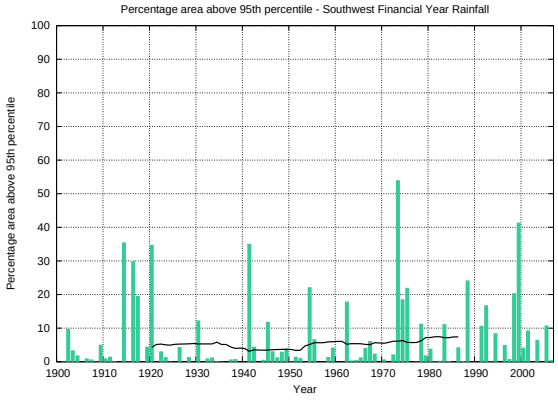
Percentage area below the 5th percentile (left) and above the 95th percentile (right) for calendar year rainfall, together with a 41-year moving average (black line).



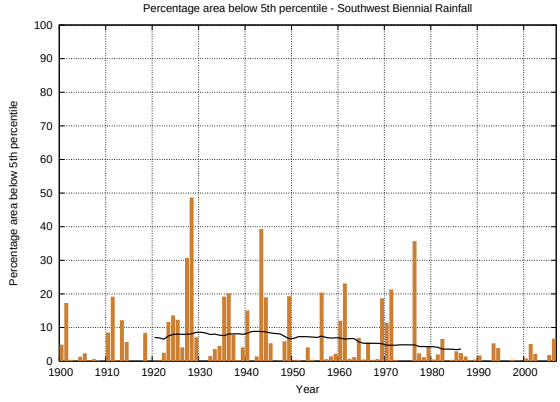


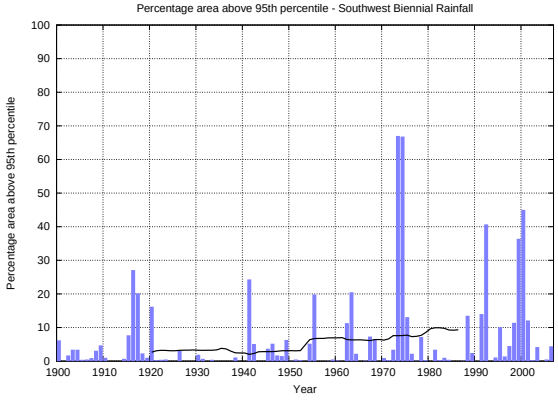
Percentage area below the 5th percentile (left) and above the 95th percentile (right) for financial year rainfall, together with a 41-year moving average (black line).



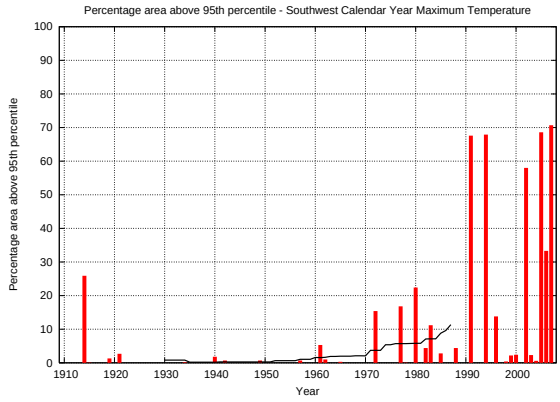


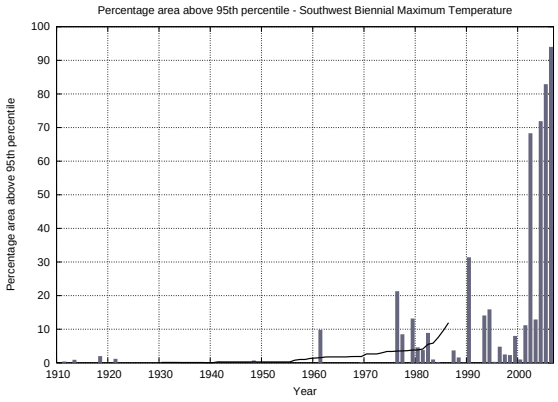
Percentage area below the 5th percentile (left) and above the 95th percentile (right) for biennial rainfall, together with a 41-year moving average (black line).



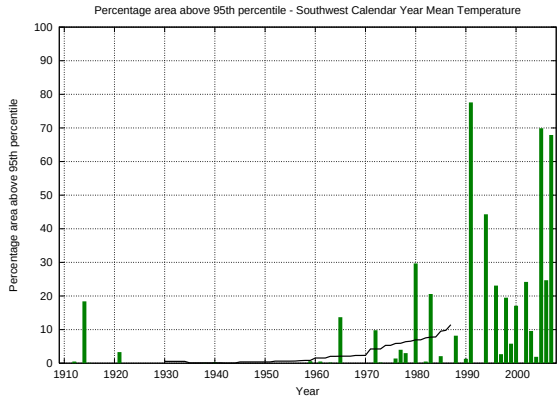


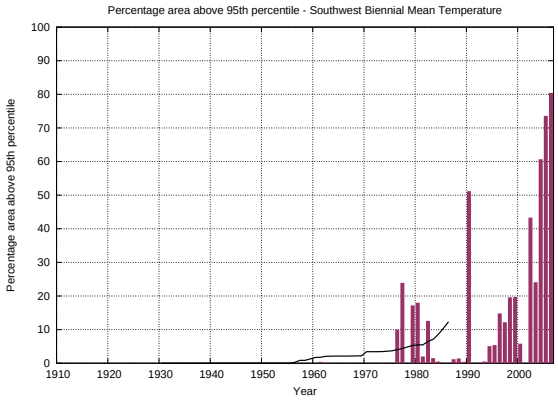
Percentage area above the 95th percentile for calendar year (left) and biennial (right) maximum temperature, together with a 41-year moving average (black line).



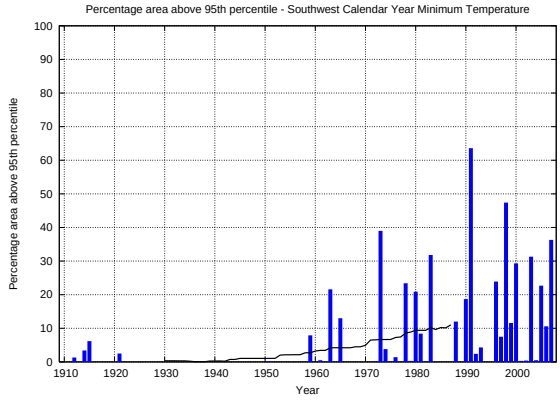


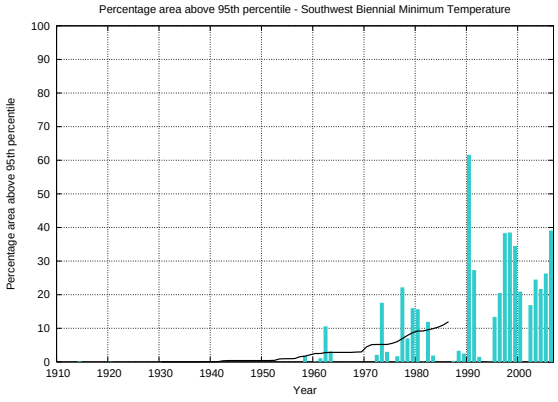
Percentage area above the 95th percentile for calendar year (left) and biennial (right) mean temperature, together with a 41-year moving average (black line).



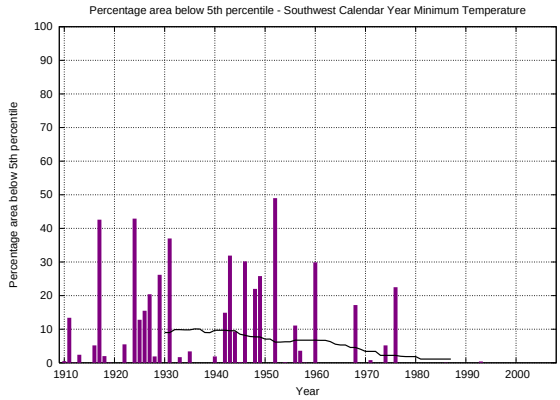


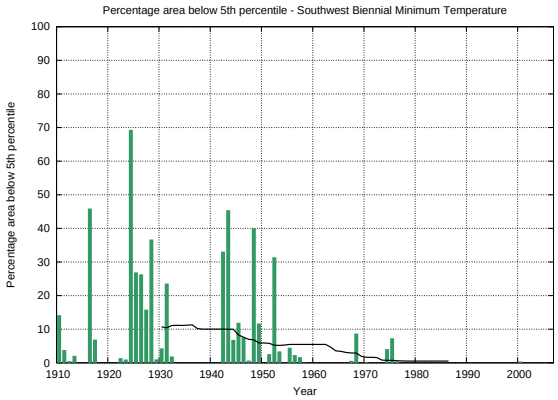
Percentage area above the 95th percentile for calendar year (left) and biennial (right) minimum temperature, together with a 41-year moving average (black line).



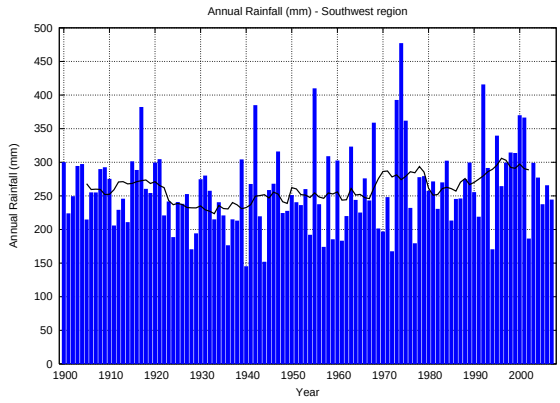


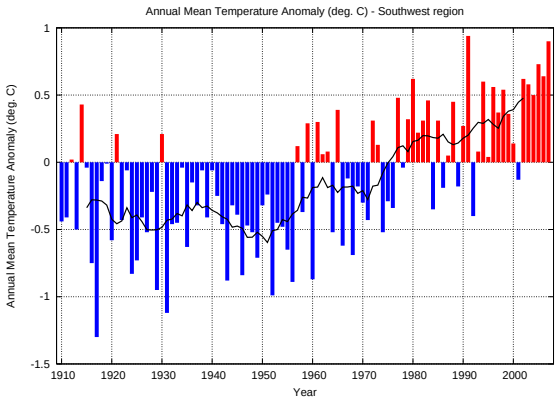
Percentage area below the 5th percentile for calendar year (left) and biennial (right) minimum temperature, together with a 41-year moving average (black line).



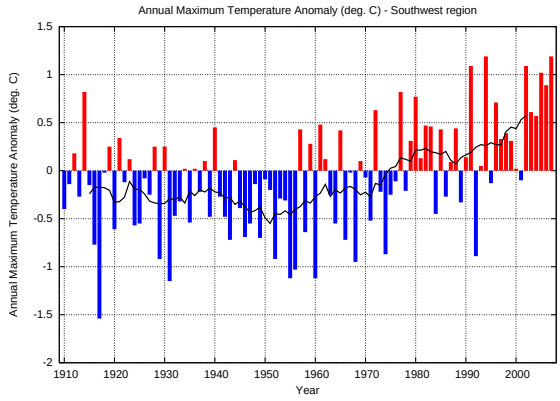


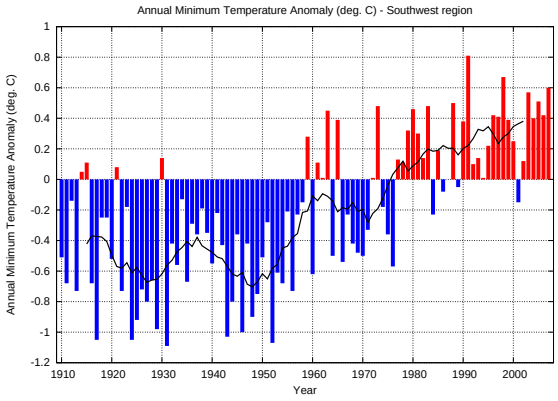
Annual rainfall totals (mm; left) and mean temperature anomalies (deg. C; right), together with an 11-year moving average (black line). The temperature anomalies are calculated with respect to the base period 1961-1990.





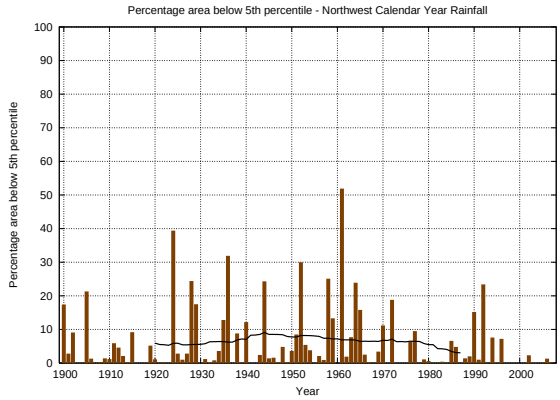
Annual maximum temperature anomalies (deg. C; left) and minimum temperature anomalies (deg. C; right), together with an 11-year moving average (black line). The temperature anomalies are calculated with respect to the base period 1961-1990.

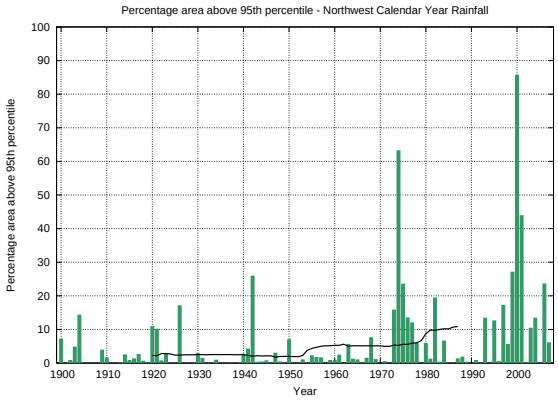




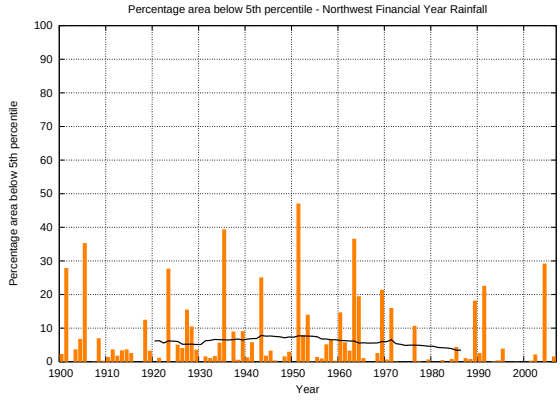
10 Graphs - Northwest region

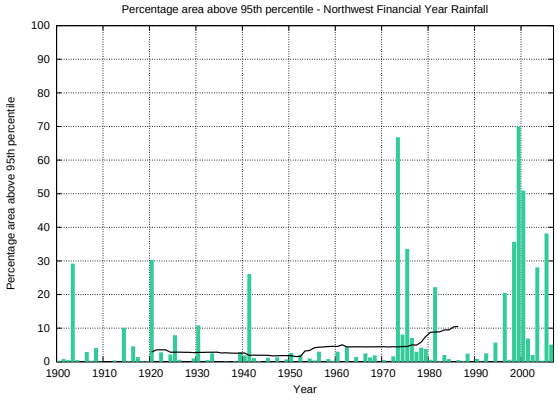
Percentage area below the 5th percentile (left) and above the 95th percentile (right) for calendar year rainfall, together with a 41-year moving average (black line).



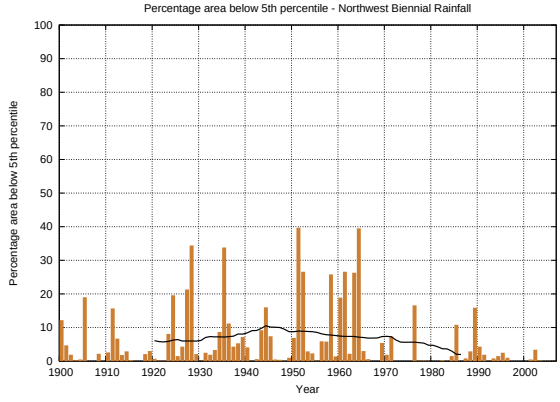


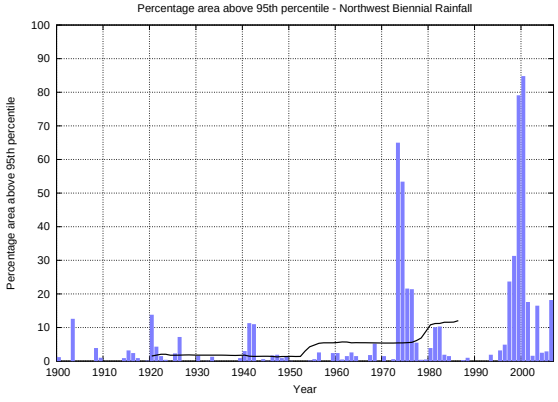
Percentage area below the 5th percentile (left) and above the 95th percentile (right) for financial year rainfall, together with a 41-year moving average (black line).



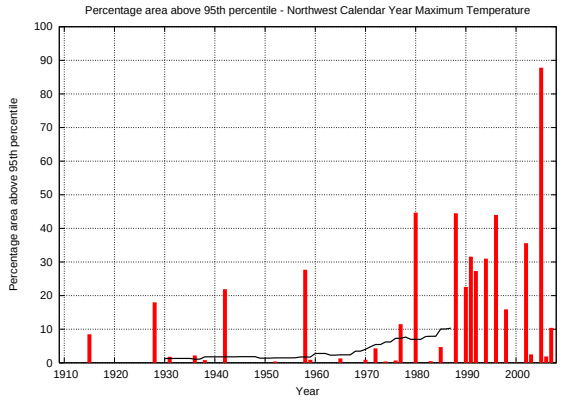


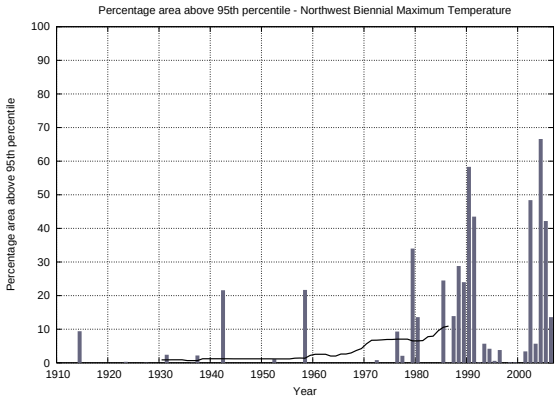
Percentage area below the 5th percentile (left) and above the 95th percentile (right) for biennial rainfall, together with a 41-year moving average (black line).



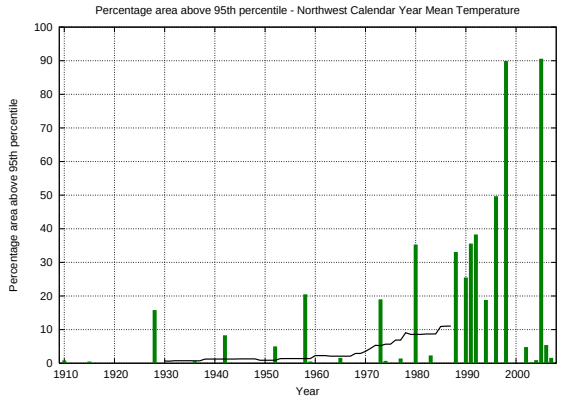


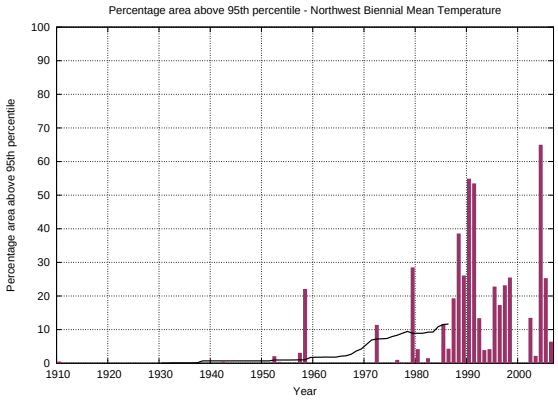
Percentage area above the 95th percentile for calendar year (left) and biennial (right) maximum temperature, together with a 41-year moving average (black line).



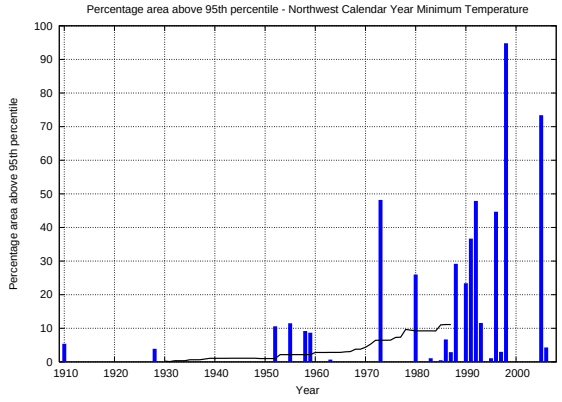


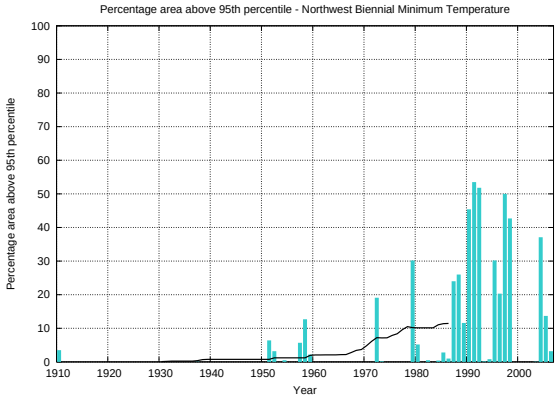
Percentage area above the 95th percentile for calendar year (left) and biennial (right) mean temperature, together with a 41-year moving average (black line).



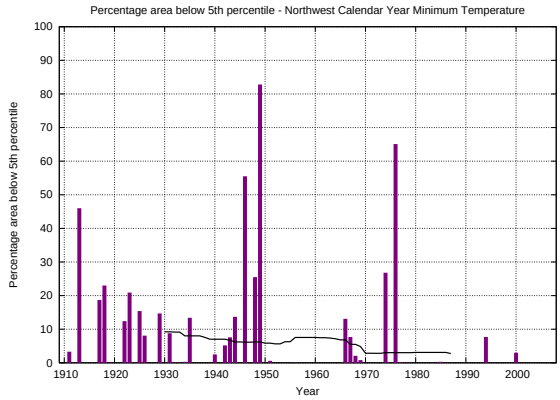


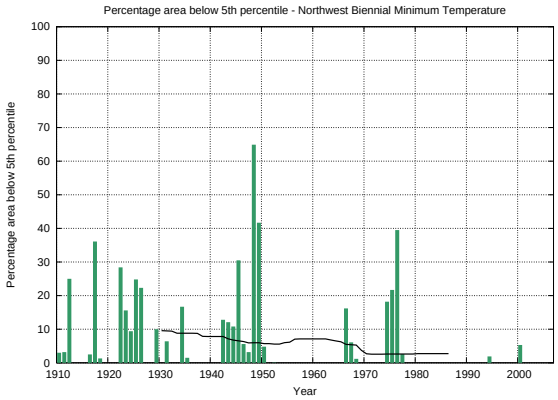
Percentage area above the 95th percentile for calendar year (left) and biennial (right) minimum temperature, together with a 41-year moving average (black line).



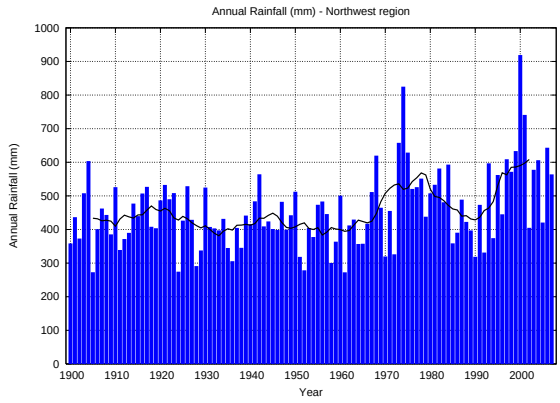


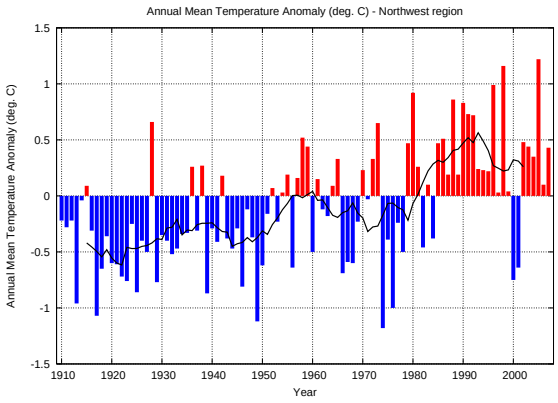
Percentage area below the 5th percentile for calendar year (left) and biennial (right) minimum temperature, together with a 41-year moving average (black line).



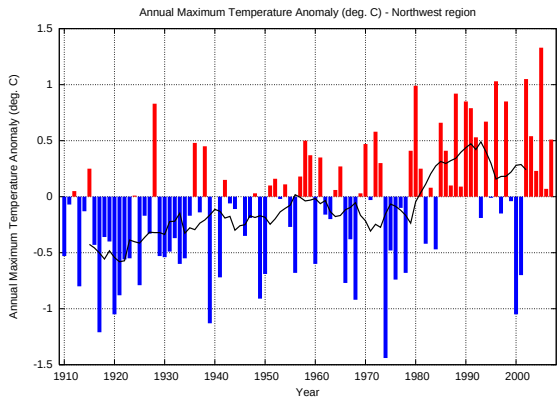


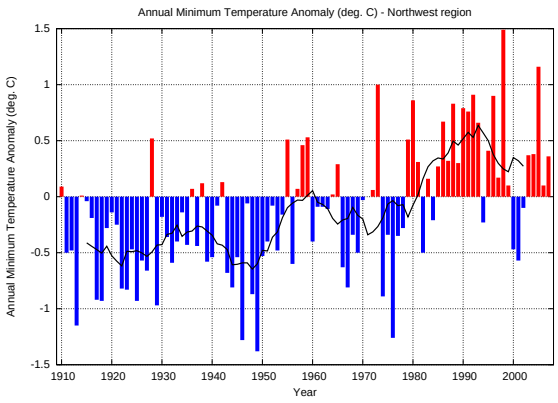
Annual rainfall totals (mm; left) and mean temperature anomalies (deg. C; right), together with an 11-year moving average (black line). The temperature anomalies are calculated with respect to the base period 1961-1990.





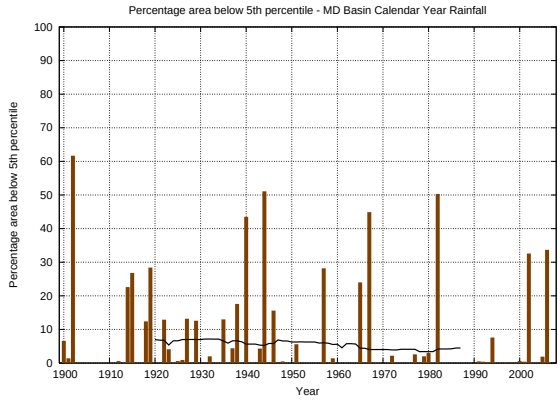
Annual maximum temperature anomalies (deg. C; left) and minimum temperature anomalies (deg. C; right), together with an 11-year moving average (black line). The temperature anomalies are calculated with respect to the base period 1961-1990.

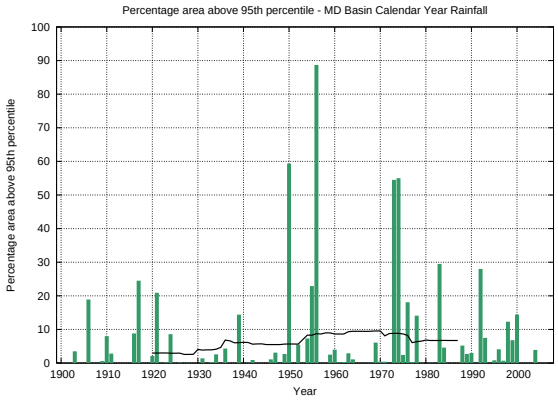




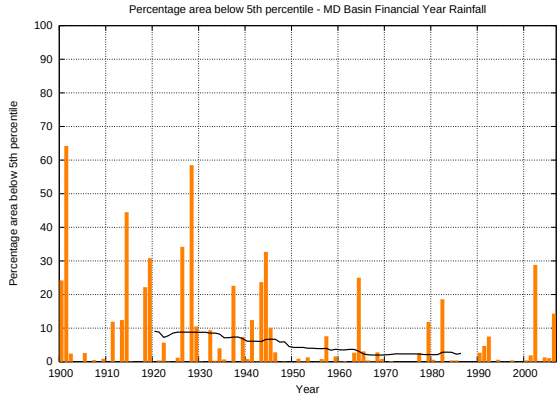
11 Graphs - Murray-Darling Basin region

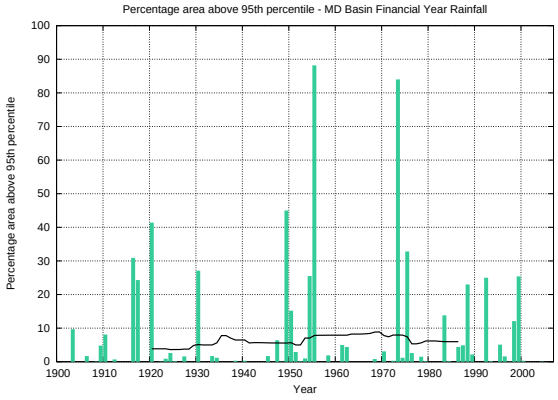
Percentage area below the 5th percentile (left) and above the 95th percentile (right) for calendar year rainfall, together with a 41-year moving average (black line).



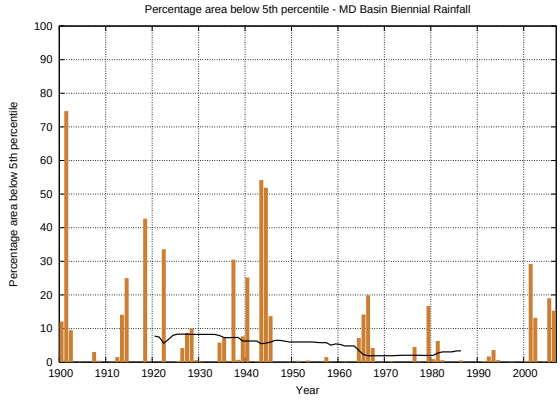


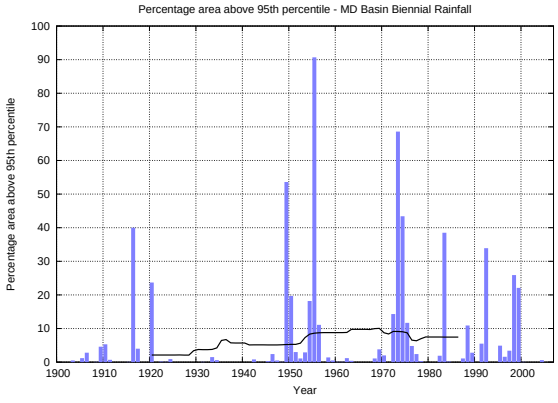
Percentage area below the 5th percentile (left) and above the 95th percentile (right) for financial year rainfall, together with a 41-year moving average (black line).



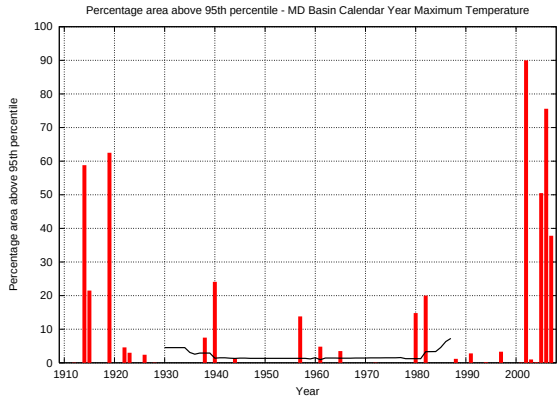


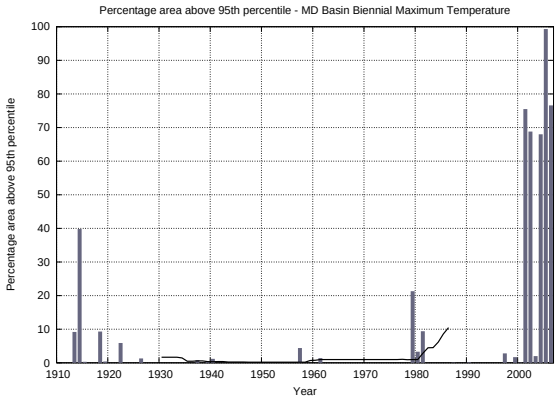
Percentage area below the 5th percentile (left) and above the 95th percentile (right) for biennial rainfall, together with a 41-year moving average (black line).



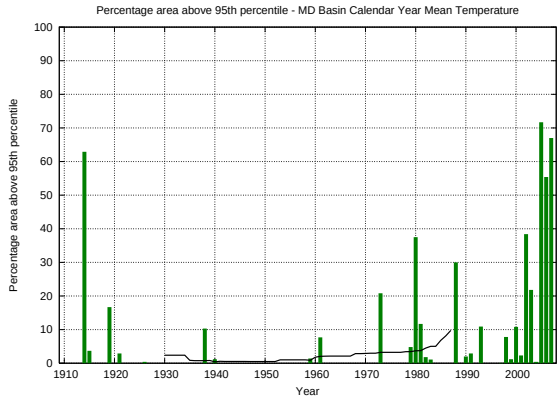


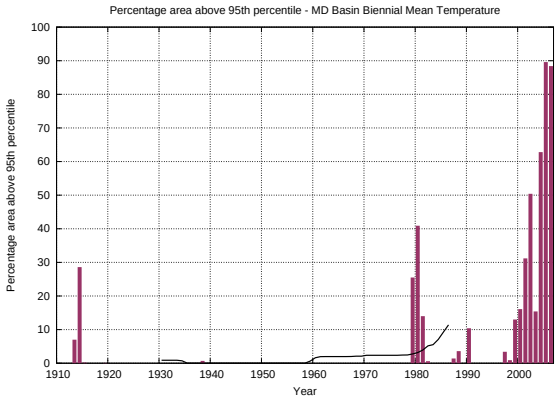
Percentage area above the 95th percentile for calendar year (left) and biennial (right) maximum temperature, together with a 41-year moving average (black line).



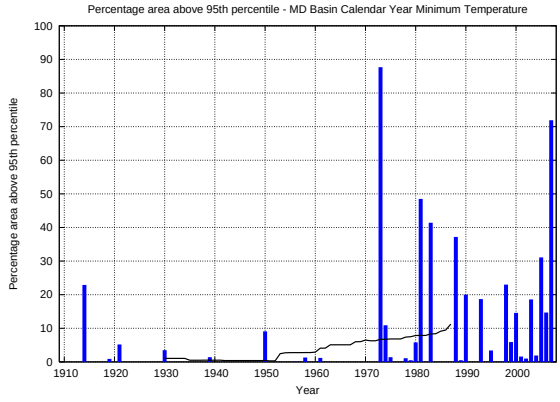


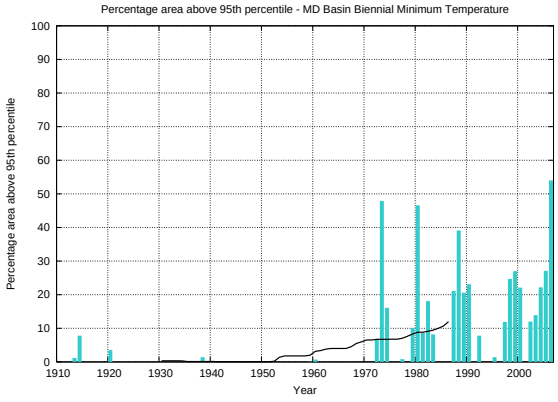
Percentage area above the 95th percentile for calendar year (left) and biennial (right) mean temperature, together with a 41-year moving average (black line).



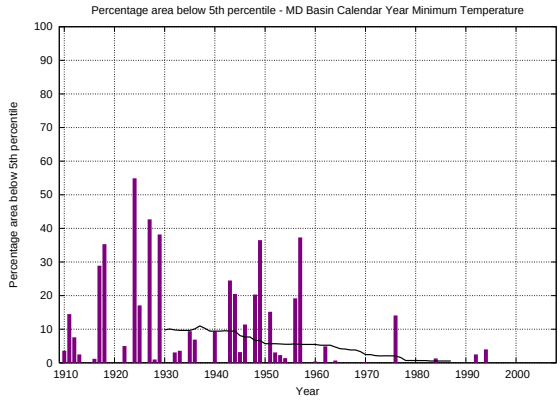


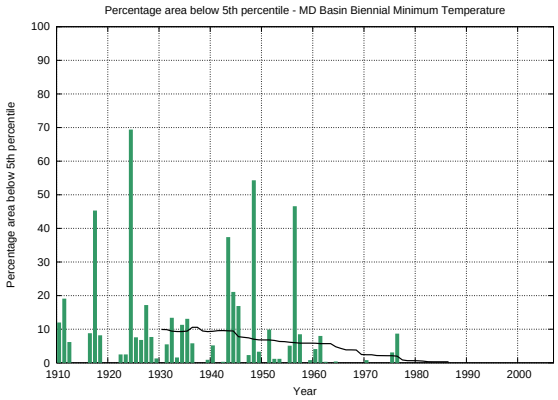
Percentage area above the 95th percentile for calendar year (left) and biennial (right) minimum temperature, together with a 41-year moving average (black line).



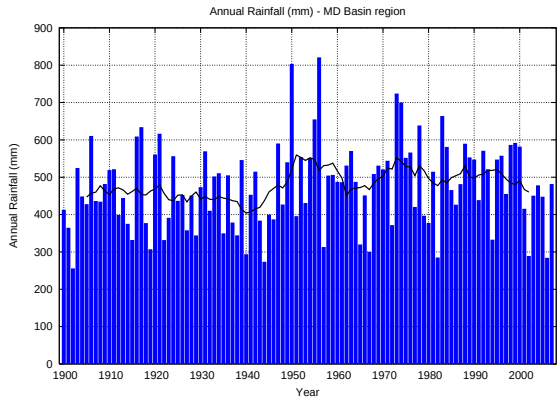


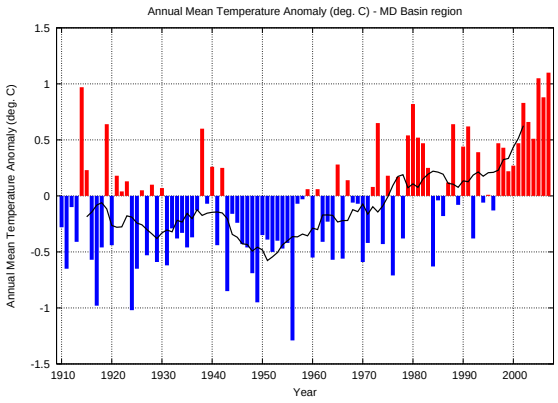
Percentage area below the 5th percentile for calendar year (left) and biennial (right) minimum temperature, together with a 41-year moving average (black line).



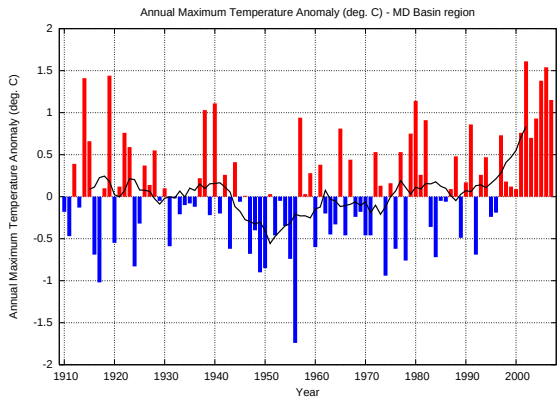


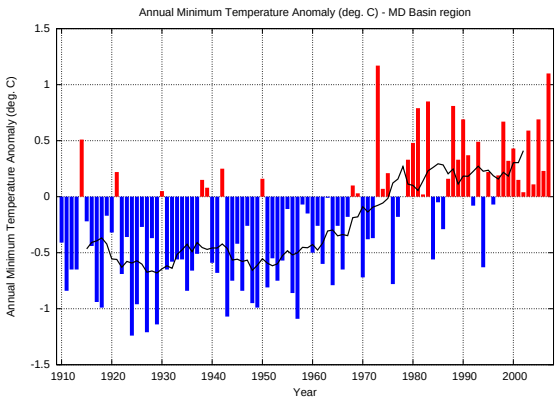
Annual rainfall totals (mm; left) and mean temperature anomalies (deg. C; right), together with an 11-year moving average (black line). The temperature anomalies are calculated with respect to the base period 1961-1990.





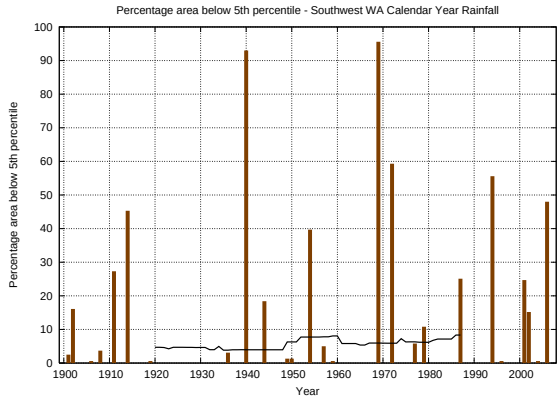
Annual maximum temperature anomalies (deg. C; left) and minimum temperature anomalies (deg. C; right), together with an 11-year moving average (black line). The temperature anomalies are calculated with respect to the base period 1961-1990.

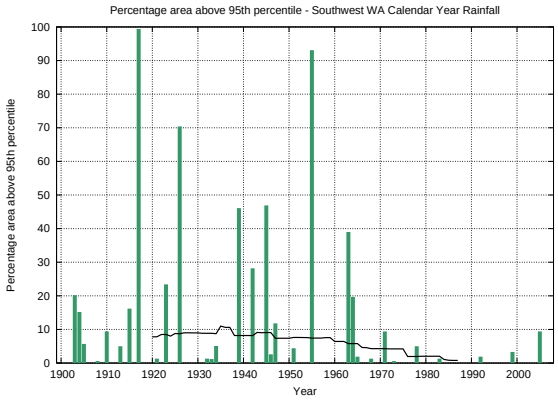




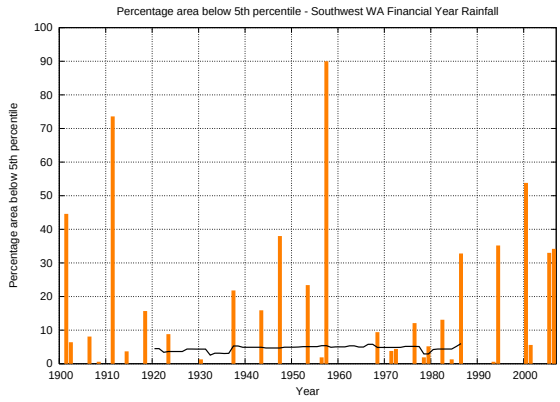
12 Graphs - Southwest Western Australia region

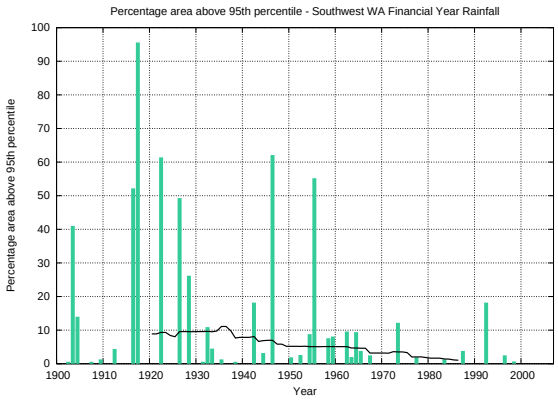
Percentage area below the 5th percentile (left) and above the 95th percentile (right) for calendar year rainfall, together with a 41-year moving average (black line).



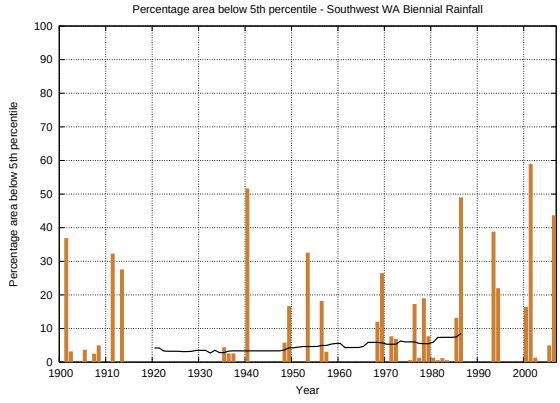


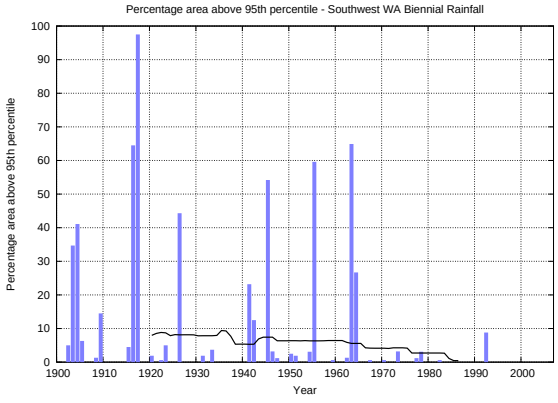
Percentage area below the 5th percentile (left) and above the 95th percentile (right) for financial year rainfall, together with a 41-year moving average (black line).



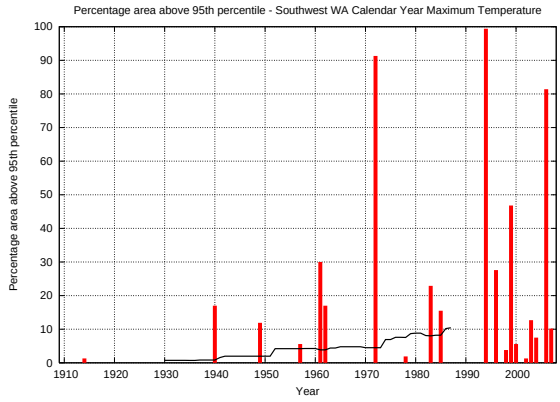


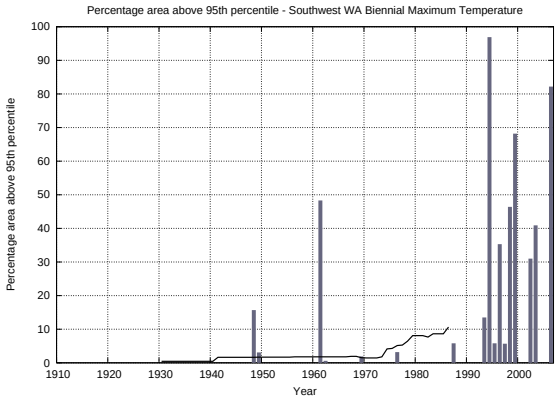
Percentage area below the 5th percentile (left) and above the 95th percentile (right) for biennial rainfall, together with a 41-year moving average (black line).



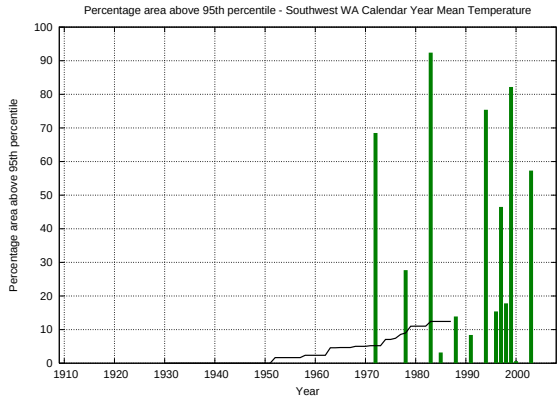


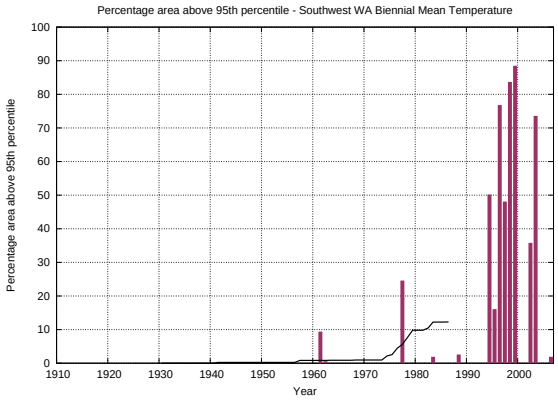
Percentage area above the 95th percentile for calendar year (left) and biennial (right) maximum temperature, together with a 41-year moving average (black line).



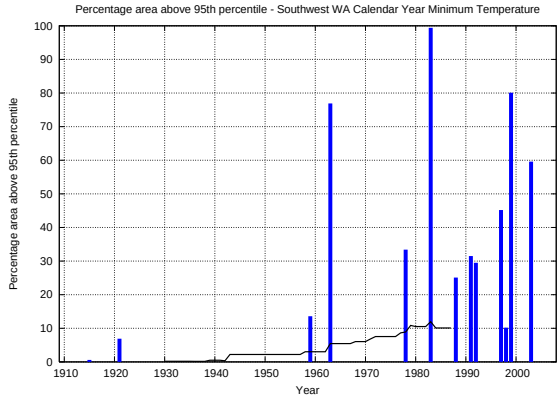


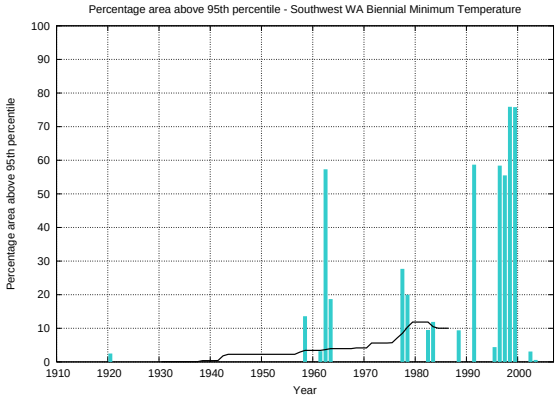
Percentage area above the 95th percentile for calendar year (left) and biennial (right) mean temperature, together with a 41-year moving average (black line).



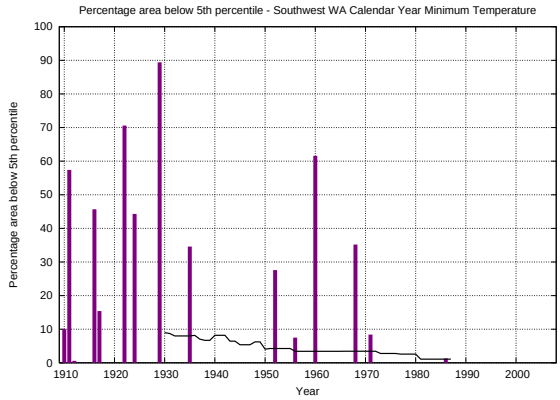


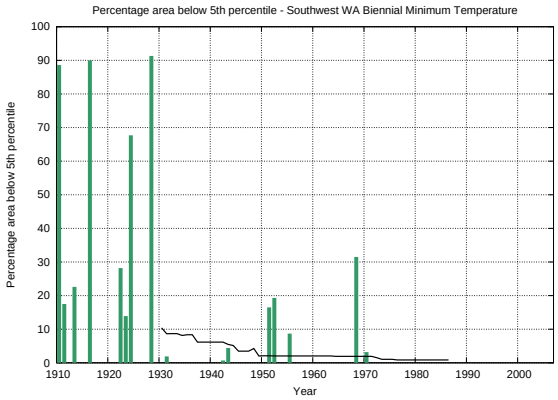
Percentage area above the 95th percentile for calendar year (left) and biennial (right) minimum temperature, together with a 41-year moving average (black line).



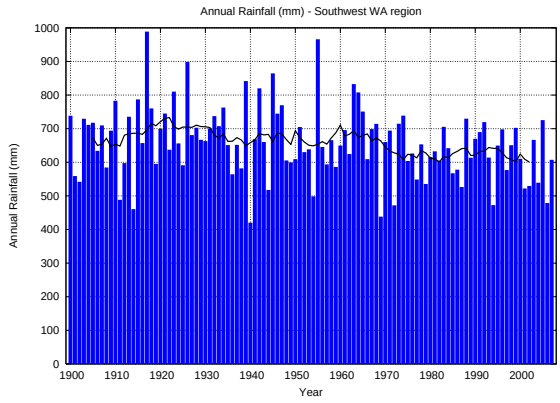


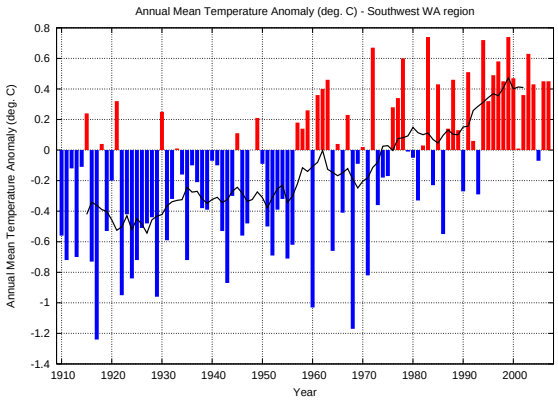
Percentage area below the 5th percentile for calendar year (left) and biennial (right) minimum temperature, together with a 41-year moving average (black line).



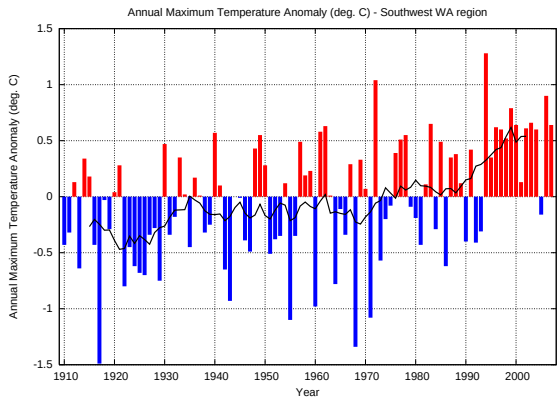


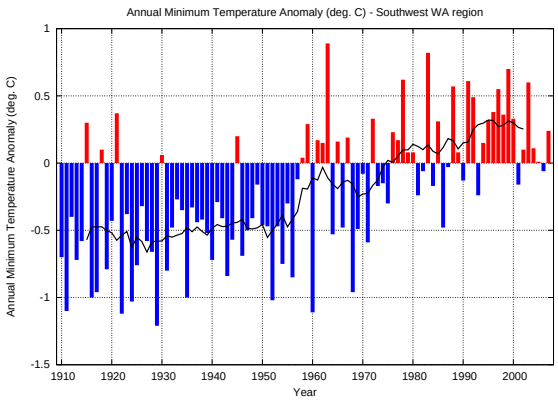
Annual rainfall totals (mm; left) and mean temperature anomalies (deg. C; right), together with an 11-year moving average (black line). The temperature anomalies are calculated with respect to the base period 1961-1990.





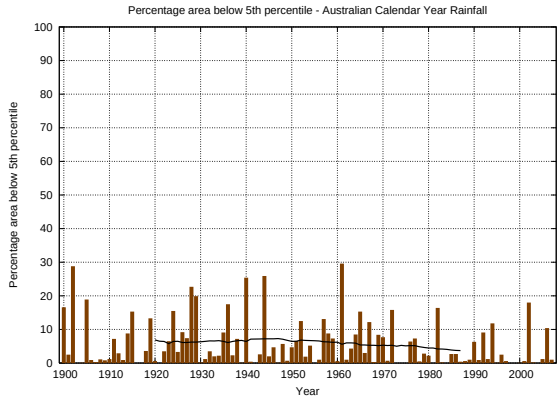
Annual maximum temperature anomalies (deg. C; left) and minimum temperature anomalies (deg. C; right), together with an 11-year moving average (black line). The temperature anomalies are calculated with respect to the base period 1961-1990.

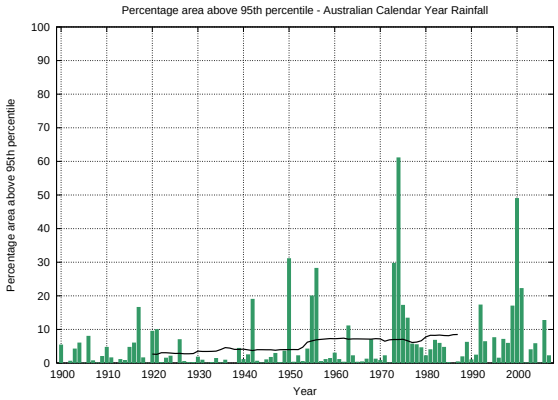




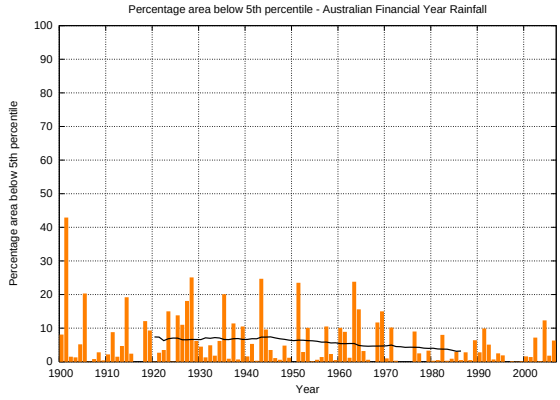
13 Graphs - Australian region

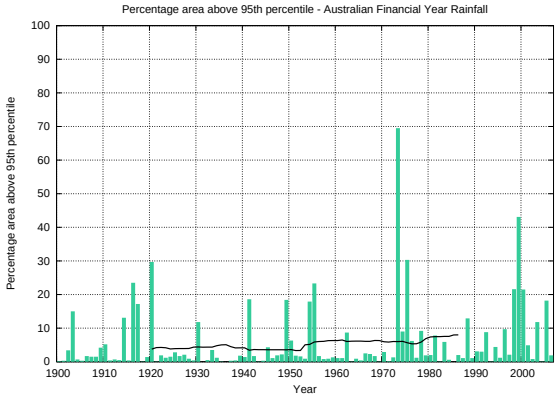
Percentage area below the 5th percentile (left) and above the 95th percentile (right) for calendar year rainfall, together with a 41-year moving average (black line).



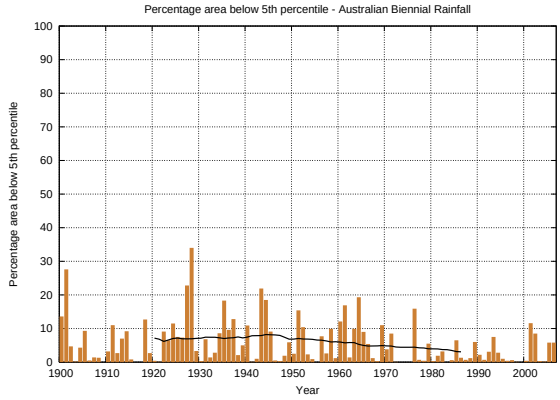


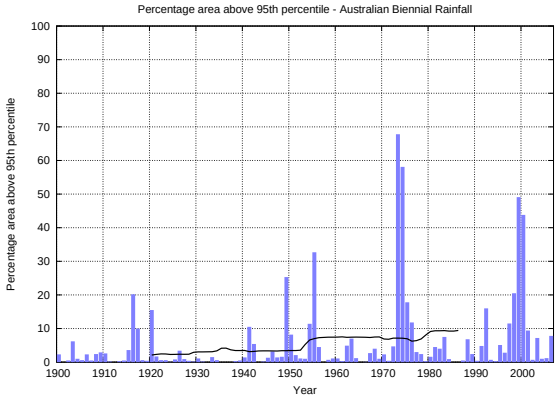
Percentage area below the 5th percentile (left) and above the 95th percentile (right) for financial year rainfall, together with a 41-year moving average (black line).



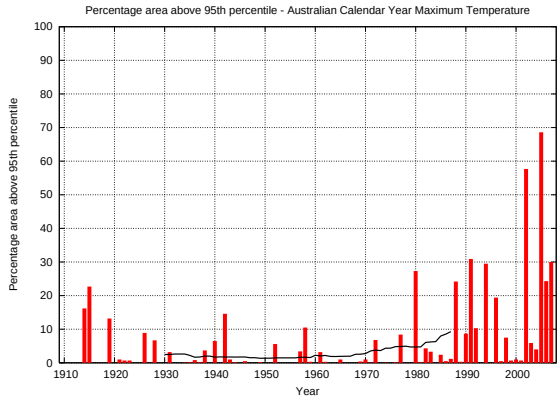


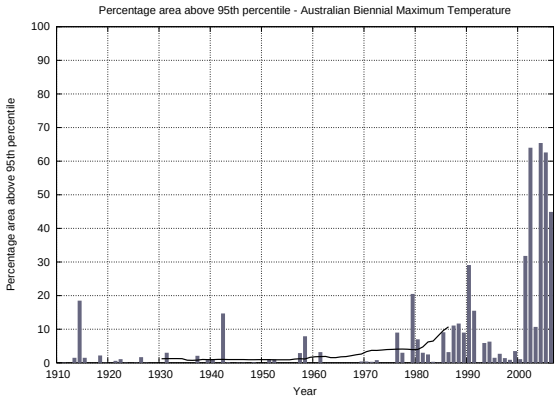
Percentage area below the 5th percentile (left) and above the 95th percentile (right) for biennial rainfall, together with a 41-year moving average (black line).



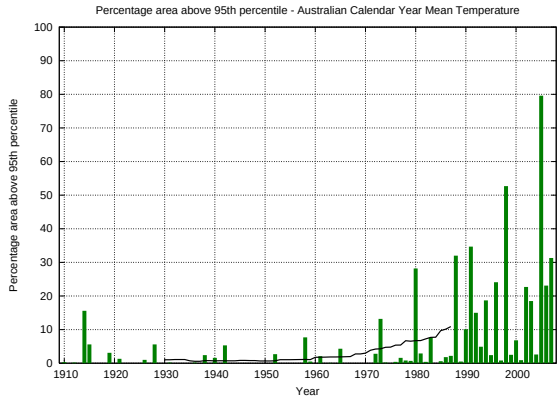


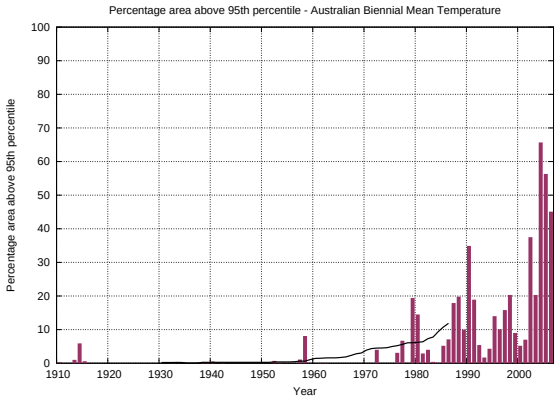
Percentage area above the 95th percentile for calendar year (left) and biennial (right) maximum temperature, together with a 41-year moving average (black line).



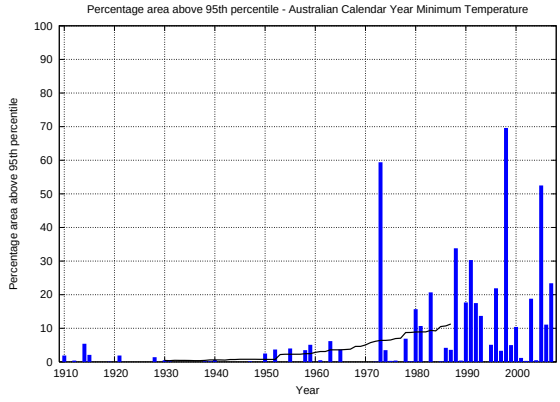


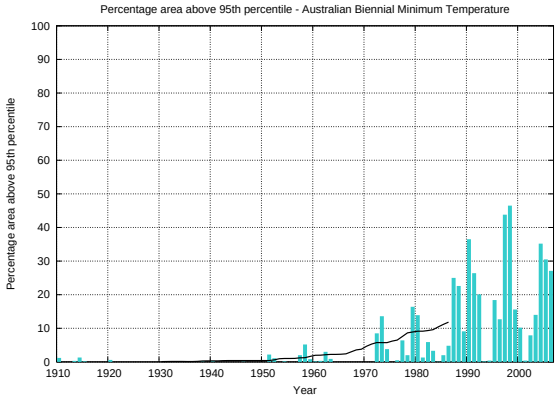
Percentage area above the 95th percentile for calendar year (left) and biennial (right) mean temperature, together with a 41-year moving average (black line).



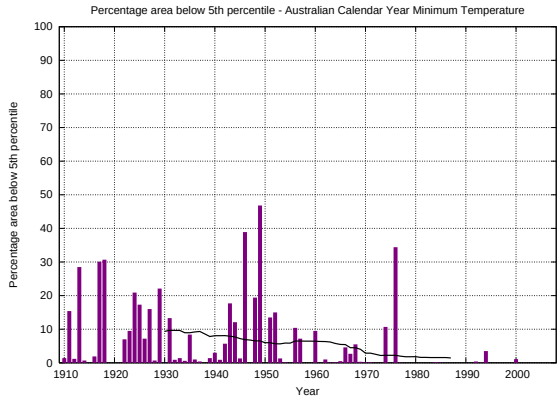


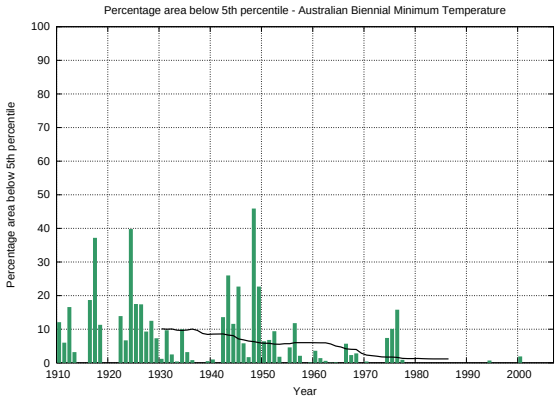
Percentage area above the 95th percentile for calendar year (left) and biennial (right) minimum temperature, together with a 41-year moving average (black line).



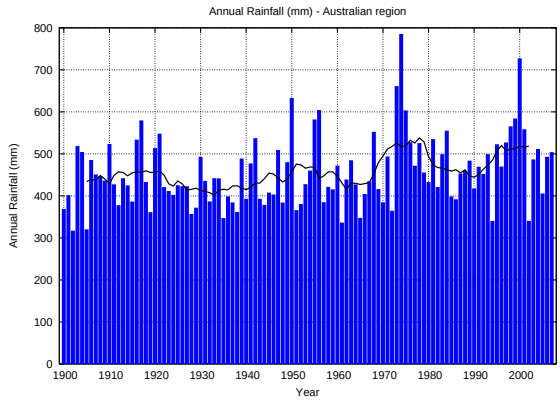


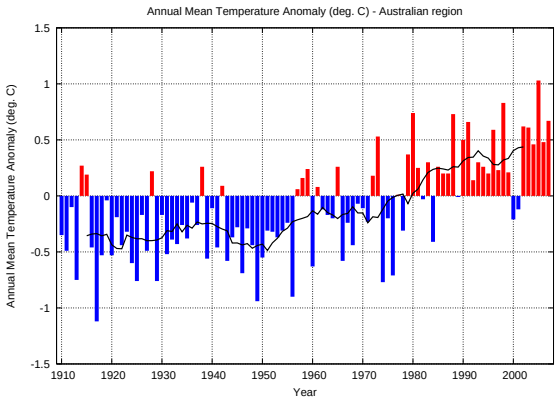
Percentage area below the 5th percentile for calendar year (left) and biennial (right) minimum temperature, together with a 41-year moving average (black line).



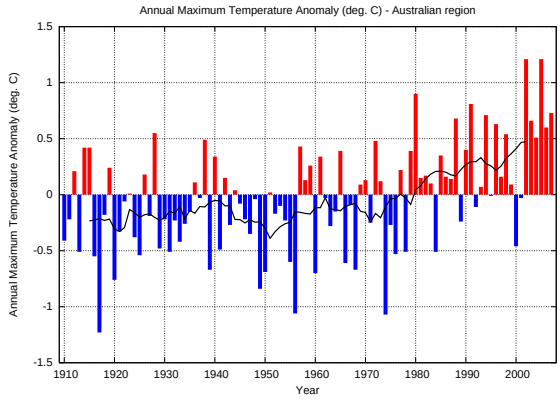


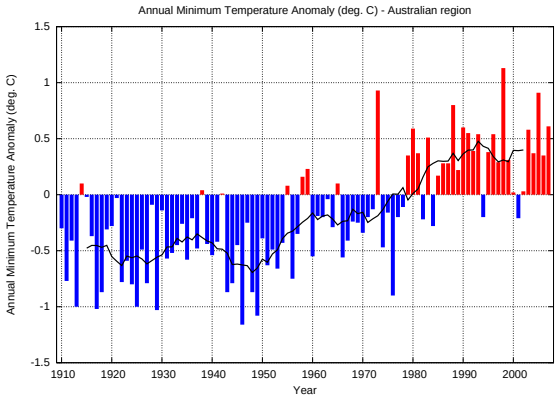
Annual rainfall totals (mm; left) and mean temperature anomalies (deg. C; right), together with an 11-year moving average (black line). The temperature anomalies are calculated with respect to the base period 1961-1990.





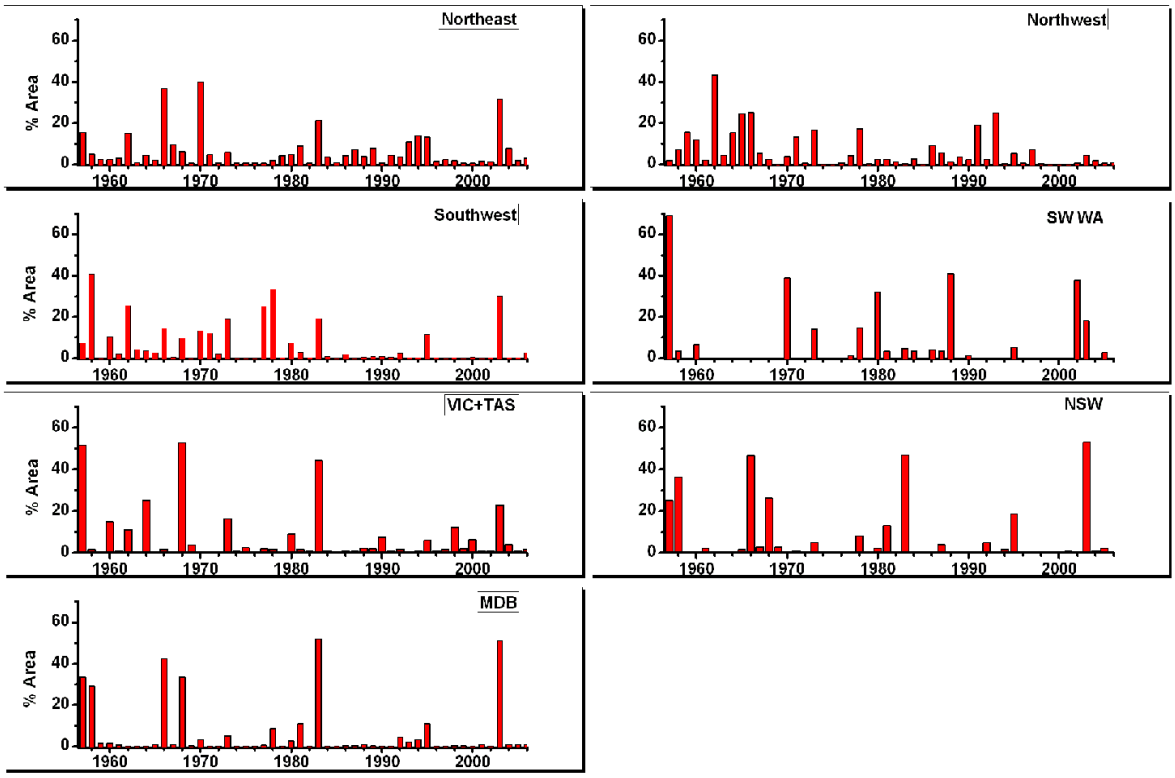
Annual maximum temperature anomalies (deg. C; left) and minimum temperature anomalies (deg. C; right), together with an 11-year moving average (black line). The temperature anomalies are calculated with respect to the base period 1961-1990.





14 Graphs - Soil Moisture

Percentage area below the 5th percentile for calendar year soil moisture. "Northeast" denotes the Queensland Region.



15 Statistical estimates of the frequency of future exceptionally low rainfall

The sensitivity of changes in exceptionally low rainfall to reductions in projected mean rainfall can be explored with a simple statistical method. Area-averaged annual rainfall (1900-2007) for the seven study regions[3] can be statistically modelled, with rainfall for some future year modelled in a similar way under the assumption of a drier climate. The probability of future exceptionally low rainfall (relative to the historical record) is shown in Figure 3 (see also Table 1) as a function of the percentage reduction in mean annual rainfall.

A 5 to 10% reduction in mean annual rainfall is a possible scenario by 2030 over much of Australia. A 10% decrease roughly doubles the risk of exceptionally low rainfall in five of the study regions, and almost triples the risk for the Vic&Tas regions. A 20% mean rainfall decrease triples the risk of exceptionally low rainfall in the same five regions and increases by more than six-fold the risk for the Vic&Tas and SW WA regions.

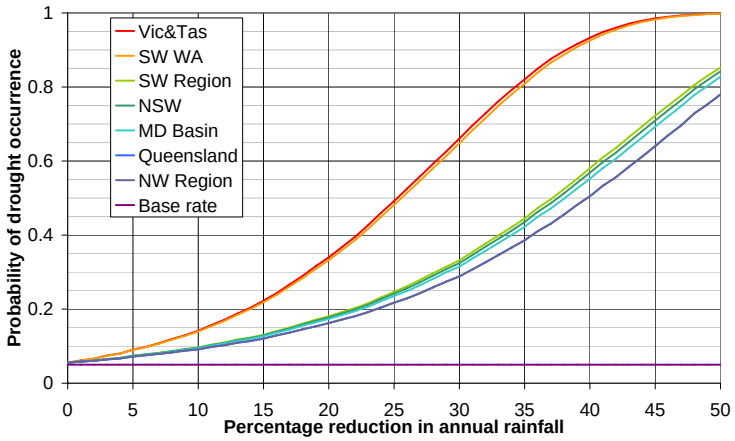


Figure 3: Probability of exceptionally low rainfall (i.e., rainfall below the 5th percentile for 1900-2007) for mean rainfall decreases of up to 50% for the seven study regions. The results for the Queensland and NW regions are almost identical. The historical data are modelled with a normal distribution of climatological mean and variance, while the projected future rainfall is modelled with reduced mean but unchanged coefficient of variation.

Region	5%	10%	15%	20%
Vic&Tas	0.09	0.14	0.22	0.34
SW WA	0.09	0.14	0.22	0.33
SW	0.07	0.10	0.13	0.18
NSW	0.07	0.10	0.13	0.18
MDB	0.07	0.09	0.13	0.17
Qld	0.07	0.09	0.12	0.16
NW	0.07	0.09	0.12	0.16

Table 1: Probability of exceptionally low rainfall for selected mean rainfall decreases of 5, 10, 15 and 20%. The regions are tabulated in order of increasing coefficient of variation. The base rate probability is 0.05, or 5%.

[3]See pages 14 (Qld), 17 (NSW), 20 (Vic&Tas), 23 (SW), 26 (NW), 29 (MDB) and 32 (SW WA) for graphs of these time series.

16 References

Della-Marta P, Collins D and Braganza K, 2004. *Updating Australia's high-quality annual temperature dataset*, Australian Meteorological Magazine, **53**, 75-93.

Hennessy K, Fawcett R, Kirono D, Mpelasoka F, Jones D, Bathols J, Whetton P, Stafford Smith M, Howden M, Mitchell C and Plummer N, 2008. *An assessment of the impacts of climate change on the nature and frequency of exceptional climatic events*, CSIRO and Bureau of Meteorology.

Jones D and Weymouth G, 1997. *An Australian monthly rainfall dataset.* Bureau of Meteorology Technical Report No. 70.

Torok S and Nicholls N, 1996. *A historical annual temperature dataset for Australia*, Australian Meteorological Magazine, **45**, 251-260.