Drier and wetter times: Rainfall is episodic

G.C. Curran

Animal and Climate Investigations, 160 Cornish Street, Broken Hill NSW 2880

Corresponding author: curran3gdc@outlook.com

Abstract

Visual inspection of rainfall change plots shows drier and wetter episodes, separated by breakpoint peaks and troughs. Exact measurements of episode rainfall and duration show drier and wetter episodes have large and distinctly different characteristics. Rainfall operates in two states, transitioning through breakpoints. At any one time, rainfall is never average; it is either '*drier*' or '*wetter*'. Selected central Australian sites spent about two-thirds of months as '*drier*'; average '*wetter*' episode monthly rainfall was about 3.2 times greater than '*drier*'. Comparing change plots of rainfall and rainfall predictors allows assessment of rainfall predictors such as SOI. The possibility of continental temperatures having predictive value is illustrated using Alice Springs maxima.

Keywords: rainfall, episode, change plot, breakpoint, cumulative residual

Introduction: The gap between experience and science

It was a poet that captured the meteorology of Australia when she spoke of a land "*of droughts and flooding rains*". Dorothea Mackellar wrote this around 1904, age 19 (Brown 2023), as the Great Drought of the 1890s to 1940s rolled over the land.

We scientists and managers in a highly variable climate still need to accurately define their durations and rainfall in Australia. There is no lack of data: Australia's Bureau of Meteorology has a wealth of publicly available daily, monthly and annual records, with 19,438 sites (BOM 2023), including rainfall for many farms and pastoral stations, with an average span of 47 years, up to 184 years.

Despite knowing subjectively that we have drier and wetter times, the most common parameter we use is the average or mean rainfall. Remarkably stable over time, the average says nothing about the dynamics and variation of rainfall, the major feature of our climate. Compare Wilcannia's rain from 1879 to 2022 with its progressive Cumulative Average: the parameter that reflects how our knowledge of the average and our expectation of rainfall has changed as records accumulate.

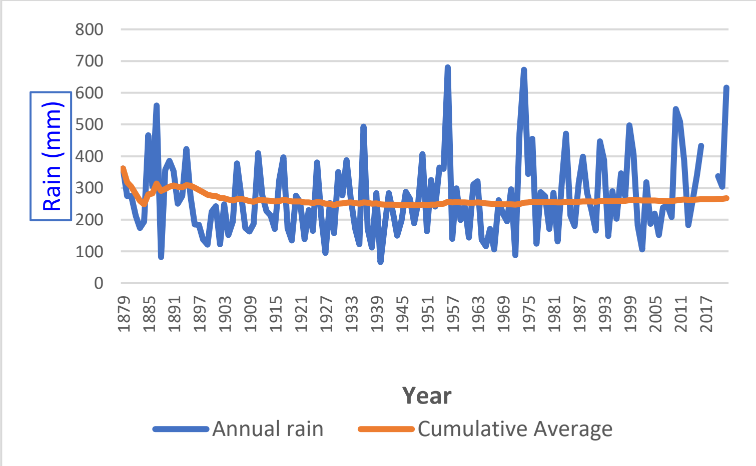

Figure 1 Wilcannia annual average rainfall versus its cumulative average (1879 to 2022).

Methods

Exploring the gap

When the differences between recorded monthly rainfall and expected rainfall are inspected as either positive or negative values over time, something unexpected is observed. Using Wilcannia as an example, a clear gap is seen (Figure 2 - **arrow**). In fact, at any one time, rainfall was always drier or wetter than expected, and never average, in all 1731 months.

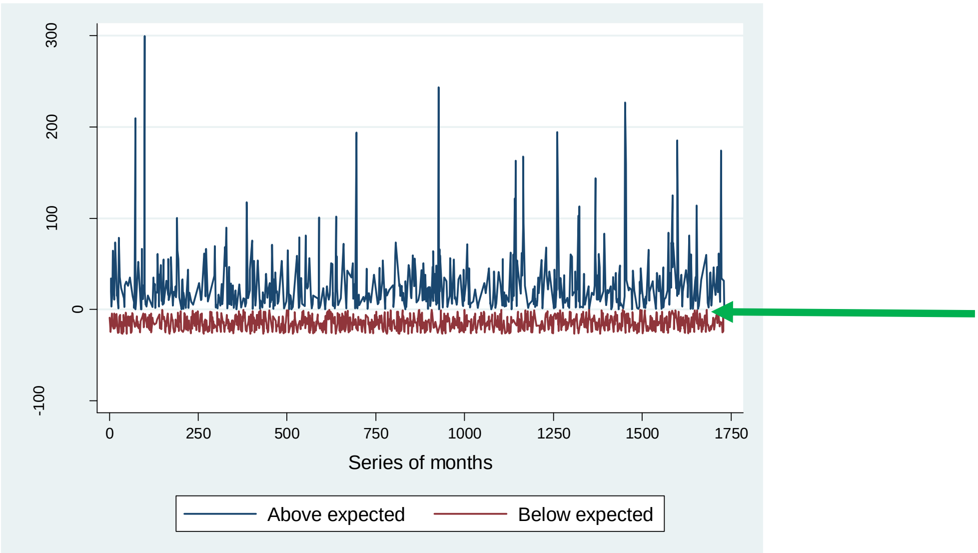

Figure 2 Plots of above and below expected monthly rainfall – Wilcannia 1879 to 2023.

The different natures of drier and wetter rainfall are apparent in the visible differences in their plots (*wetter*: spiking; high amplitude and variability; *drier:* low amplitude and lower variability); the highly significant differences in their means, confidences levels, and frequency {*wetter*: mean – +27.46mm [99.99%CI: (+22.14 – +32.77)]; 35% of months}; {*drier*: mean – -14.90mm [99.99%CI: (-15.73 – -14.07)]; 65% of months}; the marked difference in distribution of Wilcannia's rainfall for (*below expected*) vs (*above expected*). See Figures 3a, 3b.

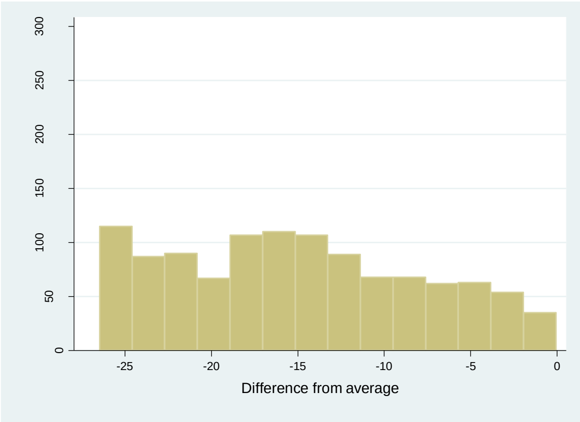

Figure 3a. Histogram of below average rain.

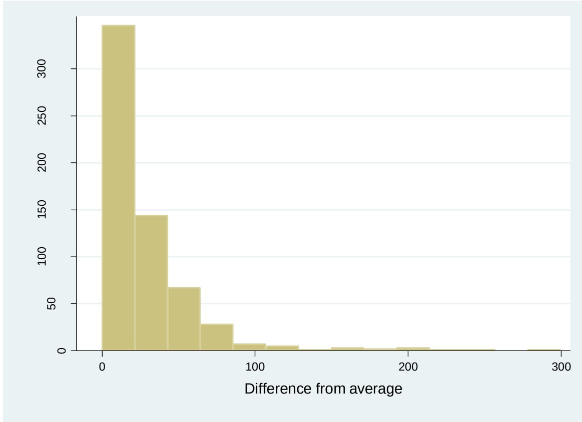

Figure 3b. Histogram of above average rain.

Figure 3.

Visualising and measuring drier and wetter times with Change Plots

The dynamic of rainfall can be displayed in a Change Plot. Wilcannia's change plot for 2000 to 2023 (Figure 4a) shows a series of inclines and declines, as well as peaks and troughs. An incline is a time when rainfall was above average; a decline is a time when rainfall was below average. A peak is a month when a wetter time changed to a drier one; a trough is a month when a drier time changed to a wetter one. These peaks and troughs, or breakpoints, delineate candidate drier and wetter episodes whose rainfall and duration are measured and compared.

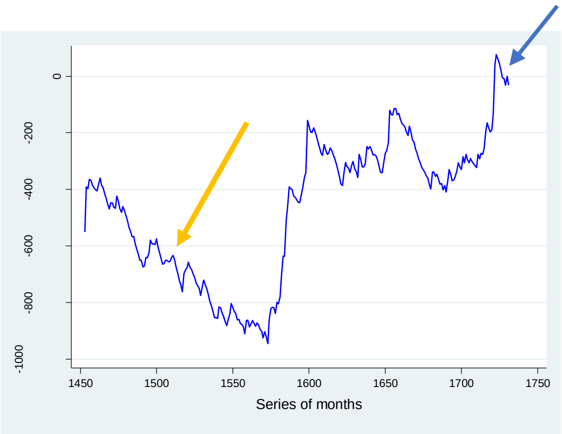

***Figure 4a** Change plot.*

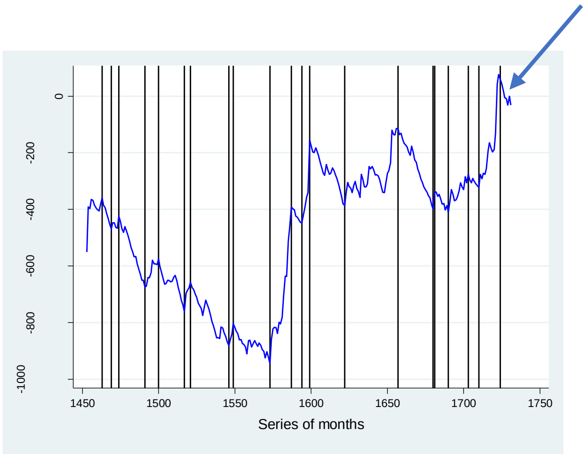

***Figure 4b** Change plot with breakpoints.*

Figure 4 Change plot of Wilcannia monthly rain 2000 to 2023.

A change plot is prepared by sequentially summing each difference to expected rainfall (also known as the cumulative residual CR (Foley 1957). Statistically different episodes (using ttest or a heuristic) are shown in Figure 4c. The Millennial Drought is arrowed in Figure 4a (from November 2000 to January 2010 for Wilcannia). Wilcannia entered a new drier episode in November 2022 (arrowed in Figures 4a, 4b and 4c).

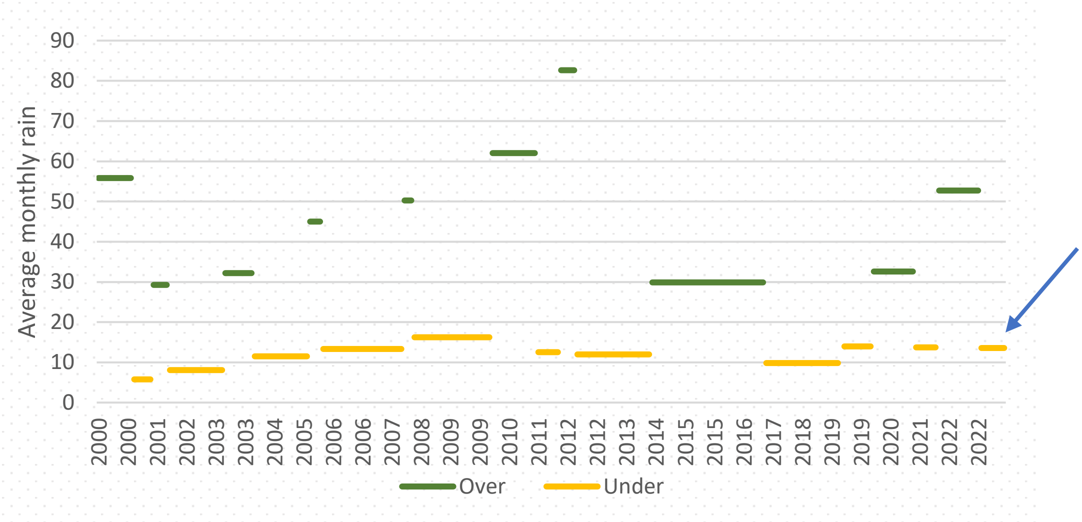

Figure 4c Rainfall and duration of Wilcannia's wetter and drier episodes 2000 to 2023.

Wilcannia's monthly change plot for 1879 to 2023 provides a broader perspective (Figure 5a): first, a wetter time to February 1895; the Great Drought to February 1949 (arrows); the very wet early 1950s; the sharp drier time from 1956 to 1973, then a generally wetter time, broken by drier episodes, including the Millennial Drought (arrowed). The marked gap between the 75 wetter episodes and 74 drier ones is clear (Figure 5b – arrowed).

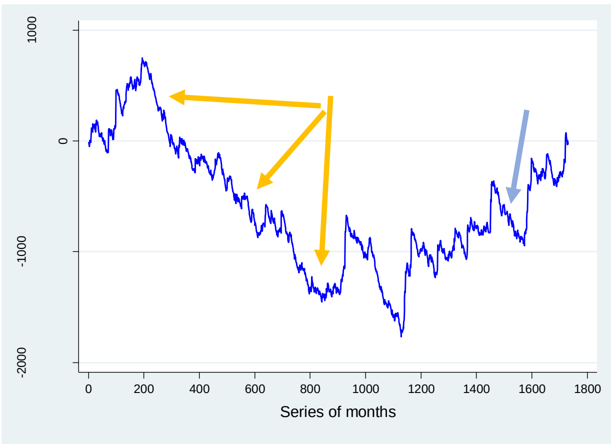

***Figure 5a** Change plot.*

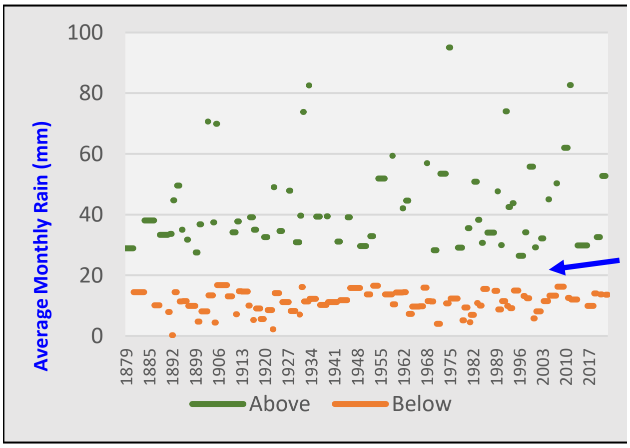

***Figure 5a** Episode rainfalls and durations.*

Figure 5 Measuring wetter and drier episodes for Wilcannia from monthly rain 1879-2023.

All data (rainfall, temperatures, SOI, IOD) was downloaded from Bureau of Meteorology website (http://www.bom.gov.au).

Comparing changes in predictors of rainfall with changes in rainfall

Change plots of rainfall predictors allow visual comparison with change plots of rainfall. Regression and correlation analysis give measures of their value as predictors of rainfall over time.

Changes in SOI may have a 30% to 50% fit, with some major discrepancies, for example. See example of Packsaddle area rainfall and SOI 2002 to 2023 (Figure 6); the Packsaddle area is north of Broken Hill.

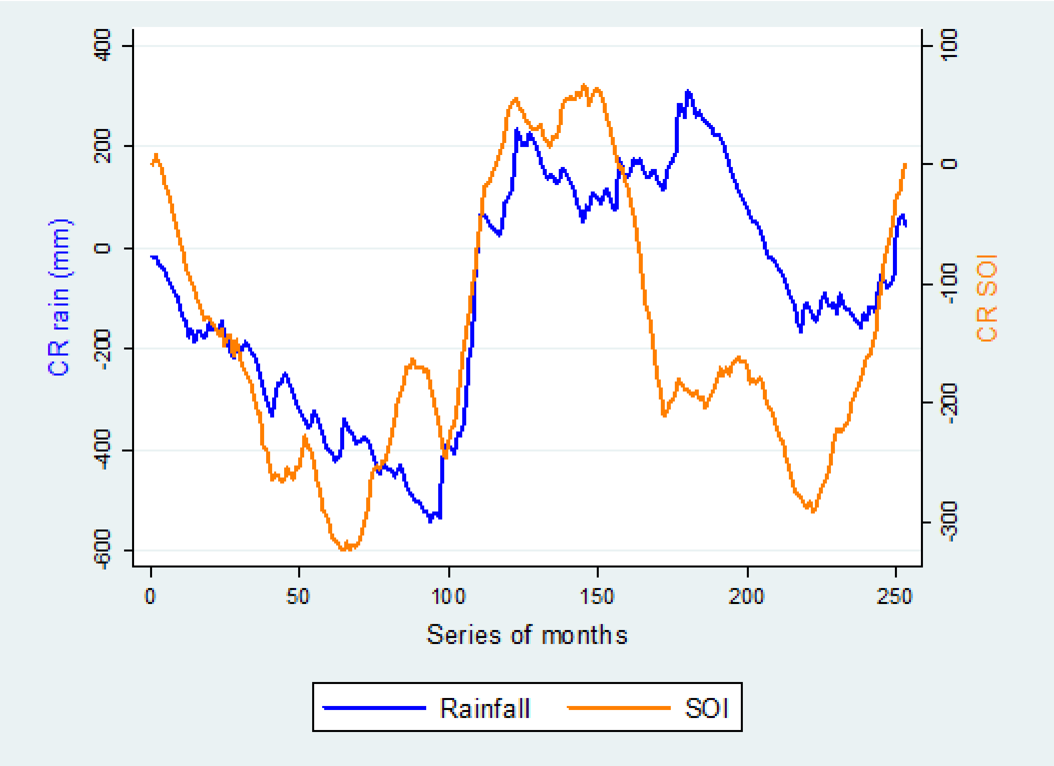

Figure 6 Change plots of SOI and rainfall in Packsaddle area 2002 to 2023.

Results

Key episode parameters for central Australia

For Wilcannia, wetter episodes averaged 480mm, 3.4 times as much rain as drier episodes. See Table 1. Drier episodes had an average duration of 15.2 months, with considerable variation; wetter episodes averaged 8.0 months. In total, 69% of all 1731 months were spent in drier episodes.

Table 1 Summary of rainfall and durations for Wilcannia's drier and wetter episodes.

Parameters	Drier	Wetter	Parameters
Average rain*	**141mm (5.5")**	**480mm (18.9")**	'*Wetter*' = 3.4 x '*Drier*'
Average duration	**15.2 months**	**8.0 months**	69% months were '*Drier*'
Episodes	**74**	**75**	

*Annualised rainfall.
Data from www.bom.gov.au
General average: 266mm (10.5") annualised.

Rainfall at seven other key sites across central Australia were assessed as for Wilcannia. See Figures 7a and 7b. Marree and Kalgoorlie had lower rainfalls; Alice Springs, Bourke and Hay had slightly higher rainfalls; Charleville and Longreach had much higher rainfalls. Durations of drier and wetter episodes varied.

An important finding was that two key parameters were similar across these eight sites (see Table 2), despite marked differences in geographic location and average rainfall.

- Wetter episodes had about 3.2 times as much rain as drier episodes.
- About two-thirds of all months were 'drier'.

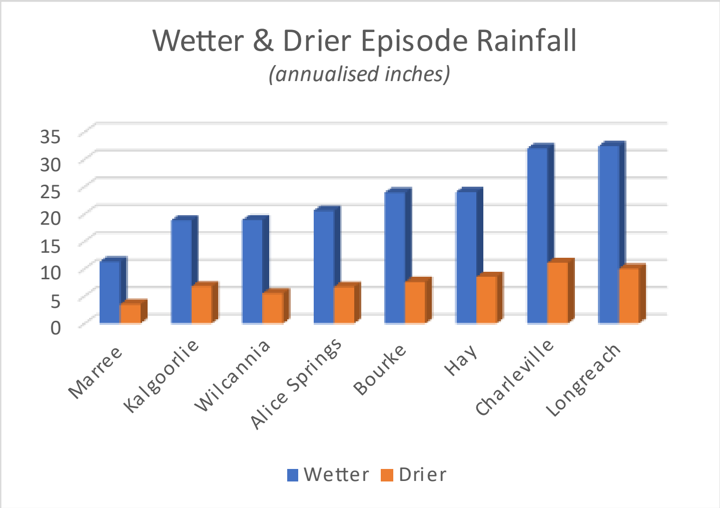

Figure 7a Episodic rainfalls for eight central Australian sites.

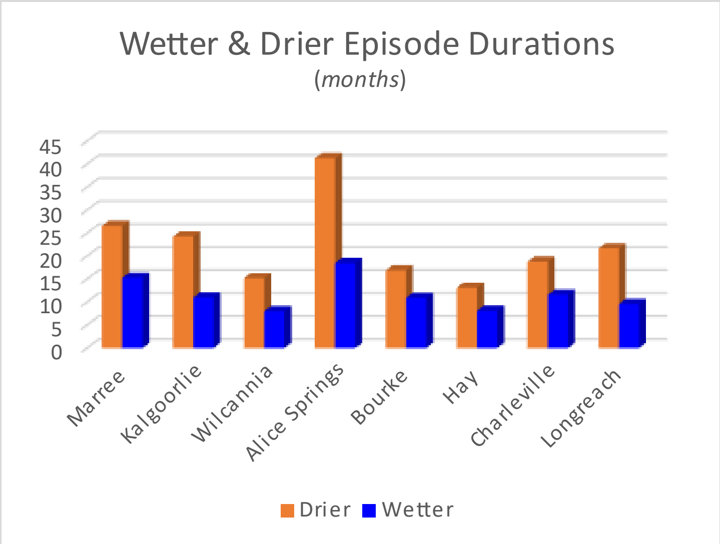

Figure 7b Episode durations for eight central Australian sites.

Table 2 Two rainfall parameters across central Australia.

Site	Duration: % Drier	Wetter: Drier Rain	Years
Marree	63%	3.2	1885-2015
Kalgoorlie	70%	3.8	1939-2023
Wilcannia	69%	3.4	1879-2023
Alice Springs	68%	3.1	1941-2023
Bourke	61%	3.1	1880-2015
Hay	62%	2.8	1871-1996
Longreach	62%	2.9	1942-2023
Charleville	69%	3.3	1949-2023
All	65%	3.2	

Towards better predictions of rainfall

Comparing change plots of temperature and rainfall allows consideration of the question: Might changes in land temperatures influence changes in rainfall in central Australia, if changes in temperatures or related parameters of distant oceans can? Changes in Alice Springs maxima had 50% to 80% fit with changes in rainfall in study sites in selected western New South Wales and western Queensland. See Figure 8.

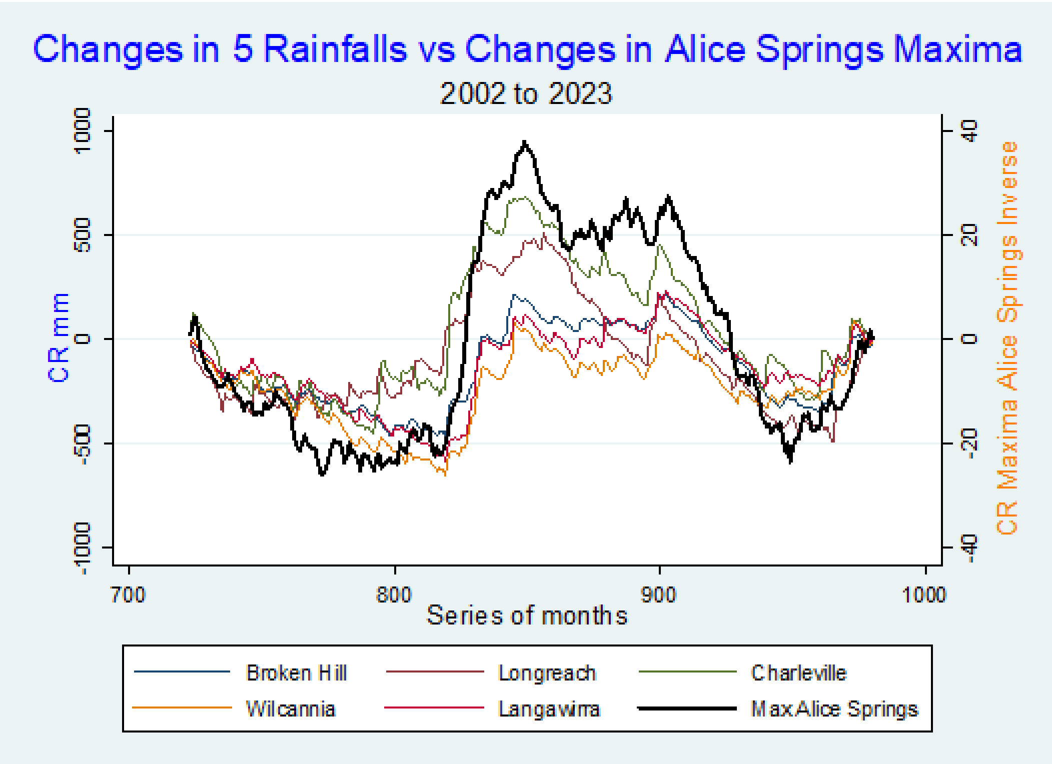

Figure 8 Comparing change plots of Alice Springs maxima and rainfall at five locations in western Queensland and western NSW.

Regression analysis of combinations of change plots of predictors of rainfall can improve predictions of rainfall. Changes in Charleville monthly rainfall (2002 to 2023) had 90% fit using a combination of changes in SOI, IOD and Alice Springs maxima. See Figure 9.

- [(CR_Charleville = 13.51463 crnegasmax +9.83519crioddt +0.3799662crsoi +101.0408]

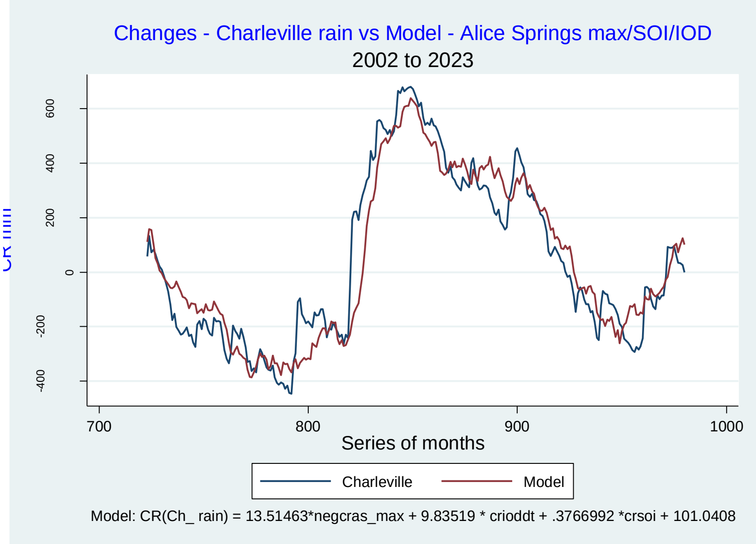

Figure 9 Changes in Charleville rain versus model of changes.

Conclusions

Key findings

- Rainfall is episodic across Australia (for over 800 rainfall records).
- Change plots allow exact measurement of rainfall and duration of each episode *to limits of measurement* and are akin to an ECG of the land.
- Rainfall is not random chance alone.
- Rainfall is structured and systemic: occurring in two states; with breakpoint transitions.
- A breakpoint is both the end of one episode and the start of the next.
- At any one time, rainfall is never average; it is either ‘Drier’ or ‘Wetter’.
- *Yet the general rainfall is stable and a characteristic of each location.*
- The general average is the balance of episodic rainfall and their durations over time.

Using episodic rainfall records to better predict rainfall

- Work out the drier and wetter episode rainfalls for your place or area

  An approximation: if two-thirds of all months are ‘Drier’, and ‘Wetter’ rainfall is ~3 times greater than ‘Drier’ episodes, then ‘Drier’ episode average rainfall equals three-fifths general average, and ‘Wetter’ episode average rainfall equals nine-fifths general average.
- Knowing if you are in a drier or wetter episode, and when the last breakpoint happened, you can estimate how long that episode will last.
- Then look at recent trends in durations and rainfall to improve your predictions.
- Comparing the change plot for your place or area with change plots of rainfall predictors indicates how useful a predictor or combination of predictors may be.

Conflicts of interest

The author declares no conflict of interest.

References

Brown C (2023) My Country Dorothea Mackellar. Available at My Country - Dorothea Mackellar [Verified at 15/10/2023]

Bureau of Meteorology (2023) General station lists. Available at bom.gov.au/climate/data/lists_by_element/stations.txt [Verified 15/10/2023]

Foley JC (1957) Droughts in Australia: Review of Records from Earliest Years of Settlement to 1955 (Bureau of Meteorology Bulletin **43**)