Shorter contribution

An artificial trend in District Average Rainfall in the Snowy Mountains

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District Average Rainfall for District 71 (the Snowy Mountains) apparently exhibits a strong downward trend since 1913. This trend is shown to be the result of changes in the mix of stations used to produce the district average. High-rainfall stations have closed, thereby producing an artificial decline in district average rainfall. The individual stations available to be used to produce the district average do not exhibit a strong downward trend. A composite high-elevation rainfall record has been produced. This composite exhibits a weak (and statistically non-significant) downward trend, late in the record.

Introduction

A strong decline is apparent in annual District Average Rainfall (DAR) for District 71, located in the Snowy Mountains of New South Wales (Fig. 1). There has been some concern that this decline of about 200 mm, i.e. about 20 per cent, since 1913 could be the result of human interference with the environment, and that a continuing decline in rainfall could threaten ecosystems and irrigation.

The DAR was originally used by the Bureau of Meteorology to provide a general overview of the rainfall across Australia (Chappel 1995). The original division of Australia into what became meteorological districts is described in Hunt (1910). The primary divisions were along State borders, with secondary divisions based on knowledge of physiographical factors (Chambers 2001). The DAR is the arithmetic mean of a sample of stations within a district, where stations were chosen using local (State) knowledge of their reliability and representativeness (Chappel 1995; Jones and Beard 1998). As stations were closed, and new stations opened, the stations used to calculate the DAR would have changed. Documentation of the stations used each year since 1913 is incomplete. Jones and Beard (1998) demonstrated that for much of Australia the DAR provides a reasonable indication of rainfall, both in the mean and for individual months. However, in areas with large spatial variations in rainfall, and few stations, they found that the conventional method of calculating the DAR led to errors. Jones and Beard identified District 71 as one such district. Chappel (1995), and Jones and Beard (1998), showed that changes in stations used to calculate the DAR could produce artificial, long-term variations in DAR. In this study, an attempt is made to identify the stations most likely to have been used in the calculation of the DAR for District 71 since 1913. The cause of the apparent decline in rainfall in this district is investigated, using these stations.

An alternative strategy would have been to use only 'high-quality' rainfall stations to estimate trends in rainfall in this region. However, Lavery et al. (1992, 1997) could not identify any high-quality stations in District 71.

The cause of the decline in rainfall

The mix of stations used each year since 1913 to calculate the DAR is not known. However, for District

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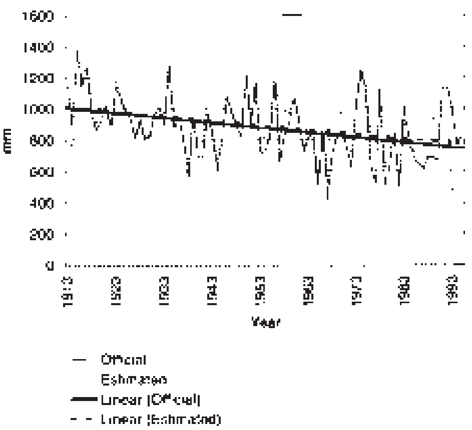
Fig. 1 'Official' District 71 annual District Average Rainfall (thin continuous line), with linear trend (thick continuous line). Annual District Average Rainfall estimated by averaging rainfall at the seven stations listed in Table 1 (thin broken line), with linear trend (thick broken line).



71, only a small number of long-term observing stations exist, so it seemed likely that these stations would have been used to produce the DAR. These stations were averaged each year to provide an estimated DAR. The result of arithmetic averaging of seven long-term stations (identified in Table 1) is shown in Fig. 1. The variations from year to year of this 'estimated' DAR and the 'official' DAR are very similar with a correlation of 0.80 between the time-series. As well as mimicking the 'official' rainfall variations from year to year, the 'estimated' DAR reproduces the strong decline in DAR (linear trend-lines are shown in Fig. 1, for both the 'official' and 'estimated' DAR).

Small differences between the two time series can be identified in some years in Fig. 1. These could have arisen if extra (short-term) stations were used to calculate the official DAR in some years. However, the remarkable similarity between the time series indicates that the seven stations listed in Table 1 do provide the basis for calculation of the official DAR through the period of record.

The annual rainfall totals for all seven stations are shown in Fig. 2. Annual rainfall totals are missing (presumably because one or more month's data were not recorded) for some stations in some years between the opening of the station and its closure. For instance, annual rainfall totals for Kiandra Chalet are not available after the late 1960s, even though the station only closed officially in 1974.

No obvious trends are evident in any of the rainfall time-series in Fig. 2. This indicates that the substantial decline in rainfall in the 'estimated' DAR (Fig. 1) results from the combination of stations with different opening and closing dates. In particular, the closure of Mt Kosciusko in 1954 meant that thereafter usually only one high-elevation (high-rainfall) station was used in the average, whereas prior to this date two such stations had been included. So, after 1954 the average gives more weight to the rainfalls recorded at lower elevation, which tend to be lower rainfall totals.

District 71 encompasses stations at moderate elevation (below 1100 m) and stations at high elevation (above 1300 m). There is no high elevation station with a continuous record since 1913. However, Kiandra Chalet and Guthega Power Station, together, cover the entire period since 1913. The two stations are at similar (high) elevation, and are quite close. There is an overlapping period from 1954–1968. During this period of overlap, rainfall variations at the two stations were closely related. Figure 3 shows a scatter diagram of annual rainfall at the two stations, for this overlapping period. The correlation between the two rainfall time series is 0.94 (significant at 99 per cent). A composite of the two stations has therefore been prepared using the regression between the

Table 1. Stations used to calculate 'estimated' DAR for District 71.

Name	*Number*	*Latitude*	*Longitude*	*Elevation (m)*	*First year of record*	*Last year of record*
Jindabyne (Lynwood)	71021	36.4872°	148.5822°	1030	1906	Still open
Kiandra Chalet	71010	35.8833°	148.5°	1395	1866	1974
Dalgety (Hamilton St)	71005	36.5042°	148.8339°	765	1896	Still open
Mt Kosciusko (Hotel Kosiusko)	71012	36.3667°	148.4833°	1518	1911	1954
Berridale (Jyndabyne Road)	71022	36.3616°	148.8299°	860	1926	Still open
Guthega Power Station	71034	36.3517°	148.4125°	1340	1952	Still open
Adaminaby (Baker St)	71000	35.9983°	148.775°	1015	1886	Still open

Fig. 2 **Annual rainfall for the seven District 71 stations listed in Table 1.**

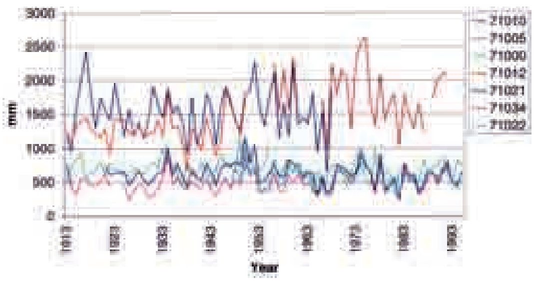


Fig. 3 **Scatter diagram of annual rainfall at Guthega Power Station versus Kiandra Chalet. Data from overlapping years (1954-1968). Thick line is linear regression between the variables.**

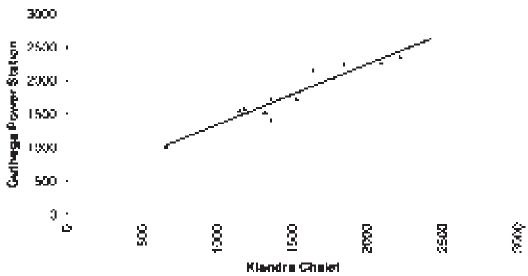
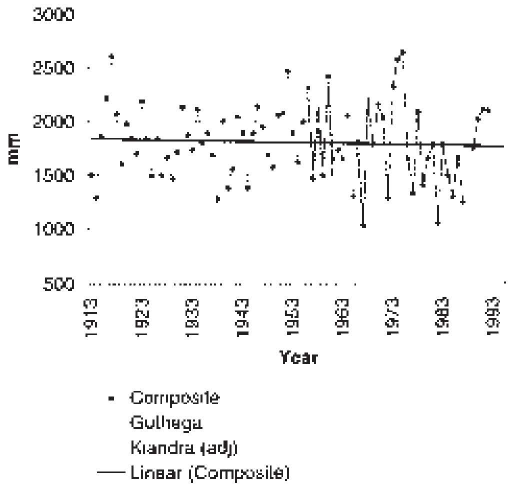


Fig. 4 **Annual rainfall at Guthega Power Station, and (before 1969) Kiandra Chalet (adjusted to Guthega rainfall by using the regression 'Kiandra (adj.) = 450 + 0.885 Kiandra' shown by the thick line in Fig. 3). The composite time series is indicated by the diamond symbols. The thick line is the linear trend of the composite.**



two stations (the thick line in Fig. 3) to adjust Kiandra Chalet rainfall to estimate Guthega rainfall prior to 1969. After the end of the Kiandra Chalet annual rainfall observations in 1968 observed Guthega rainfall was used for the composite.

The composite, high elevation rainfall record is shown in Fig. 4, which also shows the Guthega observations and the Kiandra Chalet observations adjusted by the regression fit. The composite record shows a weak (approximately five per cent) downward trend in rainfall. The trend arises because of low rainfall around 1980 (a period of widespread drought through New South Wales). The correlation of the composite rainfall with year between 1913 and 1992 is only –0.06. This correlation is not statistically significant at even the 90 per cent level. If data only up to the mid-1970s are used even this weak downward trend disappears.

The process of adjustment was repeated using a simple multiplicative factor between the annual rainfall at the two stations, derived from the mean rainfall in the overlapping years. Guthega rainfall in this period was a factor of 1.19 higher than that of Kiandra. This composite also exhibited a very weak (and very similar, and statistically non-significant) downward trend, almost identical to that in Fig. 4.

Changes in precipitation measuring techniques through the 20th century may, potentially, confound this analysis. Ruddell et al. (1990) discussed possible changes in precipitation gauges, and how these may lead to biases. However, Guthega Power Station has used a 203 mm gauge since it opened. Ruddell et al. (1990) suggested that a 203 mm gauge had been used at Kiandra as early as the 1920s. It seems unlikely that changes in instrumentation at the two stations have seriously compromised the production of the composite record.

Conclusions

Since the 'estimated' DAR shows excellent agreement with the 'official' DAR, it is concluded that the stations used here were, for most years, those used in the 'official' DAR calculations. Hence, the attribution of the apparent decline in the 'estimated' DAR to changes in the stations used in the arithmetic average leads to the conclusion that the decline in the 'official' DAR is similarly artificial. Neither the composite high-elevation rainfall series, nor the individual station rainfall time series, exhibit a strong or statistically significant downward trend, confirming that the strong downward trend in the DAR is artificial.

Further evidence of the artificial trend in DAR is available in Ruddell et al (1990) who examined southeast Australian alpine climate data and concluded that: 'Long term records of snow cover generally suggest slightly negative trends over the last 40 or so years but there is very little statistical significance associated with these trends. The slightly negative trends reflect the sequence of below average snow seasons during the 1980s and the low significance reflects the highly variable nature of this quantity. This is partly attributable to its close association with precipitation which is also highly variable and which also exhibits no significant trends'.

This study has provided further evidence supporting the conclusion (from Chappel (1995) and Jones and Beard (1998)), that District Average Rainfalls can produce misleading evidence of trends. District Average Rainfalls are not appropriate for studies of trends or decadal fluctuations.

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