THE IMPACT OF DEcadAL Fluctuations in MEAN PRECIPITATION AND TEMPERATURE ON RUNOFF: A SENSITIVITY STUDY OVER THE UNITED STATES

THOMAS R. KARL
National Climatic Data Center/NESDIS NOAA, Federal Building, Asheville, NC 28801-2696, U.S.A.
and
WILLIAM E. RIEBSAME
Department of Geography, University of Colorado, Boulder, CO 80309, U.S.A.

Abstract. The nature of climate variability is such that decadal fluctuations in average temperature (up to 1 °C annually or 2 °C seasonally) and precipitation (approximately 10% annually), have occurred in most areas of the United States during the modern climate record (the last 60 years). The impact of these fluctuations on runoff was investigated, using data from 82 streams across the United States that had minimal human interference in natural flows. The effects of recent temperature fluctuations on streamflow are minimal, but the impact of relatively small fluctuations in precipitation (about 10%) are often amplified by a factor of two or more, depending on basin and climate characteristics. This result is particularly significant with respect to predicted changes in temperature due to the greenhouse effect. It appears that without reliable predictions of precipitation changes across drainage basins, little confidence can be placed in hypothesized effects of the warming on annual runoff.

1. Introduction

Results from general circulation models (GCMs) and other analyses indicate that a marked global warming will occur by the middle of the next century associated with increasing CO₂ concentration in the atmosphere (World Meteorological Organization, 1985). A 1 to 4 °C rise in temperature is predicted within the middle latitudes (e.g., Schlesinger and Mitchell, 1985). Increased precipitation is also expected, but the timing and regional character of the increase varies substantially from model to model, ranging from no increase (or even a decrease) in summertime precipitation, to an increase of over 50 mm d⁻¹ at other times of the year (Schlesinger and Mitchell, 1985). These climate scenarios have important implications for various human activities such as water resources management. The first step in addressing this issue is to explore the relationships between changing climate and surface water runoff.

2. Background

Langbein (1949) related the mean annual runoff ($\bar{R}$) from 22 drainage basins in the

United States to the mean annual total precipitation ($\bar{P}$) and the weighted temperature $T_w$ which is defined by:

$$T_w = \sum_{i=1}^{12} (\bar{T}_i \bar{P}_i)/\bar{P},$$

where $\bar{T}_i$ is the mean temperature in month $i$ and $\bar{P}_i$ is the total precipitation for month $i$ averaged over the period of record. When $T_w$ is greater than the mean annual temperature ($\bar{T}$), more precipitation occurs during the warmer months compared to the colder months. The opposite is indicated where $T_w$ is less than $\bar{T}$.

Across the United States, there are large differences in $T_w$, $\bar{P}$, and $\bar{R}$. Values of $T_w$, $\bar{P}$, and $\bar{R}$ near 5°C, 750 mm, and 300 mm, respectively, are characteristic in the upper Midwest, whereas for areas in the southern Great Plains, more typical values of $T_w$, $\bar{P}$, and $\bar{R}$ are 20°C, 750 mm, and 50 mm. Langbein (1949) used these differences to develop the well-known nomogram depicted in Figure 1.

Revelle and Waggoner (1983) applied Langbein's climate-runoff relationships to assess the impact of CO$_2$-induced changes of temperature and precipitation on runoff from the Colorado River Drainage. They concluded that a 2°C rise in temperature would decrease runoff nearly three times more than a 10% decrease in precipitation, a result which we evaluate using decadal timescale climate fluctuations from the historical record. Other studies and reports (Stockton and Boggess, 1979; Callaway and Currie, 1985), either directly or indirectly, have also used Langbein's technique in assessing the runoff impacts of changes of temperature and