Estimating areal mean monthly time series of rainfall+

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Abstract

Estimated time series of mean monthly rainfall over catchments are used extensively in water resources analyses and planning in Southern Africa. In this paper the existing method of estimating the catchment mean monthly time series is compared with a newly developed technique. It is not possible to determine a true rainfall surface and therefore no statement is made in this paper regarding the goodness of fit between the hypothetical true surface and the estimated surfaces.

The estimates produced by the two methods are compared for various catchment locations, sizes, topographic and climatological regimes and rain-gauge coverages. The analysis reveals only small differences between the estimates on large catchments with an adequate rain-gauge coverage. However, on smaller catchments with poor rain-gauge coverage and steep rainfall and altitude gradients the two techniques produce markedly different estimates of the monthly mean rainfall time series.

Further research is required before it is possible to make a definitive statement with regard to which of the techniques is better. However, at this stage it is sufficient to note the substantial differences and therefore to proceed with caution when employing existing techniques in complex areas.

Introduction

In Southern Africa water budget modelling for large catchment water resources analyses is conducted primarily at the monthly time step and through the use of the Pitman Monthly Model, WRSM90. Unfortunately poor spatial and altitudinal distribution of rainfall stations prevails, generally, in the key water resources areas of the region. This is particularly so in mountain and other small catchments and in the catchments feeding many of the short coastal rivers on our eastern seaboard. Midgley et al. (1983) warn that care should be taken in estimating the rainfall input to the Pitman Monthly Model in such catchments. Midgley and Pitman (1969) found, for example, that an underestimation of catchment rainfall by 10% at 1 300 mm/a can lead to an annual streamflow underestimation of 26%. Improved techniques for estimating monthly mean rainfall time series over such catchments are thus desirable.

In this paper the gridded images of mean annual precipitation (MAP) developed by Dent et al. (1989) were utilised in the formulation of a new approach to the areal distribution of monthly rainfall. The methodology includes elements of interpolation from all gauges both inside and outside the catchment and a pixel by pixel weighting of these interpolated values according to the MAP estimates of Dent et al. (1989). For the sake of convenience and brevity this new technique shall be referred to as the ACRU3M method and the Pitman Monthly Model method (the HDYP08 routine) as the PMM method.

One of the difficulties experienced when developing a new technique for estimating the areal distribution of rainfall is that the true rainfall surface is not known. It is therefore not the objective of this paper to make a statement with respect to the goodness of fit between the true surface and the estimated surface. Rather it is intended to show that there is a difference in the estimates produced by this technique and those estimates of monthly rainfall produced using the technique outlined by Pitman (1973).

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Pitman monthly model and ACRU3M methods

The PMM method followed that outlined by Pitman (1973) wherein the monthly rainfall totals at each gauge are expressed as a percentage of the MAP at the gauge. These monthly percentage values are averaged to yield the catchment percentage values which are then converted to average depths by multiplying by the catchment MAP. In this study the catchment MAP utilised in the PMM method was derived from the digital estimates of MAP reported by Dent et al. (1989).

The ACRU3M model calculates the monthly rainfall at each gauge as a percentage of the MAP at that gauge. These percentages are then interpolated onto a 1' x 1' grid. The non-operational gauges are ignored in each successive monthly interpolation exercise. This grid of values is then multiplied by the MAP grid described by Dent et al. (1989) to yield a monthly rainfall surface in grid form. Finally the grid values, within the predefined catchment area, are averaged for each month to form the areal mean monthly rainfall time series.

Topographical and rainfall surface complexity as well as the location and representativeness of rainfall stations have an influence on the quality of the estimates of monthly rainfall by the PMM and ACRU3M methods. One of the objectives in developing the ACRU3M method is to lessen this influence and to enable reasonable estimates to be made in areas of complex topography and climatology and which are not well served by rain gauges.

Comparison of methods

In comparing the relative performance of the PMM and ACRU3M models it was decided to investigate the manner in which the monthly rainfall estimates would vary according to:

- The areal extent
- The physiographic complexity
- The variability in mean annual precipitation (MAP) in the area under investigation.

The analyses were therefore conducted in three areas viz. the Natal Drakensberg/Lesotho, in the Langkloof in the South-

Western Cape (west of longitude 24°), specifically because of the complex nature of the rainfall surfaces in these areas and in the Southern Transvaal. These locations are shown in Fig. 1. The results are presented in the form of a frequency analysis of absolute differences between the two methods (Figs. 2 to 7 and Tables 1 to 3).

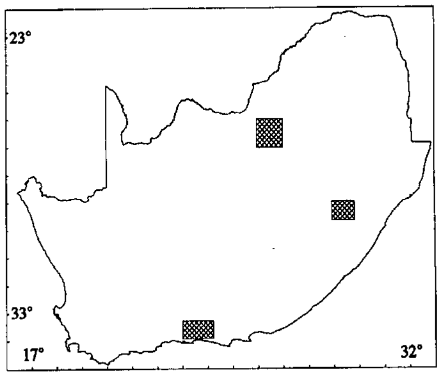

Figure 1
Location of the three study areas in Southern Africa

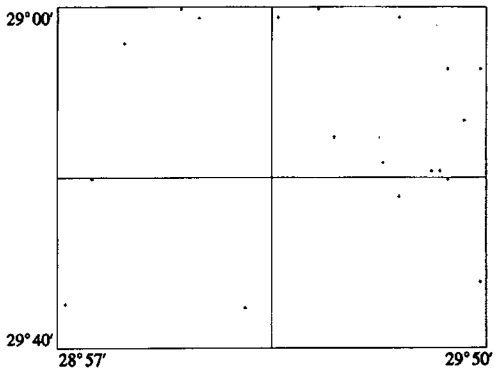

Figure 2
Location of rain gauges and blocks in the Drakensberg/Lesotho study area

TABLE 1
INDICES OF RAINFALL AND PHYSIOGRAPHY IN THE DRAKENSBERG/ LESOTHO STUDY AREA

Block	MAP (mm)	SD MAP (mm)	SD Alt (m)	Alt (m)	No. of gauges
Bottom left	672	224	306	2616	2
Top left	759	318	407	2592	4
Top right	1047	219	389	1700	10
Bottom right	992	169	395	1817	5
Left blocks	717	281	360	2605	6
Right blocks	1019	195	388	1749	15
Total area	863	283	568	2182	21

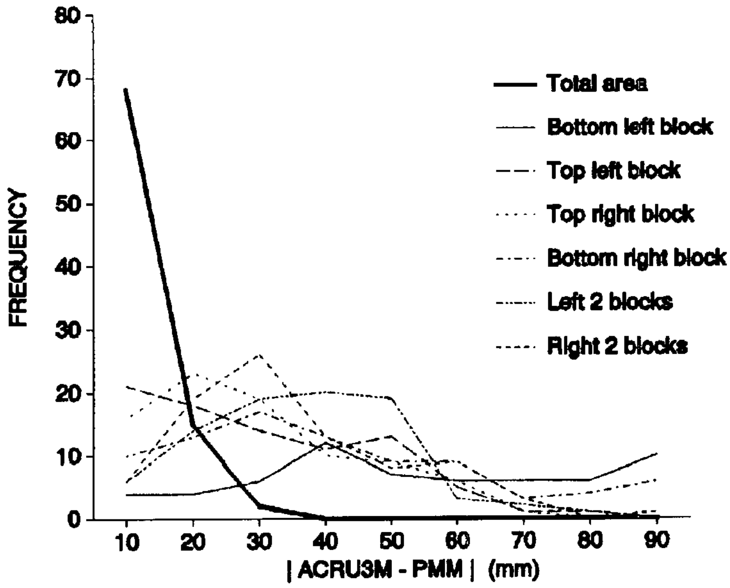

Figure 3
Frequency analysis of the absolute difference between areal mean monthly January rainfall estimates using the ACRU3M and PMM methods in the Drakensberg/Lesotho study area

TABLE 2
INDICES OF RAINFALL AND PHYSIOGRAPHY IN THE LANGKLOOF STUDY AREA

Block	MAP (mm)	SD MAP (mm)	SD Alt (m)	Alt (m)	No. of gauges
Bottom left	691	214	288	749	15
Top left	353	156	190	932	9
Top right	346	172	231	840	6
Bottom right	656	226	257	745	7
Left blocks	521	251	258	843	24
Right blocks	499	252	244	785	13
Total area	509	252	252	808	37

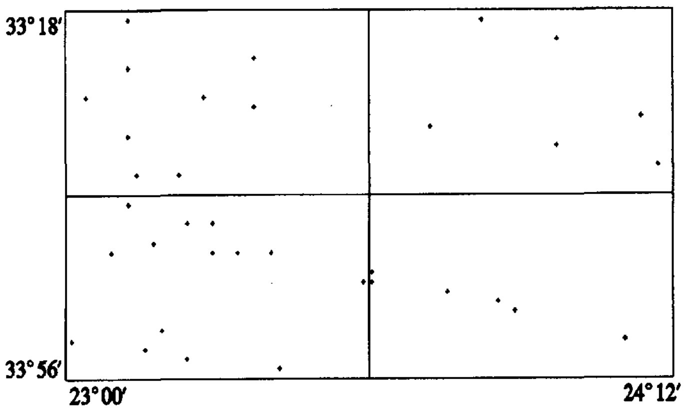

Figure 4
Location of rain gauges and blocks in the Langkloof study area

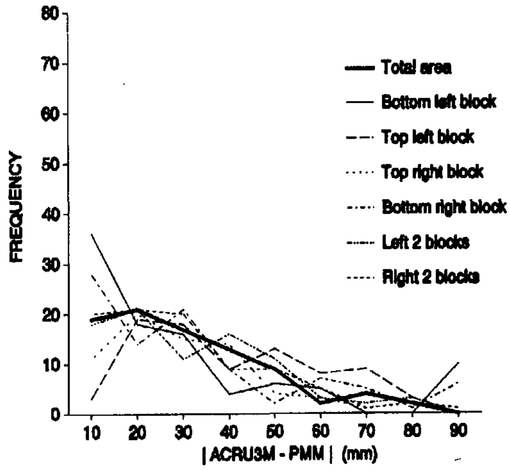

Figure 5
Frequency analysis of the absolute difference between areal mean monthly January rainfall estimates using the ACRU3M and PMM methods in the Langkloof study area

Conclusions

It is evident from the results that in certain circumstances there are important differences between the monthly mean rainfall estimate over an area using the two techniques. In areas of complex physiography and highly variable MAP the differences between the estimates using the PMM and ACRU3M become marked. The ACRU3M method incorporates the benefits of a pixel by pixel weighting for the region as derived by Dent et al. (1989). The PMM on the other hand is reliant on a single weighting. In the PMM method the distribution of rain gauges is therefore required to be representative of the area under study before the method can be applied with confidence. This point is stressed by Pitman (1973) and by Midgley et al. (1983).

It is not intended that a statement regarding the goodness of fit between the two and estimated rainfall surface be made in this paper. However, if reference is made to Schäfer (1991) and Schäfer et al. (1991) in which estimates of daily rainfall by this method are compared with observed rainfall then it is probable that the ACRU3M method is producing the better estimates of the monthly time series of rainfall over catchments with complex monthly rainfall surfaces.

The ACRU3M method is considerably more intensive computationally than the PMM method. However, given current computing power on scientific workstations this should not prevent its use. Further research is required to establish which of these two methods perform best and in which areas of Southern Africa they do so.

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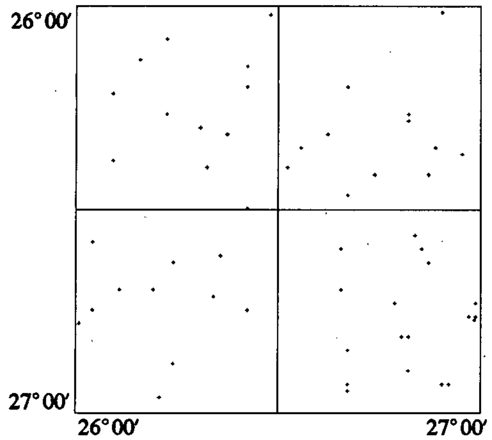

Figure 6
Location of rain gauges and blocks in the Southern Transvaal study area

TABLE 3
INDICES OF RAINFALL AND PHYSIOGRAPHY IN THE SOUTHERN TRANSVAAL STUDY AREA

Block	MAP (mm)	SD MAP (mm)	SD Alt (m)	Alt (m)	No. of gauges
Bottom left	569	10	54	1492	12
Top left	577	12	33	1482	12
Top right	572	25	52	1493	12
Bottom right	581	16	56	1377	19
Left blocks	573	12	45	1487	24
Right blocks	576	21	80	1435	31
Total area	574	17	70	1462	55

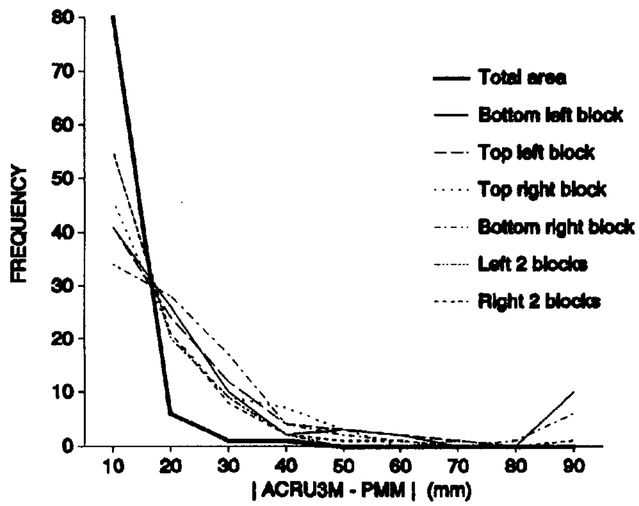

Figure 7
Frequency analysis of the absolute difference between areal mean monthly January rainfall estimates using the ACRU3M and PMM methods in the Southern Transvaal study area

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