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Adjustment of CLIGEN parameters to generate precipitation change scenarios in southeastern Australia

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Abstract

Global climate model predictions are often downscaled with stochastic weather generators to produce suitable climate change scenarios for impact analysis. Proportional adjustment to generated daily precipitation and direct adjustment to parameter values for weather generators have been used for assessing the impact of climate change on runoff and soil loss. Little is known of how these parameter values should be realistically adjusted, the amount of adjustment, and whether the adjustments are correlated among different parameters. Rainfall in southeastern Australia has significantly increased since the late 1940s. Rainfall records in Sydney show a similar trend. Long term daily and 6-min intensity data from Sydney have made it possible to examine how CLIGEN parameter values have changed in relation to the underlying significant increase in rainfall. This study shows that for Sydney, most of the increase in rainfall is a result of the increase in wet day precipitation. The increase in the standard deviation of wet-day precipitation is greater than that in the mean, implying a greater rainfall variability during wetter periods. The wet-following-wet transition probability, and maximum 30-min rainfall intensity are all positively and significantly correlated with the change in wet-day precipitation. The change in peak intensity is about half the change in rainfall. No significant relationship can be established between the changes in mean monthly rainfall and those in the skewness coefficient for wet day precipitation and wet following dry transition probability for the site. Simultaneous adjustment of all these parameters is needed for generation of precipitation change scenarios for the region. Using simple proportional adjustment to generated precipitation sequences would lead to maximum impacts on runoff and soil loss predicted with WEPP, while attributing precipitation

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change equally to the change in wet day precipitation and the number of wet days would underestimate the magnitude of the impacts considerably for the site.

Keywords: Climate change; Runoff; Soil erosion; Weather generator; Sydney

1. Introduction

Global Climate Models (GCMs) are widely used to predict the likely climate change as a result of the enhanced greenhouse effect. Output from GCMs is often too coarse at the sub-regional and sub-monthly scales for impact assessment. To have climate input at the appropriate spatial and temporal resolution, stochastic weather generators are commonly used to downscale climate change scenarios produced by Global Climate Models (GCMs) (Semenov and Barrow, 1997; Wilby and Wigley, 1997; Goodess and Palutikof, 1998; Wilby et al., 1998). These weather generators are particularly useful in producing the required climate input to drive crop, hydrologic, and soil erosion models (e.g. Xu, 1999; Prudhomme et al., 2002, Favis-Mortlock and Savabi, 1996; Pruski and Nearing, 2002a).

Soil erosion prediction model such as WEPP (Water Erosion Prediction Project) can be used to assess the likely impact on runoff, soil loss, and biomass production for given climate change scenarios. CLIGEN is a stochastic weather generator to produce the required climate input for WEPP. Of the ten daily weather variables generated by CLIGEN, the four precipitation-related variables are most important because predicted runoff and soil loss are most sensitive to them (Chaves and Nearing, 1991). To generate daily precipitation variables, CLIGEN requires 84 parameter values (Table 1). Two additional relevant parameters were set internally, hence not accessible to most users of the program. Typically CLIGEN and WEPP are run based on the current climate conditions first. Some of the CLIGEN parameters are then perturbed to simulate future climates (Pruski and Nearing, 2002a,b). Alternatively, observed or simulated rainfall or temperatures values can be adjusted directly to generate climate change scenarios (Favis-Mortlock and Savabi, 1996; Favis-Mortlock and Guerra, 1999). The difference in terms of

Table 1
Precipitation-related parameters for CLIGEN

Required parameters	Variable name	Number of values
Average precipitation on wet days for each month	meanP	12[a]
Standard deviation of daily precipitation for each month	sdP	12[a]
Coefficient of skewness of daily precipitation for each month	skP	12[a]
The probability of a wet day following a wet day for each month	$Pr(W\|W)$	12[a]
The probability of a wet day following a dry day for each month	$Pr(W\|D)$	12[a]
Average maximum 30-min peak intensity	MX.5P	12[a]
Cumulative distribution of the time to peak as a fraction of the storm duration[b]	timePk	12[b]

[a] One value for each month.
[b] The distribution is represented by 12 discrete values.

predicted soil loss erosion can be interpreted to represent the likely impact of climate change on soil erosion.

There is, however, limited treatment in the literature on how to adjust parameter values to simulate changed climates for erosion prediction purposes. In theory, any of the 86 CLIGEN parameters could be altered to simulate precipitation change scenarios. Little is known about how these parameters can be realistically adjusted, the amount of adjustment, and whether the adjustments are correlated. The objective of this paper is to show how to adjust CLIGEN parameter values to generate realistic precipitation change scenarios. This was made possible only because long-term historical daily and 6-min data from Sydney have shown that rainfall since 1949 has significantly increased compared to the three previous decades.

2. Data and method

2.1. Rainfall data for Sydney

It is well documented that since the late 1940s much of southeastern Australia has experienced higher rainfall compared to that in the preceding decades (Pittock, 1983; Cornish, 1977; Yu and Neil, 1991; Suppiah and Hennessy, 1998; Hennessy et al., 1999). Weather records from Sydney show a similar trend with a mean annual precipitation significantly higher since the late 1940s. Sydney (station no. 66062, 151°12′E, 33°52′N) has one of the longest precipitation records in Australia. Daily precipitation data were available since 1 July 1858. Pluviograph data at 6-min intervals were available since 3 January 1913 for the site. The pluviograph data for Sydney dated at least 24 years earlier than any other sites in southeastern Australia. Thus, this is a unique opportunity to examine the changes to CLIGEN parameter values when precipitation climatology has significantly changed.

The daily rainfall data for Sydney were of good quality in terms of their completeness. A comparison of the daily and 6-min rainfall records showed that the pluviograph data at 6-min intervals have a number of problems. First, missing or incomplete 6-min rainfall data are common for certain periods. Secondly, there are obvious discrepancies between daily total and 6-min rainfall data when cumulated on a daily basis. With a careful assessment of data discrepancy on daily and monthly basis, 6-min data were discarded for 1918, 1920, and all the years since 1992. For CLIGEN precipitation-related parameters, the data for the period 1913–1948 and that for 1949–1991 were used for comparison purposes. For CLIGEN parameters in relation to storm patterns, 1918 and 1920 were excluded from the first period. For the entire 76 years (1913–1991 minus the 2 years), the gross discrepancy was less than 1% between daily rainfall total (1252 mm year^{-1}) and accumulated 6-min rainfall total (1240 mm year^{-1}).

2.2. CLIGEN parameters

CLIGEN generates precipitation occurrences on a daily basis, and produces four precipitation-related variables for each wet day, namely, the amount of precipitation, P

(mm), storm duration, D (h), time to peak as a fraction of the storm duration, t_p, and the ratio of peak intensity over average intensity, i_p. The average intensity is defined as P/D. In total, 84 parameter values are needed to generate these four daily variables stochastically (Table 1).

Precipitation data required to compute these CLIGEN parameters are time series of daily precipitation amounts and break-point/tipping bucket/pluviograph data at sub-daily intervals no greater than 30 min. In principle, there is no need to distinguish between these two types of precipitation data because sub-daily data can be accumulated to produce daily values. In practice, however, these two types of data usually come from two different sources. The coverage of the daily data, both in space and time, is much more extensive in comparison to sub-daily data at short time intervals. In addition, the two types of data are normally stored in different formats. It is therefore useful to treat the two types of precipitation data separately.

The first three parameters for precipitation in Table 1 are straightforward. Definitions and the procedure to calculate the remaining precipitation-related parameter values are given below because these have not been well documented in literature.

Let r be the amount of precipitation on the current day in a month, rp be the amount of precipitation on the previous day which may or may not be in the same month, and cr be the critical precipitation amount to define a wet day, i.e. a wet day occurs when

$$r \geq \mathrm{cr}$$

and cr of 0.2 mm is commonly used. A day is often defined as a 24-h period ending at 9.00 am, and the day is indicated by the date on which the period ends. Let Ndd be the total number of dry days in the month following a dry day; Ndw be the total number of wet days in the month following a dry day; Nwd be the total number of dry days in the month following a wet day; Nww be the total number of wet days in the month following a wet day. These exhaust all possible combinations. Then, the wet-following-wet and wet-following-dry transition probabilities, $\Pr(W|W)$ and $\Pr(W|D)$, respectively, can be calculated as follows:

$$\Pr(W|W) = \frac{\mathrm{Nww}}{\mathrm{Ndw} + \mathrm{Nww}} \tag{1}$$

$$\Pr(W|D) = \frac{\mathrm{Ndw}}{\mathrm{Nwd} + \mathrm{Ndd}} \tag{2}$$

These formulas follow from the definition of conditional probability:

$$\Pr(A|B) = \frac{\Pr(A \cap B)}{\Pr(B)} \quad \text{when } \Pr(B) \neq 0 \tag{3}$$

For the parameter on the average maximum 30-min intensity, let Δt (min) denote the sub-daily interval. There are then $1440/\Delta t$ intervals in a day. For each wet day, discard all the dry intervals to create a single storm event with continuous rain for, say, M intervals. Then the storm duration (min) is given simply by

$$D = M\Delta t \tag{4}$$

Find the maximum precipitation intensity for any 30-min period within the storm, and call this I_{30}. If there are n wet days in a month, find the maximum of these n I_{30} values, and denote this maximum I_{30} for the month as maxI_{30}. If there are k months on record, then the parameter MX.5P is given by

$$\mathrm{MX.5P} = \frac{1}{k}\Sigma \max I_{30} \quad (5)$$

A numerical example is presented here for clarity. Let us say it rained on 3rd and 10th of May 2001 with peak 30-min intensity of 30.5 mm/h and 38.1 mm/h, respectively. Then maxI_{30} would be 38.1 mm/h for May 2001. If we have 5 years of data for May, say 20.3 mm/h for May 1997, 20.9 mm/h for May 1998, 7.6 mm/h for May 1999, 71.1 mm/h for May 2000, and 38.1 mm/h for May 2001, then the MX.5P value for May for this hypothetical site would be 32 mm/h.

If the peak intensity occurs in ith interval out of M intervals, then the time to peak (min), T_p, is given by

$$T_p = \left(i - \frac{1}{2}\right)\Delta t \quad (6)$$

and time to peak as a fraction of storm duration is given by

$$t_p = \frac{T_p}{D} = \frac{(i - 0.5)}{M} \quad (7)$$

Let Ntp(i) be the number of wet days with $t_p \le i/12$ for $i=1, 2, \ldots, 12$, then

$$\mathrm{TimePk}(i) = \frac{\mathrm{Ntp}(i)}{\mathrm{Ntp}(12)} \quad \text{for } i = 1, 2, \ldots, 12 \quad (8)$$

NB TimePk(12) ≡ 1 because t_p is always less than or equal to 1.

In CLIGEN input files, each of the seven precipitation related parameters occupies a single line. Each line contains 12 values. For the first six parameters, the 12 values correspond to 12 calendar months, i.e. 1st = January, . . ., 12th = December. The last of the seven parameters, i.e. TimePk, is quite different. The 12 values for TimePk describe an empirical probability distribution of the time to peak as a fraction of storm duration. CLIGEN assumes that this distribution does not vary seasonally, unlike all other precipitation related parameters. It is also worth noting that while CLIGEN-generated climate variables for WEPP are measured in metric units. All the input parameter values are currently in the US customary units.

Mean monthly precipitation is the product of mean wet day precipitation, P_w, and the number of wet days for the month, N_w. The mean wet day precipitation is one of the input parameters for CLIGEN, the average number of wet days are related to the transition probabilities:

$$N_w = \frac{N_d \Pr(W|D)}{1 - \Pr(W|W) + \Pr(W|D)} = N_d f_w \quad (9)$$

where N_d is the number of days in the month, and f_w is the fraction of days that are wet. Therefore, changes in precipitation amount can be effected through adjusting wet-day precipitation, or transition probabilities, or both. Specifically, for relatively small changes in precipitation, the 1st order approximation leads to a relationship between the relative change in precipitation amount and that in wet day precipitation and the number of wet days:

$$\frac{\Delta P}{P} = \frac{\Delta P_{\mathrm{w}}}{P_{\mathrm{w}}} + \frac{\Delta N_{\mathrm{w}}}{N_{\mathrm{w}}} \tag{10}$$

where Δ indicates a small change so that linear approximation applies. Similarly, the relative change in the number of rain days are further related to the changes in the transition probabilities:

$$\frac{\Delta N_{\mathrm{w}}}{N_{\mathrm{w}}} = \frac{1}{\Pr(W|D)}[(1-f_{\mathrm{w}})\Delta\Pr(W|D) + f_{\mathrm{w}}\Delta\Pr(W|W)] \tag{11}$$

In the context of using CLIGEN to generate precipitation change scenarios, the change in precipitation therefore can be represented by changes in any one of the three parameters, namely, wet day precipitation, wet-following-wet and wet-following-dry transition probabilities.

A number of different approaches have been used to generate climate sequences for assessing climate change impact on soil erosion. A most straightforward approach is simply to multiply the generated rainfall amount by a constant so that the rainfall is either increased or decreased by a fixed percentage (Favis-Mortlock and Boardman, 1995; Favis-Mortlock and Savabi, 1996; Favis-Mortlock and Guerra, 1999). The number of wet days and the rainfall variability in terms of the coefficient of variation are unchanged. Pruski and Nearing (2002a) simulated precipitation change scenarios by adjusting input parameters to CLIGEN. Three alternatives were considered: (1) adjust parameter values for precipitation-amount only, (2) adjust parameter values for precipitation occurrences only; (3) adjust parameter values so that half of the change is attributed to change in precipitation amount, and the other half to that in precipitation occurrences. When adjusting precipitation occurrences, the proportion between the two transition probabilities was held constant (Pruski and Nearing, 2002a). They suggested that the third alternative was more realistic compared to the other two because equal adjustments to precipitation amount and occurrences gave more consistent results when compared with a sensitivity analysis using the relationship between the precipitation and R-factor for the Universal Soil Loss Equation (Pruski and Nearing, 2002a). In this paper, the following generic relationship among CLIGEN parameters and the change in precipitation was sought:

$$\frac{\Delta C}{C} = \alpha\frac{\Delta P}{P} \tag{12}$$

where C is a CLIGEN parameter for the month, and P precipitation for the same month. The left hand side of Eq. (12) represents the percent change in the parameter, and the right hand side is the percent change in mean monthly rainfall. Data for the Sydney site were used to estimate the coefficient, α, with the standard regression technique.

To evaluate the effects of these different approaches to generate precipitation change scenarios, CLIGEN was used to generate 100-year climate sequences to predict runoff and soil loss with WEPP. Caribou and tilled fallow on a unit plot (22 m and uniform slope at 9%) were used. This scenario has been previously used to validate CLIGEN for sites in the US and Australia, and the soil has an effective baseline saturated hydraulic conductivity of 4.66 mm/h in the middle of the observed range for this important parameter for runoff and soil loss predictions (Yu, 2000, 2003). Likely changes to temperature and the effect of elevated CO_2 concentration on biomass production were not considered in order to isolate the effects of precipitation change on runoff and soil loss predictions.

3. Results

Rainfall change in Sydney between contrasting periods is presented first to set the scene. This is followed by the corresponding changes in CLIGEN parameter values for the two contrasting periods. Finally, changes to predicted runoff and soil loss using WEPP using different adjustment schemes are presented and discussed.

3.1. Climate setting

Mean annual rainfall in Sydney was 1339 mm for the period from 1949 to 1991. This was 21% higher than the mean annual rainfall for the period from 1913 to 1948 (1106 mm) (Fig. 1). The increase is statistically significant with a p-value of 0.0016 using the standard t-test. The increase in rainfall is greater (43%) for summer half of the year (October–March) than the winter half (April–September, 3%) (Table 2). The change in rainfall on a monthly basis is not uniform between the two contrasting periods. Mean monthly rainfall was significantly higher for 6 months (January, February, March, June, August and November) in 1949–1991 than in 1913–1948 with a p-value$<$0.1 using the t-test (Fig. 2).

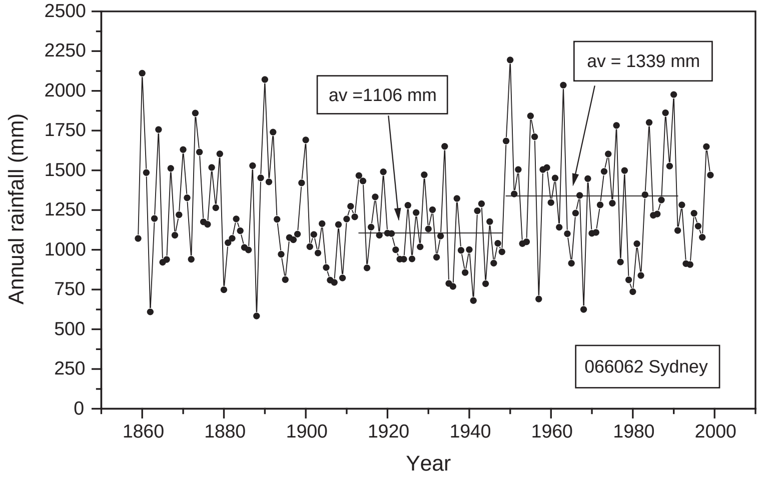

Fig. 1. Time series of rainfall for Sydney (1859–2000) constructed from daily observations. The average rainfall between the two contrasting periods is significantly different. Two periods were selected because the corresponding 6-min rainfall data were available to calculate CLIGEN parameters in relation to storm patterns.

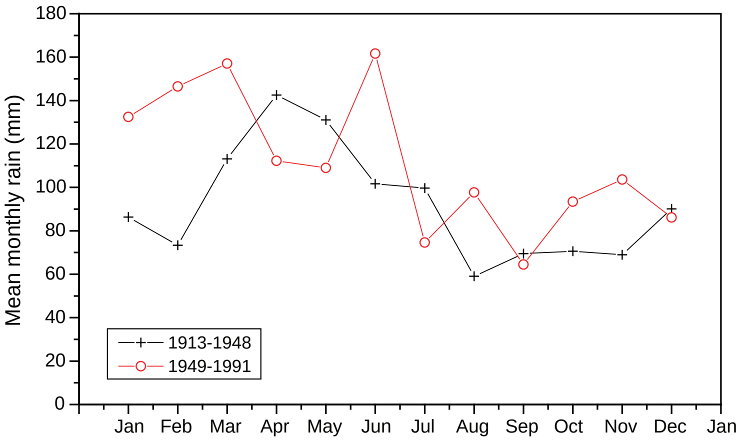

Fig. 2. Mean monthly rainfall in Sydney for two contrasting periods. Significant (p-value<0.1) increase in rainfall has occurred in January, February, March, June, August and November at the site.

The increase for the six months ranged from 39% for March to 100% for February. The difference is not statistically significant for those months when the average rainfall was less in the latter period. This marked and statistically significant increase in rainfall provides an extremely useful setting to examine the likely change to parameter values for CLIGEN.

3.2. Parameters for generating daily rainfall amounts and storm patterns

Fig. 3 shows the change in the average precipitation on wet days between the two contrasting periods. The overall pattern is quite similar to that for month total precipitation for the site (cf. Fig. 2). In fact, the overall increase in precipitation of 21% in Sydney can be attributed to a 22% increase in precipitation amount on wet days and a 1% decrease in

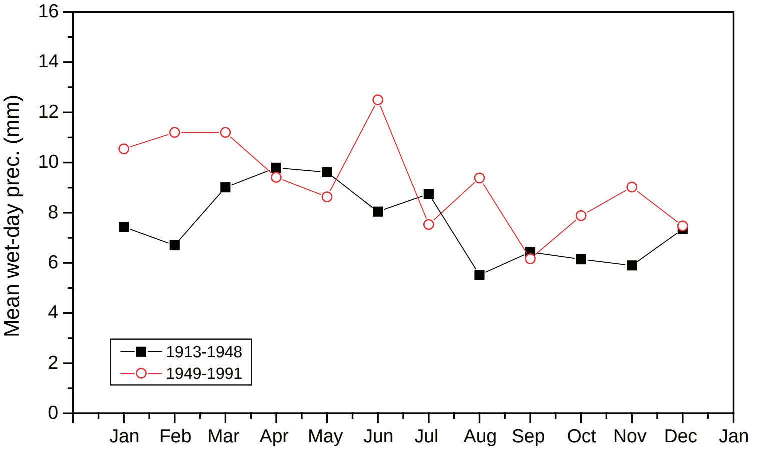

Fig. 3. Mean wet day precipitation between the two contrasting periods for Sydney.

the number of wet days on average. The reduction in the number of wet days is a net result of a slight increase in wet-following-wet transition probability (0.004) and a slight decrease in wet-following-dry transition probability (−0.006) (see Eq. (9)). On a seasonal basis, the increase in the wet day precipitation (35%) in summer (October–March) is much higher than that in winter months (11%) (Table 2). It was also found that on a monthly basis, changes in the standard deviation in wet day precipitation are significantly correlated with the change in wet day precipitation amount ($r^2=0.81$). No significant correlation between changes in wet day precipitation and skewness coefficient was detected ($r^2=0.06$), although the skewness coefficient tends to increase with an increased wet-day precipitation.

The number of wet days depends on the transition probabilities (Eq. (9)). The change to the wet-following-wet transitional probability was found to positively correlate with the change to wet-day precipitation ($r^2=0.62$), although the change to the number of wet days is small and insignificant between the contrasting periods. No significant correlation between changes in wet day precipitation and wet-following-dry transition probability was detected ($r^2=0.01$).

In terms of the mean maximum 30-min rainfall intensity, the increase in summer (October–March) is 28%, while the increase is only 2% for winter months (April–September) (Table 2 and Fig. 4). The seasonal contrast is much greater with respect to peak intensities than the wet day precipitation (cf. Figs. 3 and 4). The magnitude of the increase in peak intensity is less than that in both wet-day precipitation and total precipitation. The change in mean maximum 30-min rainfall intensity is also significantly related to the changes in mean precipitation amount on wet days ($r^2=0.81$). The distribution of the time to peak parameter for CLIGEN is similar for both periods, although it is more likely for rainfall intensity to peak in the latter part of a storm in the relatively wet period than in the dry period with the median tp value reduced from 0.65 for the first period to 0.62 for the second period.

To present a consistent methodology, changes in precipitation-related parameters for CLIGEN were correlated with the change in mean monthly rainfall totals using Eq. (12). All the significant relationships are summarised in Table 3 and presented in Fig. 5. It can be seen that the strongest of the relationships is between the changes in average wet day

Table 2
Change in rainfall in Sydney between two contrasting periods

	1913–1948	1949–1991	Change (%)
Total rain (mm/year)	1106	1339	21
Summer (October–March)	502.5	719.3	43
Winter (April–September)	603.4	619.6	3
Wet-day rain (mm/day)	7.6	9.2	22
Summer (October–March)	7.1	9.6	35
Winter (April–September)	8.0	8.9	11
No. of rain days	144.3	142.8	−1.0
Summer (October–March)	70.6	74.6	5.6
Winter (April–September)	73.7	68.3	−7.4
Max. 30-min intensity (mm/h)	18.5	21.5	16
Summer (October–March)	20.1	25.7	28
Winter (April–September)	16.9	17.2	2

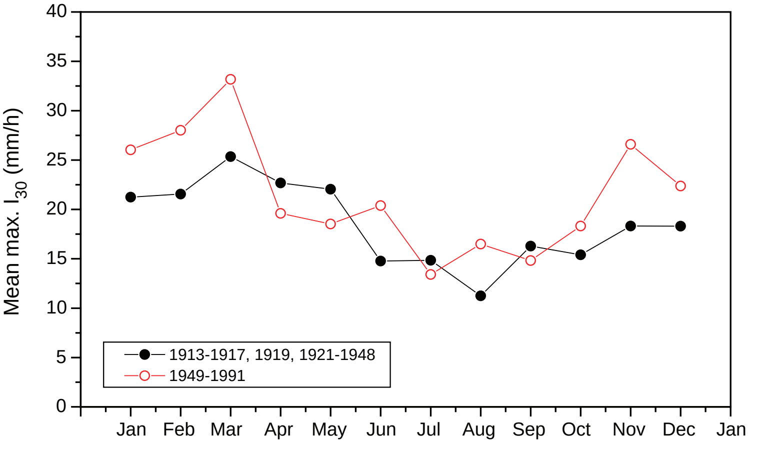

Fig. 4. Mean maximum 30-min rainfall intensity between the two contrasting periods for Sydney.

precipitation and those in mean monthly precipitation, while no significant correlation could be established between changes in mean monthly precipitation and those in the skewness coefficient for wet day precipitation and those in wet following dry transition probabilities. Parameter values presented in Table 3 reinforced the notion that most of the increase in precipitation is a result of an increase in wet day precipitation. Furthermore, the increase in the standard deviation is greater than that in the wet day precipitation, implying the variability of wet day precipitation has increased since the late 1940s in Sydney. The relationship between changes in peak 30-min intensity and the mean monthly precipitation shows that the change in peak intensity is about half the change in total rainfall.

Predicted runoff and soil loss with WEPP shows that the simple proportional adjustment would lead to the greatest impact on runoff and soil loss for precipitation change scenarios given the same amount of rainfall change, while the impact is the smallest with half of the change attributed to wet day precipitation amount and the other half to the number of wet days (Fig. 6). Impacts on runoff and soil loss using the relationship between changes in CLIGEN parameters and those in monthly rainfall developed based on historical data for Sydney lie in between the two extremes. The simulated results are closer to those using the simple proportional adjustment to rainfall amount, especially for predicted runoff, because most of the rainfall increase since the late 1940s can be attributed to the increase in precipitation amount on wet days rather than an increase in the number of wet days. Simple proportional adjustment to generated precipitation sequences brought about maximum

Table 3
Significant relationships between percentage changes in CLIGEN parameter values and mean monthly rainfall in Sydney

Parameter	Coefficient α in Eq. (12)	r^2
Mean wet day precipitation	0.8096	0.91
Standard deviation of wet day precipitation	1.0118	0.58
$\Pr(W\|W)$	0.0991	0.47
I_{30}	0.3464	0.67

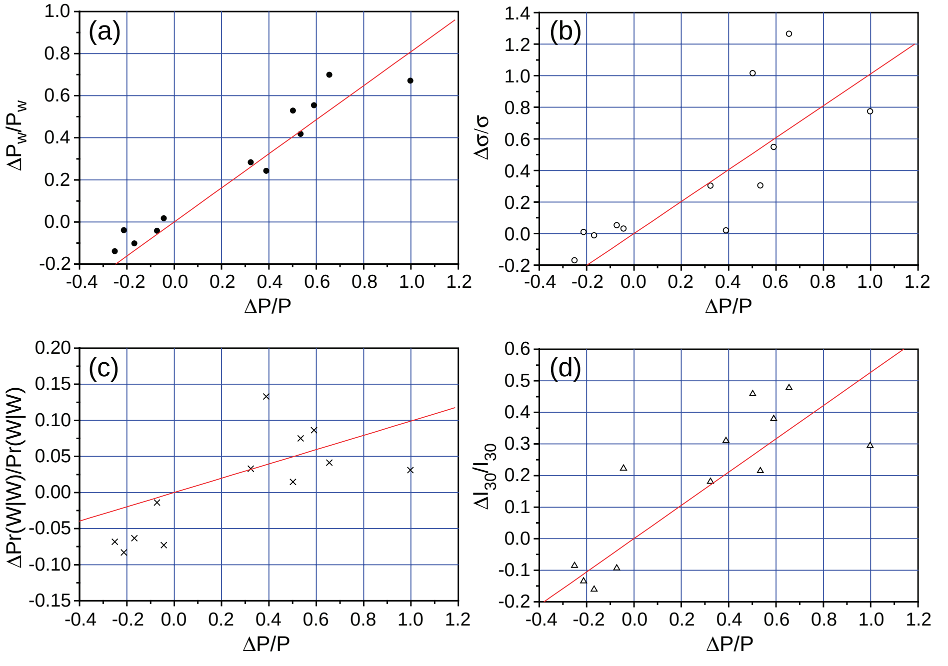

Fig. 5. Relationships between changes in mean monthly rainfall and (a) wet day rainfall; (b) standard deviation of wet day rainfall; (c) wet-following wet transition probability; and (d) mean monthly maximum 30-min rainfall intensity for Sydney.

impacts on predicted runoff and soil loss predicted with WEPP for the site. Compared to the simple adjustment scheme and that using relationships between changes in precipitation and those in other CLIGEN parameters, attributing precipitation changes evenly to the change in wet day precipitation and that in the number of wet days has led to an under-estimation of the magnitude of the impact for the site.

Proportional adjustment to generated precipitation sequences guarantees the amount of change intended. Adjusting CLIGEN parameters cannot in general ensure that the generated precipitation will have the desired magnitude of change for the following reasons. CLIGEN is a stochastic weather generator; each run can therefore produce a random realization of the underlying statistical models and associated parameter values only. The exact and prescribed change cannot in general be realised without a rescaling process similar to proportional adjustment to all generated precipitation values. Precision of input parameter values for CLIGEN also limits the feasible magnitude of change, a fact not widely recognised in literature. For instance, 0.59 and 0.27 are typical values for wet-following-wet and wet-following-dry transition probabilities, respectively, for the Sydney site. If we increase both probabilities by 0.01, the minimum feasible change to these probabilities because transition probabilities are accurate to 2 decimal places in all CLIGEN input parameter files, we would increase the number of wet days by 4%. If we decrease these by 0.01, we would decrease the number of wet days by 12%. Therefore, there is a limit to the minimum change and minimum change increment that can be made to CLIGEN input parameters. Lastly, percentage changes

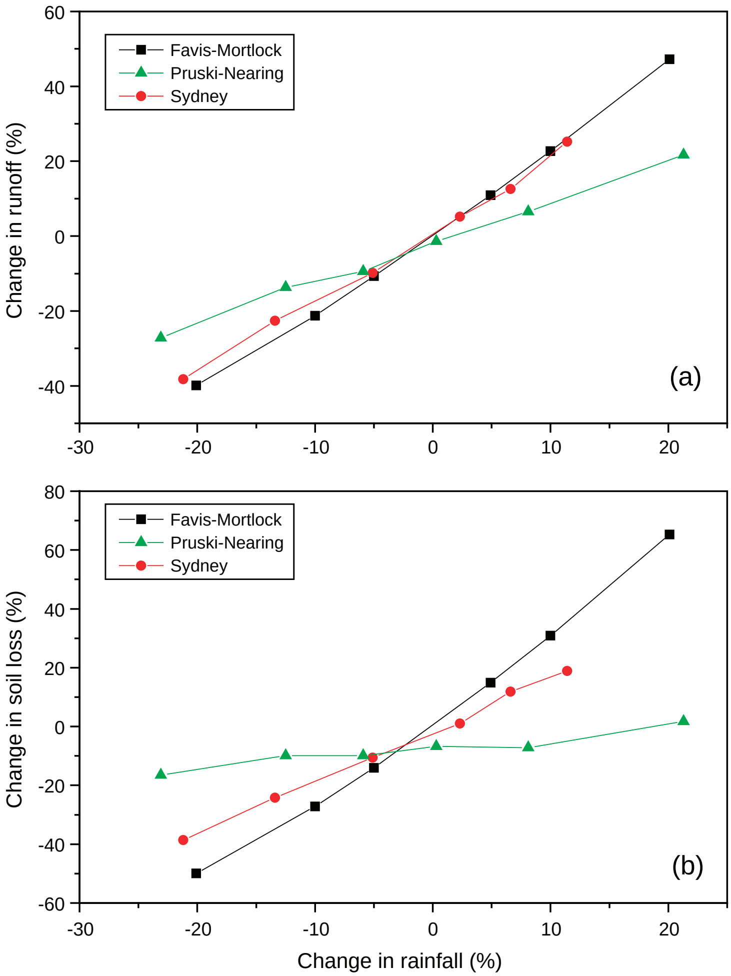

Fig. 6. Changes in runoff and soil loss predicted with WEPP as a result of prescribed changes to rainfall amount using three different adjustment schemes.

are simply not additive unless the changes are fairly small. Ten percent increase in the wet day precipitation amount and 10% increase in the number of wet days will lead to an increase of 21% in total precipitation. Since the change in the number of wet days is further determined by the change in the transition probabilities, the combined effects of adjusting all the parameters can be complicated (see Eqs. (10) and (11)).

4. Discussion and conclusion

This study is made possible with long-term daily and 6-min rainfall for the Sydney site. This unique data set, however, has limited the spatial scope of this study. There were simply no 6-min rainfall data in this region where rainfall has significantly increased since the late 1940s. If we are only concerned with daily rainfall amounts, high-quality data are available for 181 sites in Australia (Lavery et al., 1992; Haylock and Nicholls, 2000). These daily data can be used to develop relationships for CLIGEN parameters with respect to daily precipitation in a further study.

Detailed analysis of historical weather data from regions with significant climate change in the recent past can inform CLIGEN users of how to adjust its precipitation-related parameter values and how to maintain the correlative structure among these parameters. This study shows that for Sydney where rainfall has increased since the late 1940s, which is typical of a large area in southeastern Australia, most of the increase in rainfall is a result of the increase in the wet day rainfall amount. The increase in the standard deviation of wet day rainfall amount is greater than that in the mean, implying a greater rainfall variability during wetter periods for this site. The wet-following-wet transition probability, and maximum 30-min rainfall intensity are all positively and significantly correlated with the change in wet day precipitation. The change in peak intensity is about half the change in rainfall amount for this site investigated. Simultaneous adjustment of all these parameters is needed for realistic simulation of precipitation change scenarios for the region. Using simple proportional adjustment to generated precipitation sequences would lead to maximum impacts on runoff and soil loss predicted with WEPP, while attributing precipitation change equally to the change in wet day precipitation and that in the number of wet days would under-estimate the magnitude of the impact considerably for the site.

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