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MOVING AVERAGES AND CYCLIC PATTERNS (NOTE)

Robert L. Beschta
School of Forestry, Oregon State University, Corvallis, OR. 97331, U.S.A.

The inherent variability displayed by many hydrological time series usually masks trends and periodic patterns. This situation has often led to "smoothing" the original time series so that the effect of random variations are reduced and trends or cyclical patterns enhanced. One of the simplest, and perhaps most common, smoothing technique employed is that of fitting a moving average (e.g. Thompson and Ibbitt, 1978, Tomlinson, 1980b). In the case of a simple moving average, all values are weighted equally. The following example, utilising annual precipitation data, illustrates how the combination of moving averages and autocorrelation techniques can be used to identify possible periodicities. In contrast, Vines and Tomlinson (1980) and Tomlinson (1980a, 1981) have used a filtering procedure to analyse temporal oscillations in time series of precipitation and river flow.

Hayward (1980), indicated that annual precipitation for the Mt Torlesse rainfall station exhibited a cyclic pattern, based on observations of the 3-year moving average. Because a periodic component has been suggested, but not characterised, I have selected this time series for further analysis. I have also included an additional six years of data (1976 through 1981) that were not available when Hayward conducted his original evaluation. The Mt Torlesse rainfall station is located approximately 60 km west of Christchurch near the base of the Torlesse Range, at an elevation of 380 m. The station has been in continuous operation since January 1909.

Annual precipitation averages 1032 mm at the Mt Torlesse station with a standard deviation of 175 mm. Coefficients of skewness and kurtosis for annual totals are -0.2 and 2.9, respectively. These compare quite closely to theoretical values of zero and three for a normal distribution. Regressing annual precipitation with time (in years) indicates no long-term trend in the data. Thus, the time series appears to be stationary (at least with regard to the mean) and normally distributed. There is a high degree of variability throughout the 73-year period of record (Fig. 1-A). Even with the smoothing time series (Figure 1-B), developed from 3- and 7-year moving averages, the occurrence of a definite periodic component remains somewhat obscure.

Autocorrelation of the annual precipitation data (Figure 2-A) indicates that little dependency and periodicity apparently exist in this time series, and suggests annual precipitation amounts are almost entirely independent from one year to the next.

Correlograms developed from the 3-, 5-, 7- and 9-year moving averages (Figure 2-B) provide a somewhat different result. For example, the 3-year

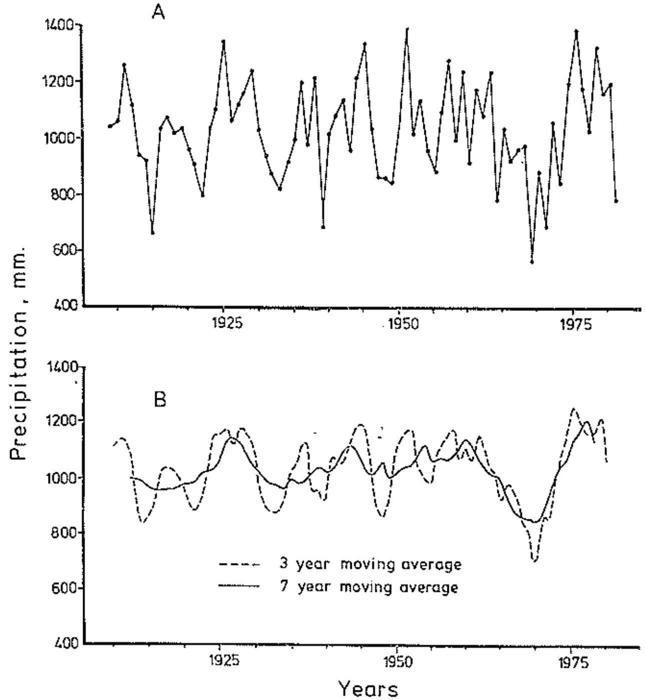

FIG. 1—(A) Annual precipitation and (B) moving averages of annual precipitation for the Mt Torlesse rainfall station.

moving average displays prominent negative correlation coefficients at lags of approximately 5 and 10 years. These would correspond to cycles with wavelengths of 10 and 20 years respectively, and are slightly shorter than major cycles identified by Tomlinson (1980a). As the time base of the moving average is increased up to 9 years, the shorter oscillatory component disappears from the correlograms. The loss of information related to periodic components with wave-lengths less than 2k in length represents a potential problem with moving averages. Information about periodic components of relatively short wavelengths, in relation to the length of the moving average, may thus be lost when the time base of the moving average is increased. It should also be noted that correlation coefficients for $k<m$, where m represents the number of successive values used to calculate a moving average, are difficult to interpret because of overlapping values in the moving-average calculations. The uniformly decreasing correlation coefficients when $o<k<m$ (Figure 2-B) reflect an introduced deterministic component as a result of comparing time series of moving averages that have overlapping values.

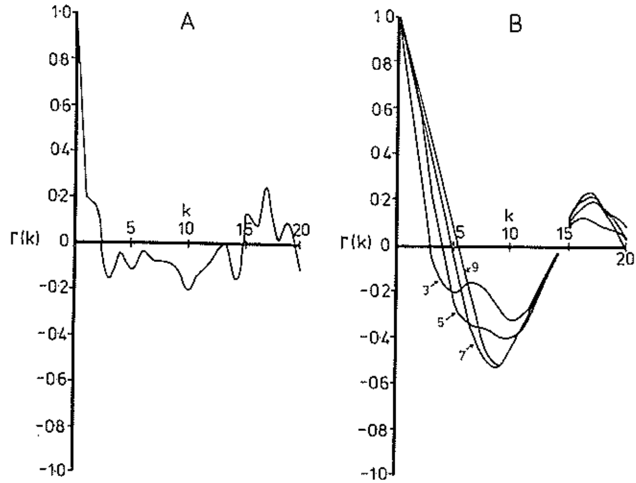

FIG. 2—Correlograms of (A) annual precipitation and of (B) 3, 5, 7 and 9 year moving averages for the Mt Torlesse rainfall station.

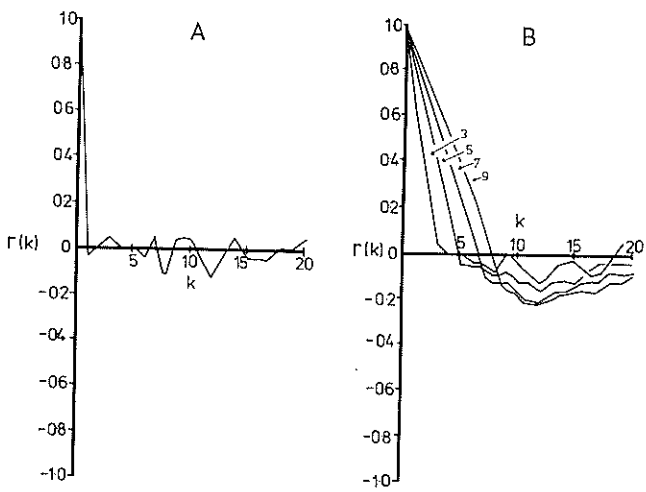

FIG. 3—Correlograms of (A) a generated time series, with mu=0 and sigma=1, and of (B) 3, 5, 7 and 9 point moving averages.

The negative correlation coefficients in Figure 2-B are most pronounced at k=9 for both the 7- and 9-year moving averages. These results would seem to indicate that an autoregressive model, developed from 7- or 9-year moving averages might be relatively effective at predicting precipitation at the Mt Torlesse station. The wavelength of the periodic component would be about 18 years, or essentially the same as the 18-21 year oscillations in New Zealand's rainfall detected by Tomlinson (1980a, 1980b).

The moving average calculation may have also introduced a certain amount of the periodicity observed in the correlograms. To illustrate this situation, a correlogram was developed from a synthetic time series of normally and independently distributed values. It shows, as expected, relatively small fluctuations of r(k) about zero for $0<k\leqslant 20$ (Figure 3-A). However, correlograms developed from moving averages (Figure 3-B) of the same time series indicate a tendency toward a periodic component with a wave-length greater than 20 time units (lags). There is also a tendency toward more negative correlation coefficients for $5\leqslant k\leqslant 20$ as the number of values included in the moving average calculations is increased from 3 to 9. Increasing the number of values in the moving average has thus introduced an apparent harmonic or oscillatory component. The effect that overlapping values (of the calculated moving averages) have on the correlation coefficient for $k<m$ is again demonstrated in Figure 3-B.

These results indicate several cyclic components exist in the annual precipitation records of the Mt Torlesse rainfall station, with an 18 year cycle being the most pronounced. These results are also similar to those of Vine and Tomlinson (1980) and Tomlinson (1980a, 1981) who analysed hydrological time series from locations throughout New Zealand.

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REFERENCES

Hayward, J. A., 1980: Hydrology and stream sediment from Torlesse Stream Catchment. *Tussock Grasslands and Mountain Lands Institute, Lincoln College, Special Publication No. 17.* 236 pp.

Thompson, S. M., and Ibbitt, R. P., 1978: Smoothing permanent records of lake level. *Journal of Hydrology (NZ), 17(1):* 44-49.

Tomlinson, A. I., 1980a: A non-random feature in New Zealand rainfall. *New Zealand Geographer 36:* 68-72.

Tomlinson, A. I., 1980b: Wet and dry years. *Soil and Water 16(5):* 3-4.

Tomlinson, A. I., 1981: Some variations of rainfall and river flow in New Zealand. *N.Z. Journal of Science 23:* 103-110.

Vines, R. G. and Tomlinson, A. I., 1980: An analysis of New Zealand rainfall, *N.Z. Journal of Science 23:* 205-216.