

Notes

The purpose of "Notes" is to periodically publish short papers (typically less than five pages in length). There is no specific format or content required for articles published here, but all papers will be peer-reviewed and must be scientifically credible. Authors may contact the Editor about the suitability of manuscripts for this section.

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Polar Plotting of Seasonal Hydrologic and Climatic Data

Abstract

A polar plot form for visualizing changes in seasonal data is presented. This representation treats time as a cyclical variable and removes the winter year-boundary discontinuity created by standard Cartesian plotting methods. Polar plots facilitate visual presentation of changes in the magnitude and phase of environmental variables and allow effective visualization of seasonal patterns. Examples of polar plots are presented using streamflow data from two streams in British Columbia. This method is particularly useful for comparing and contrasting systems that exhibit different patterns of seasonal shifts.

Introduction

The need for improved methods of presenting complex scientific information has been recognized in the statistical literature for some time (Fienberg, 1979). When scientific results are presented to both technical and non-technical audiences, as is often the case in the environmental sciences, this need is especially strong. Recently, formal procedures for identifying effective graphical methods have been proposed (Cleveland and McGill, 1984; 1987). They show how certain graph types can be better than others at presenting certain types of information.

Traditionally, the direction, magnitude, and significance of changes and trends in environmental data have been reported via results from hypothesis tests. As pointed out by Loftus (1993), the graphical presentation of experimental data offers a more effective way of communicating this information to an audience. Overlaying time-series plots of environmental variables (i.e. hydrographs for presenting changes in discharge) is one means of graphically presenting this type of information (e.g. Leith and Whitfield, 1998). However, time-series plots do have drawbacks. These methods can obscure observed changes and

make graphical comparisons between different systems difficult. We present a method developed to better illustrate impacts of climate variations on environmental systems. This method is particularly useful for illustrating changes in the phase and magnitude of seasonal variables.

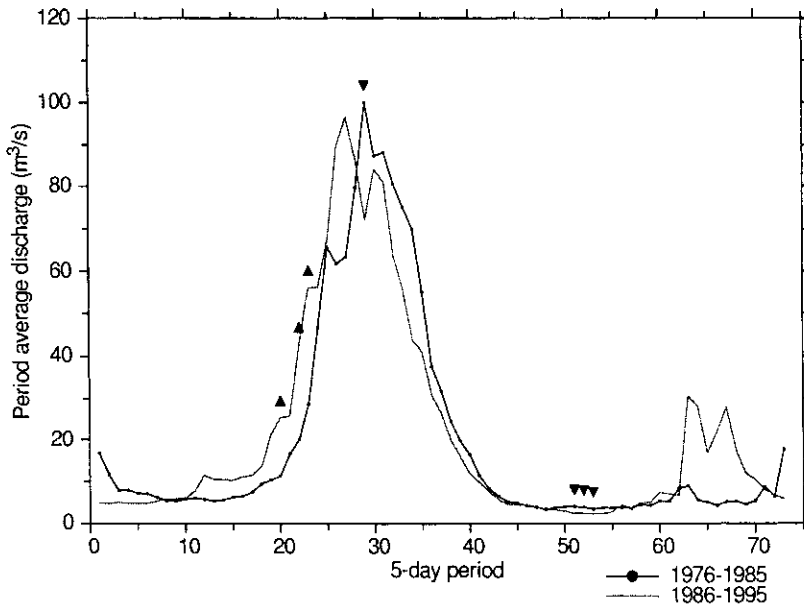
Method

We will illustrate the effectiveness of this presentation method using changes in discharge in streams in British Columbia as an example. Leith and Whitfield (1998) and Whitfield (2000) have shown that the magnitude and timing of runoff events in streams in British Columbia have changed over recent decades. Onset dates of hydrologic spring and fall in streams in south-central B.C. are occurring earlier in the year. From our research perspective, we also deal with coastal streams where the highest discharges are during the winter and lowest during summer.

Traditional hydrographs from two streams in British Columbia during two recent decades are shown in Figure 1. Peak flows from the snow melt driven Tulameen River (at Princeton) occur in spring and summer while peak flows from the rainfall driven Sarita River (near Bamfield) occur

08NL024 TULAMEEN RIVER AT PRINCETON

1760 km²; 49° 27' 27" N, 120° 31' 5" W



08HB014 SARITA RIVER NEAR BAMFIELD

162 km²; 48° 53' 34" N, 124° 57' 54" W

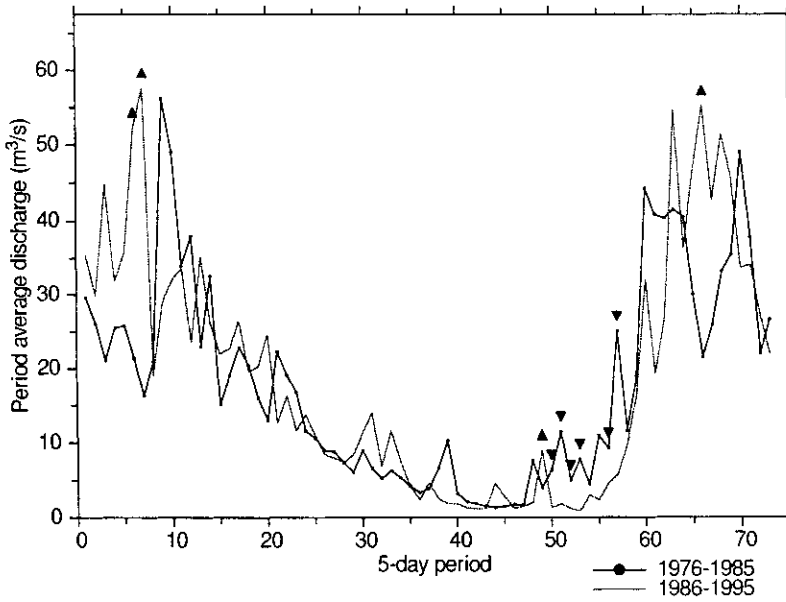


Figure 1. Discharge hydrographs for the Tulameen River at Princeton and Sarita River near Bamfield. Discharge values are decadal means of 5-day averages.

during winter. Arrowheads on each graph indicate periods during which changes in flow between the two decades are statistically significant ($p < 0.05$). Leith and Whitfield (1998) present details of the statistical methodology. The Tulameen River exhibits earlier spring flows and an earlier summer low-flow period; the Sarita River exhibits increases in winter and decreases in summer.

By treating time in a linear fashion, the hydrograph imposes an artificial break in discharge across the winter year-boundary (December-January). Visually, we have found that this discontinuity can be confusing when trying to compare shifts in cyclical variables, such as discharge, which peak at different times of the year. In Figure 1, changes in peak flows that occur in winter, such as those observed in the Sarita River, are de-emphasized when they are split between the two ends of the plot.

We have developed a polar plot form for presenting information on changes in magnitude and phase of seasonal variables. The polar plot form we present treats time in a cyclical fashion. This removes the year-boundary discontinuity and facilitates visual presentation of shifts in magnitude and phase of environmental variables.

Polar plots of the two hydrographs shown previously are given in Figure 2. The rules used to construct these plots are:

1. The beginning of the calendar year is located at the bottom of the graph.
2. The time interval t_i of the data is converted into degrees by $360(t_i - t_{min})/(t_{max} - t_{min})$. The interval of data is indicated by the number of lines, and the names of the calendar seasons are applied for the reader's benefit.
3. The maximum and minimum of the data is determined and used to set the values of the outer ring (maximum) and the inner ring (minimum). The vertical scaling may be either linear or logarithmic.
4. The two data series are plotted, each shaded differently.
5. The area between the curves is shaded dark when the second curve is larger, light when the second curve is smaller.
6. Significance arrows are attached to the curves. If the second curve is significantly larger then a light-shaded up arrow is located on the radial line indicating the time period; if significantly smaller then a dark-shaded down arrow is applied.
7. The time period of the maximum for each data set is determined and a shaded radial line is drawn indicating each period. An arc is then drawn between the two peaks.
8. A vertical bar indicating the vertical scaling is placed to the left, and other details of annotation are applied as appropriate (i.e. station name and numbers).

The essential features of this graphic are:

1. The cyclical view shows the timing of the seasons and shifts between calendar time and ecological time.
2. Differences in discharge between time periods are shaded.
3. Periods exhibiting statistically significant changes are marked with arrowheads. The direction of the arrowheads indicates whether the significant trends are increasing or decreasing.
4. A shaded radial line shows the peak in each decade. An arc between the lines indicates the amount and direction of the shift in the peak.
5. The axis on the left shows the range of values observed at the station; the outer ring is the maximum value, and the inner ring is the minimum value.

Data are plotted with a common temporal scale and a scaled discharge scale to facilitate comparison between systems. Shapes and attributes of multiple polar plots showing different systems can be compared and contrasted quite easily as a result. Plotting with polar coordinates uses direction, angle, and length of the plotted rays and arcs to convey information on the timing and magnitude of discharge events. Use of shading emphasizes the types of changes (increases and decreases), and the area between curves gives an indication of the relative size of changes. The addition of arrows denoting significance of changes allows results of statistical tests to be integrated with graphical cues showing actual magnitudes of observed changes. While similar information could be portrayed on a traditional hydrograph, the visual discontinuity between December and January would still be present.

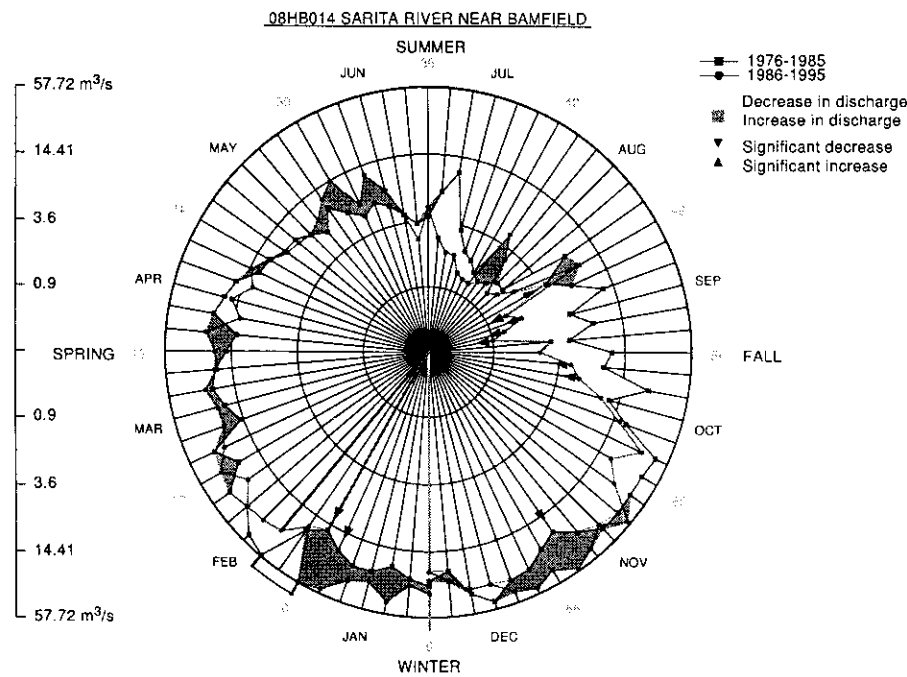
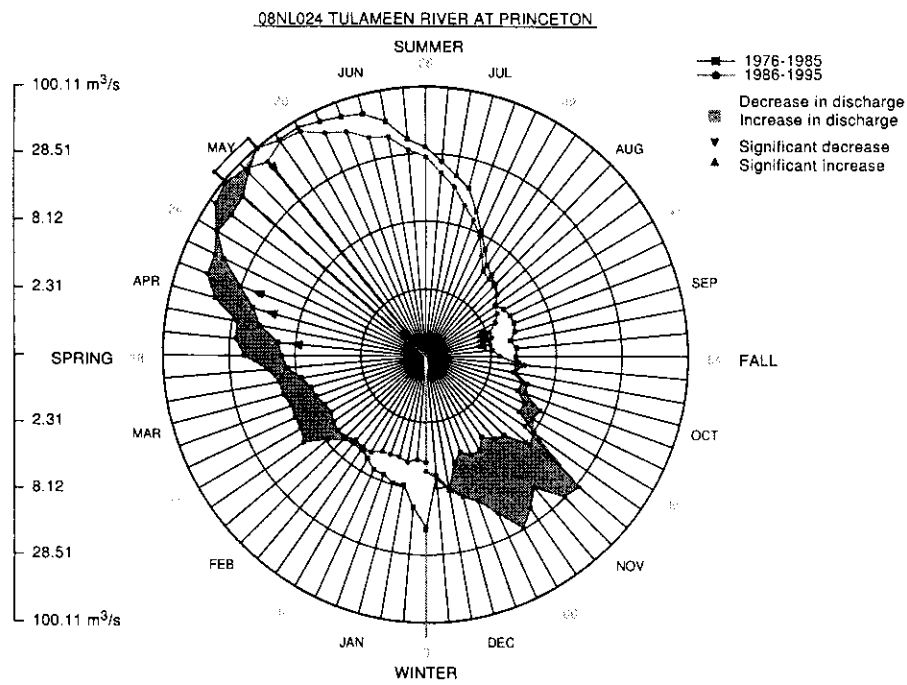


Figure 2. Polar plot representations of the discharge hydrographs shown in Figure 1. Discharge values are log scaled.

This form of graph allows effective communication of changes in discharge both within a given system and between different systems. Direct comparisons between systems are possible and effects of the winter discontinuity are no longer present. While our examples were chosen to compare differences between decades, the methodology could also be used to compare more than two time periods or sets of data. Depending on the number of data sets, multiple shading patterns could be introduced to account for the different rela-

tionships between the curves and sets of arrows could be plotted to portray results from the multiple comparisons in the statistical tests.

Conclusion

While polar plots are not new, the application we present here is a useful form to present seasonal hydrologic and climatic data. Our experience has been that plots of the type we have developed allow effective communication with both technical and non-technical audiences.

Literature Cited

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