DESCRIPTION OF VERY WET TO VERY DRY PERIODS AT GROOTFONTEIN, EASTERN KAROO: 1889-2012

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BACKGROUND

Rainfall is an important driver of vegetation productivity, structure and functioning (Gentry, 1988), and hence of forage production and livestock productivity (Behnke & Scoones, 1992). Semi-arid rangelands experience high rainfall variability, and droughts can cause significant changes in botanical species composition (Westoby et al., 1989). The eastern Karoo is an ecotone between the Nama Karoo to the west and semi-arid grasslands to the east, and vegetation composition is driven, inter alia, by rainfall and grazing (O'Connor & Roux, 1995).

Predicting future rainfall patterns is of obvious interest to farmers, and considerable research effort has been focused on describing changes and patterns in rainfall in many areas and at many temporal and spatial scales (Tyson, 1971; Nicholson, 2000; Kane, 2009). While it is usual to focus on trends in actual precipitation, another method is to classify rainfall experienced in a particular time period (e.g. annual, monthly, or seasonal) along a gradient from Very Dry to Very Wet on a percentile basis (Ramos, 2001). Such a classification system can be conceptually more meaningful as it decomposes the continuous nature of rainfall data into easily understood, intuitively manageable classes.

The Grootfontein Agricultural Development Institute has monthly rainfall records dating back to 1888, which lend themselves to such an analysis. A description of other rainfall patterns at Grootfontein on a subset of the data has been undertaken (du Toit, 2010).

The objective of this paper is to provide a descriptive record of rainfall patterns since 1888 using a Very Wet to Very Dry classification system, and to identify statistically significant indicators of pattern.

METHODS

Rainfall data were categorized as follows:

- Annual rainfall (July of year t to June of year t+1. Therefore, a year of e.g. 1973 refers to the period from July 1973 to June 1974).

- Warm season rainfall (October of year t to March of year t+1) and cool season rainfall (April to September of year t).
- Spring rainfall (September to November of year t), summer rainfall (December of year t to March of year t+1), autumn rainfall (April to May of year t), and winter rainfall (June to August of year t).
- Monthly rainfall (for brevity, only the months January, March, May, July, and October were included).

Rainfall data (R) were classified as one of five categories based on percentiles following the method of Ramos (2001): Very Dry ($0<R\leq10$), Dry ($10<R\leq25$), Normal ($25<R\leq75$), Wet ($75<R\leq90$), and Very Wet ($90<R\leq100^{th}$ percentile). This yielded five binomial time series (binomial because a specific year either did or did not fall into any particular class). A 5-year moving average was calculated as an indicator of rainfall stability.

Statistically significant evidence of clumping at multiple scales was explored using both lacunarity analysis and Three-Term Local Quadrat Variance (3TLQV); two methods were used because this is likely to reveal more insight into the distributions than if only one method is used (Dale, 2000; Saunders et al., 2005). Lacunarity analysis describes the gap structure of an object, in this case a binomial time series, at multiple scales (Plotnick et al., 1993). Lacunarity analysis has been offered as a method broadly applicable to ecological data for detecting multi-scale patterns (Plotnick et al., 1996). 3TLQV is a method of describing patterns in data, developed by Hill (1973) that calculates the variance of three contiguous blocks from every possible starting point (i.e. the blocks overlap) along the series. Blocks range in size from small to large, thereby describing overall pattern. Specifically, the scale at which variance peaks is interpreted as being the scale at which pattern occurs (Dale, 2000). Analyses were conducted using the statistical software PASSaGE (Rosenberg & Anderson, 2011).

RESULTS

Annual rainfall shows significant clumping for Very Dry and Wet classes (Figure 1; Figure 5). Two or more Very Dry years, over a period of two to five years, have occurred approximately every twenty years, with the last period being from 1992 to 1994. Wet seasons occurred in the late 1800’s, sporadically from 1924 to 1943, and nine times since 1980. Twelve of the past twenty-eight years, a higher proportion than expected, have been either Wet or Very Wet. Warm season rainfall shows a similar pattern to annual rainfall.

There were no statistically significant groupings for cool season years, although there was approximately double the number of Very Wet cool seasons (nine) from 1925 to 1974 than would be expected.

Very Wet summers showed significant clumping (Figure 2; Figure 5), with eleven of the thirteen Very Wet summers occurring since 1973. Most Very Dry summers occurred either from 1901 to 1911, or from 1964 to 1969. Spring and autumn rainfall did not show any obvious pattern.

January rainfall appears to contribute importantly to summer, warm season, and annual rainfall (Figure 3). Dry and Very Dry January months were scattered approximately randomly over the time series, but there have been twelve Wet or Very Wet Januaries over the past twenty years. The variability of January rainfall has meant that the chance of having Normal rain in that month has declined over time.

March rainfall showed significant clumping for Dry and for Wet years (Figure 5). Dry March months occurred only during the periods from 1889-1909, 1936-1952, and since 1992. The likelihood of having a Wet March appears to have decreased, with only three Wet March months having been recorded since 1950. However, there is no evidence that the likelihood of having a Very Wet March has declined.

There was a significant clumping of Normal rainfall May months, where the likelihood of having Normal rainfall in May was high until about 1920, and has since declined. This may be an indicator of increased variability. July and October months showed no significant patterns.

DISCUSSION

The analyses indicate that rainfall at Grootfontein is not a random process over time, despite the high levels of variability. Of most interest from an agricultural perspective are the findings that firstly there appears to be a repeating pattern of Very Dry annual and warm season rainfall, and that if the pattern continues then some low rainfall seasons can be anticipated within the next few years. Secondly, Very Wet summers have been much more common over the past approximately twenty years than they were before. These two finding are compatible with each other, and may give insight into cyclicity of rainfall at Grootfontein.

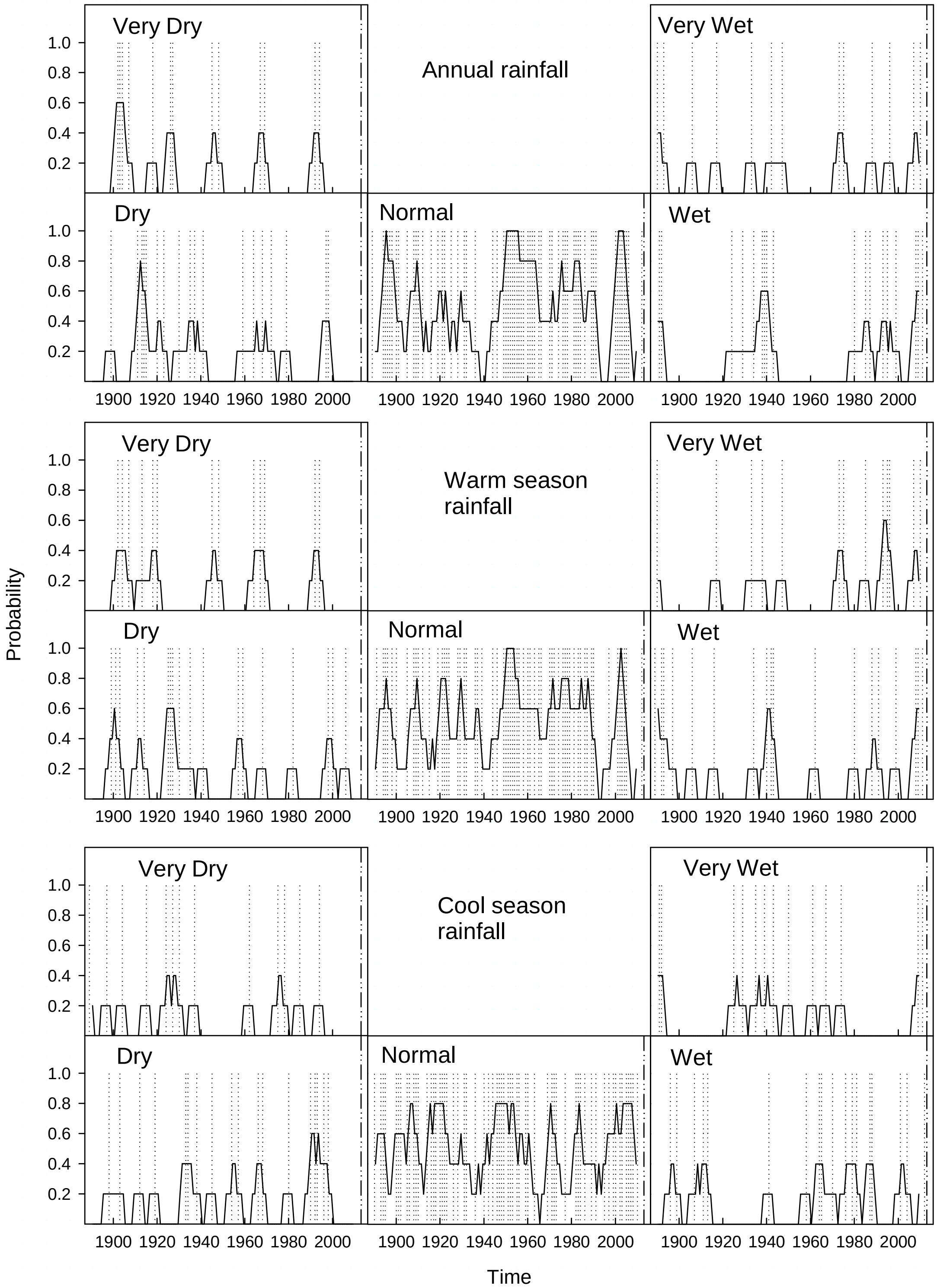

Figure 1. Occurrence of rainfall of various classes (vertical dotted lines) for annual, warm season, and cool season rainfall at Grootfontein. Solid lines are a 5-year moving average; the dotted-and-dashed line shows 2013 for perspective

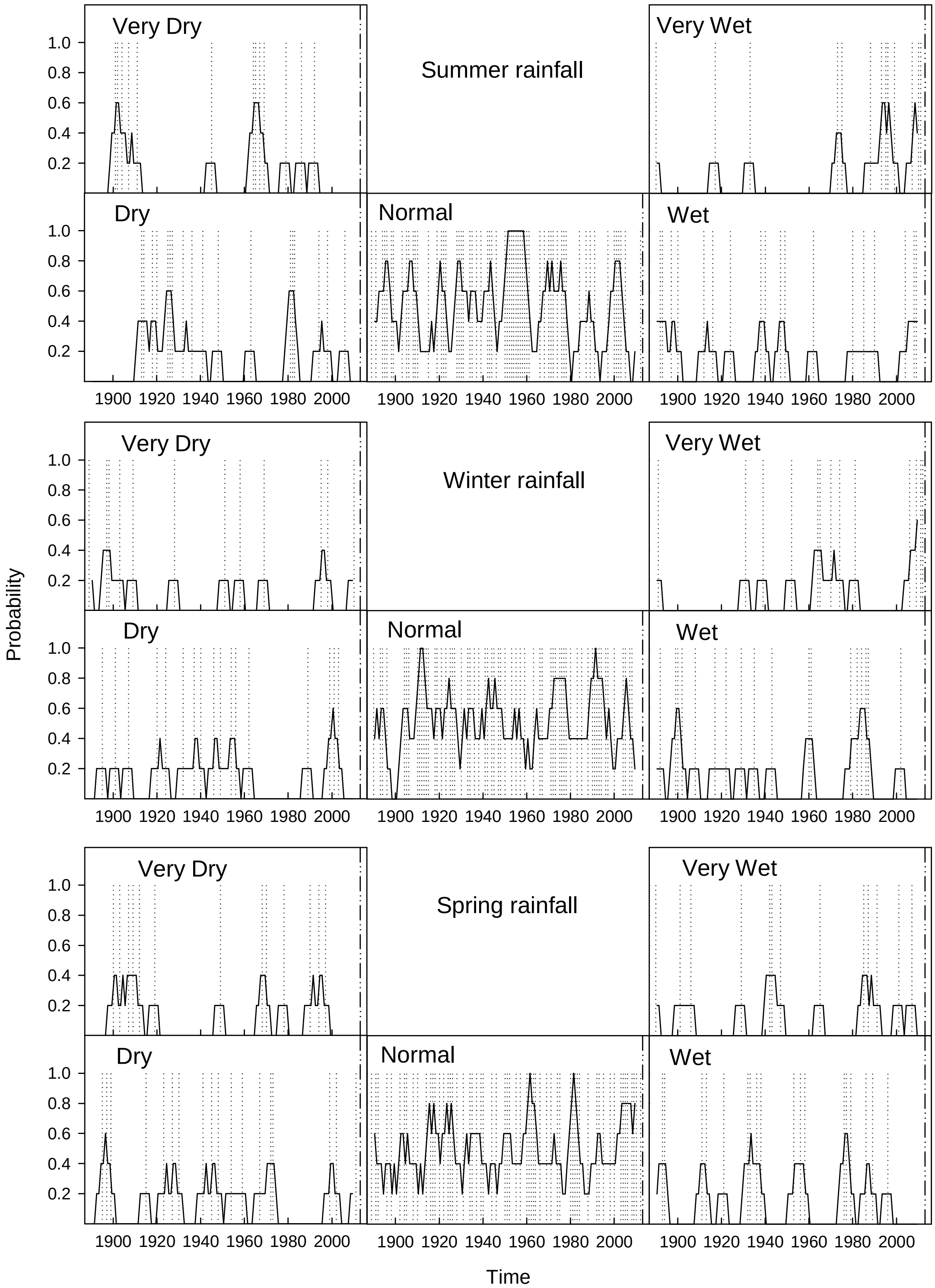

Figure 2. Occurrence of rainfall of various classes (vertical dotted lines) for summer, winter, and spring rainfall at Grootfontein. Solid lines are a 5-year moving average; the dotted-and-dashed line shows 2013 for perspective

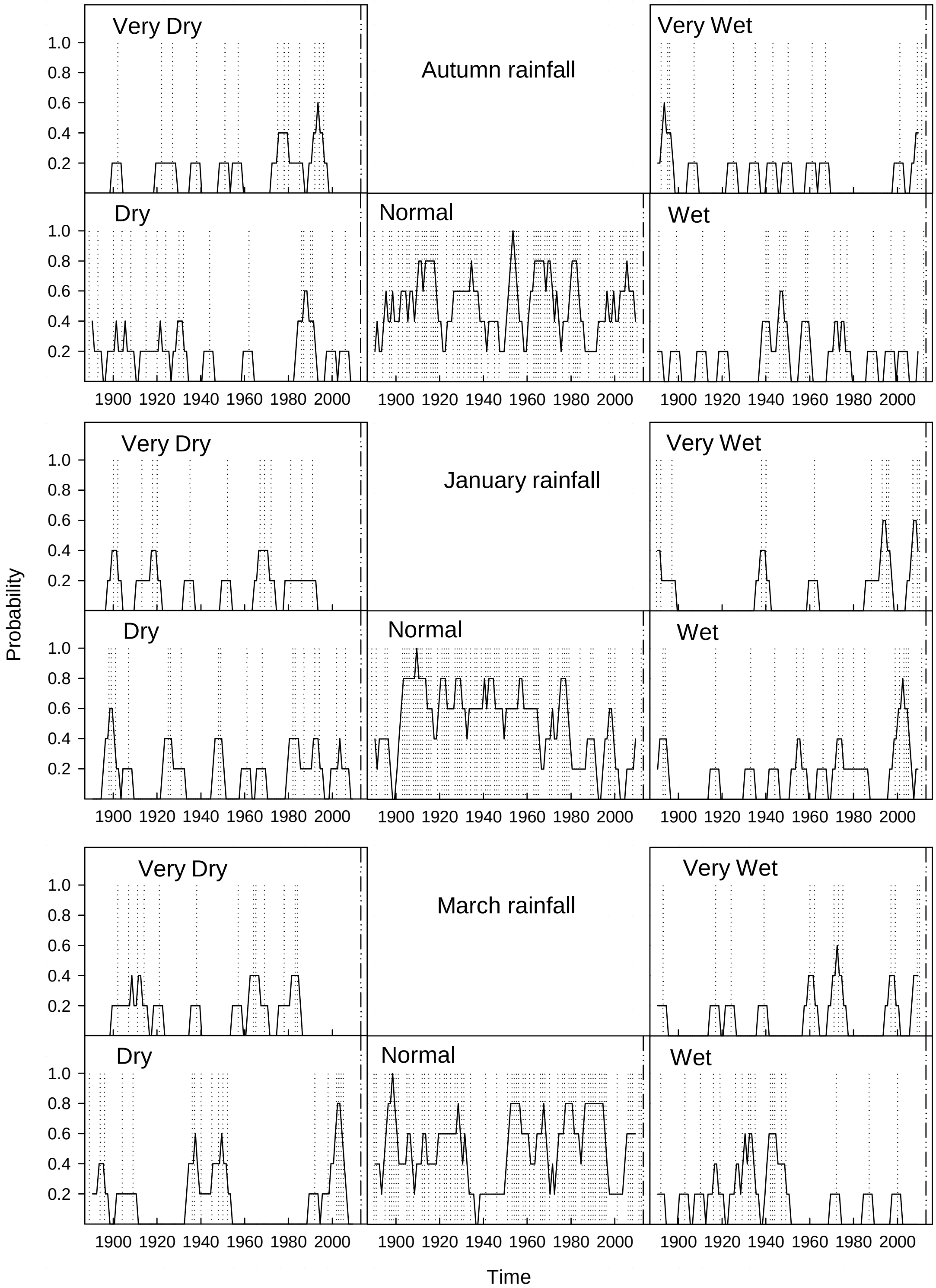

Figure 3. Occurrence of rainfall of various classes (vertical dotted lines) for autumn, January, and March rainfall at Grootfontein. Solid lines are a 5-year moving average; the dotted-and-dashed line shows 2013 for perspective

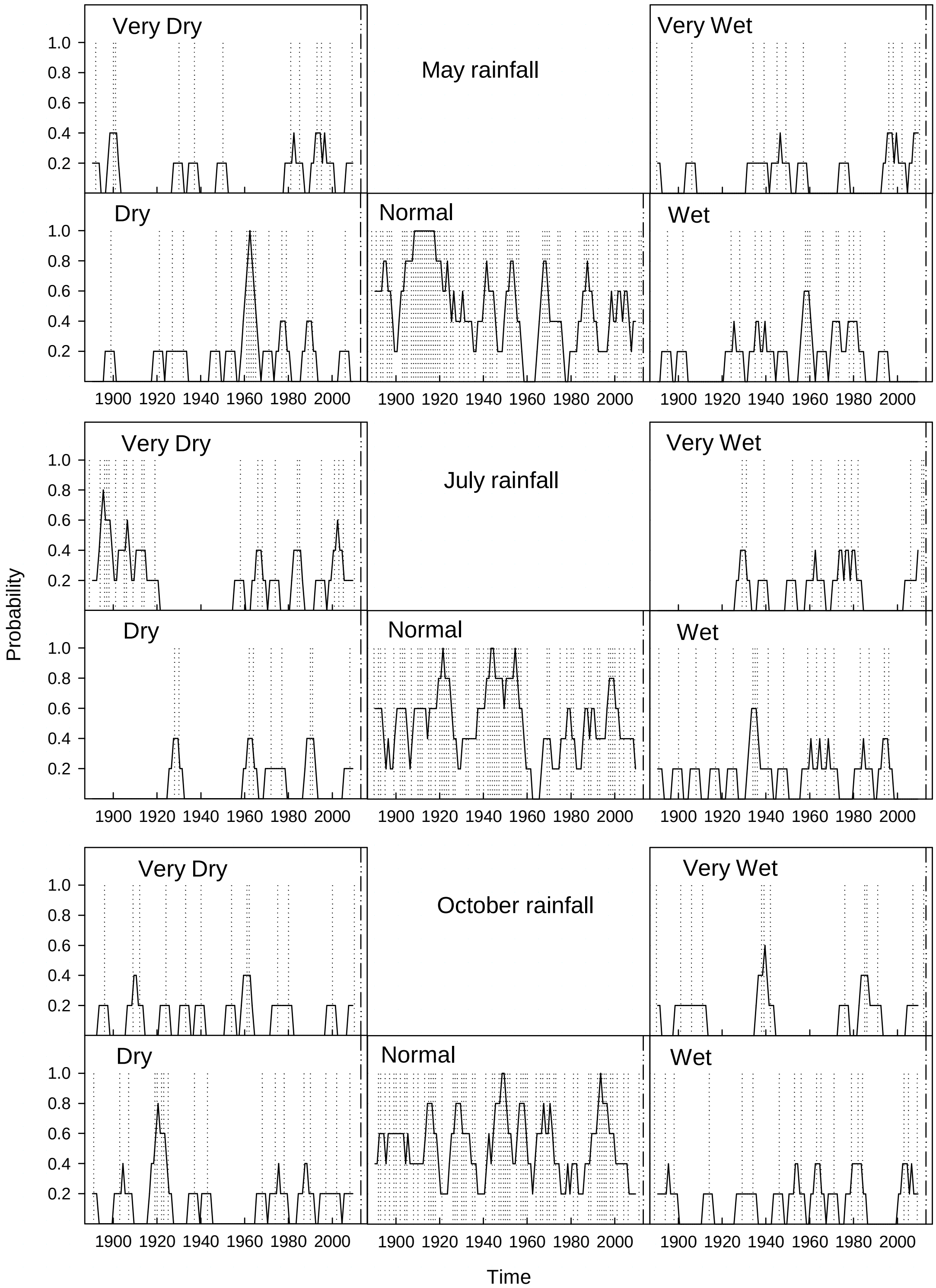

Figure 4. Occurrence of rainfall of various classes (vertical dotted lines) for May, July, and October rainfall at Grootfontein. Solid lines are a 5-year moving average; the dotted-and-dashed line shows 2013 for perspective

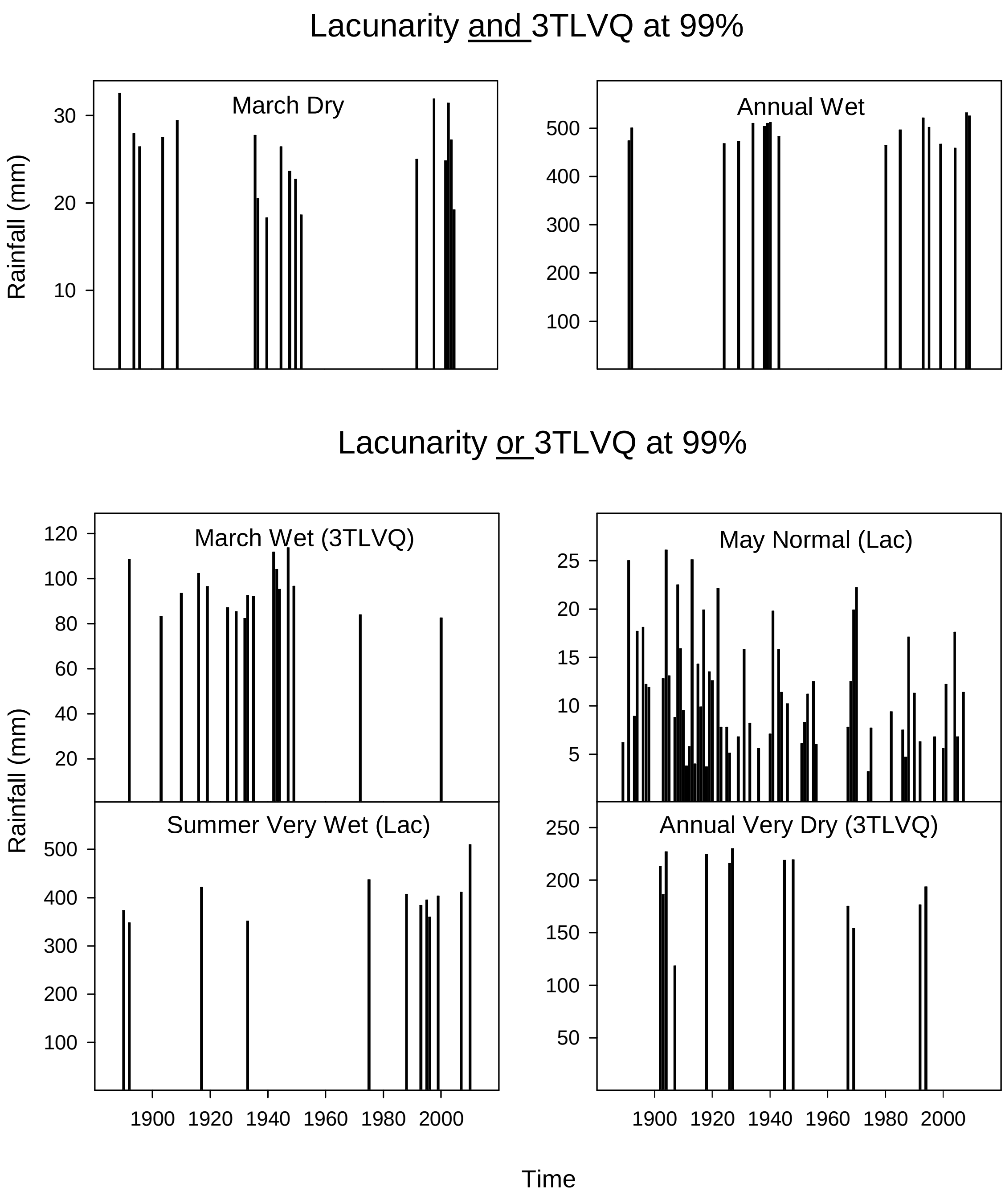

Figure 5. Evidence of clumping of various classes (Very Wet to Very Dry) of rainfall over time using lacunarity (Lac) and three-term local quadrat variance (3TLQV) analysis

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