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 ACRTJ3M 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-