USGS

WATER RESOURCES RESEARCH GRANT PROPOSAL

Title: Growing Season Hydroclimatology, focusing on Soil Moisture Deficits, for Kentucky and Surrounding Climate Divisions.

Focus Categories: CP, DROU

Keywords: hydroclimatology, soil moisture, atmospheric processes

Project duration: March 1, 2000 through February 28, 2001

Federal Funds requested: $9,035

Non-Federal Funds: $18,121

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Critical Nature of the Problem

Overall, mean monthly precipitation in Kentucky is adequate and consistent enough for considerable agricultural productivity. The economies of many regions within the Commonwealth are intimately tied to agriculture. Therefore, moisture deficits due to interannual precipitation variability can cause major agricultural disruptions and subsequent economic losses. Moreover, portions of eastern Kentucky rely primarily on surface water for consumption and sanitation needs. Deficits in these regions lead to serious water shortages that restrict the supply for normal activities. Developing a growing season hydroclimatology focusing on soil moisture deficits will provide a foundation for the analysis of drought type, severity, and causal mechanisms. Findings from this research will be incorporated with agricultural productivity in order to develop a model correlating agricultural losses to drought type and severity.

Studies such as this investigation provide valuable information to planners, farmers, and climatologists interested in changes in soil moisture variability associated with climatic fluctuations. Before impact assessments of soil moisture deficit periods can be completed, hydroclimatologies must be developed to identify the strength of relationships

between the multitude of factors producing droughts in a particular region. Identification of the underlying processes leading to soil moisture deficits in the Commonwealth will aid in the recognition of drought development and in determining the temporal and spatial evolution of drought conditions. This will further assist planners and agricultural representatives in mitigating the potential hazards and losses posed by drought conditions.

Results and Benefits of Proposed Research

This study will develop a hydroclimatology for Kentucky and surrounding climate divisions for the period 1895 through 1996 using the Thornthwaite-Mather water budget model. This technique allows for the calculation of a long time series of soil moisture parameters making it ideal for developing a climatology. Expected results of the investigation include

long-term trends in soil moisture conditions for the region, including cyclic trends in soil moisture between very dry and moist periods; identifying spatial patterns of soil moisture deficit within the 19 climate divisions making up the region;

determining causal mechanisms leading to soil moisture deficit conditions by examining the inputs and outputs of the water budget model;

developing conceptual models illustrating meteorological conditions associated with severe soil moisture deficit conditions in the region; and,

evaluating relationships between growing season soil moisture deficits and agricultural yield statistics for the region.

Research Objectives

1) Develop a hydroclimatology for Kentucky and surrounding climate divisions based on the Thornthwaite-Mather water budget for the period: 1895 to 1996. Identify historical periods of drought during the growing season (May - September) and determine causal mechanisms (i.e. soil moisture deficits, meteorological factors, hydrologic stress, or a combination of factors).

2) Select several severe droughts for detailed case studies. Temporal and spatial evolution of each drought will be studied in conjunction with atmospheric forcing mechanisms. Examine periods of drought and develop composites of prevailing weather patterns that occurred during these periods

3) Develop a model correlating agricultural losses in Kentucky to drought type and severity.

Methods & Procedures

A climatology of soil moisture drought for Kentucky and the surrounding region will be produced using an empirically based water budget technique designed by Thornthwaite and Mather (Mather, 1978). It is a mass conservation technique that balances input values such as precipitation with output values such as evaporation from the surface and transpiration from plants (the addition of evaporation and plant transpiration equals evapotranspiration). Evapotranspiration in this method is estimated using monthly temperature, solar angle, and day-length. The Thornthwaite-Mather scheme is useful for developing a long-term hydroclimatology because it requires as inputs only monthly values for temperature and precipitation. Therefore, soil moisture values can be calculated far into the past using commonly measured variables with long periods of record.

To drive the water budget scheme, monthly average temperature, total monthly precipitation, and the water holding capacity of the soil are needed. Temperature and precipitation data will be obtained from the climate division data set available from the National Climatic Data Center. In addition, the water holding capacity in each climate division will be based on estimates by Main (1979). The water budget will be run for the four climate divisions within Kentucky as well as the 15 climate divisions that neighbor the Commonwealth from 1895 through 1996. At each climate division, a monthly value for soil moisture will be produced. To better analyze soil moisture deficits during the growing season, an aggregate soil moisture deficit value will be computed by adding up monthly soil moisture deficits from April through March. The data, software and computer hardware needed to produce the hydroclimatology is contained in the Climatology Research Laboratory at the University of Georgia.

An investigation of the relationship between inputs and outputs will be conducted to determine the causes of soil moisture deficits. That is, during a period with a soil moisture deficit, was there less precipitation, more evapotranspiration, or a combination of factors that led to the deficit? The relative importance of water budget variables such as precipitation and evapotranspiration on the development of the soil moisture deficit will be evaluated.

Further analysis will examine the meteorological conditions that are present during severe droughts. Case studies will be developed examining the five worst growing season droughts since 1960. Thunderstorm beginning and ending times, sea-level pressure, temperature, humidity, and upper-level circulation features will be analyzed and possibly composited in order to develop conceptual models of synoptic-scale meteorological conditions associated with severe soil moisture deficits. These data will be obtained from a variety of sources contained within the library of the Climatology Research Laboratory at the University of Georgia.

An examination of the effects of growing season soil moisture deficits on agricultural yields will also be conducted. Relationships between soil moisture deficit values and corn and tobacco yields across the Commonwealth for the period 1955 through 1996 will be developed. Agricultural yield values will be given as departures from a linear trend line fit to the agricultural yield data. Correlation coefficients will be calculated to determine

the strength of the relationship between monthly and accumulated soil moisture deficit values for the growing season.

Related Research

Surprisingly, little research has been conducted on soil moisture droughts in Kentucky or surrounding regions. The focus of investigations into droughts has been on a national or continental scale. Namias (1989) examined the importance of reduced soil moisture on maintaining warm, dry conditions over the growing season in North America. Oglesby and Erickson (1989) determined that by reducing soil moisture in model simulations, atmospheric conditions observed during droughts and sharp decreases in rainfall occurred. Further numerical simulations by Wolfson et al. (1987) confirmed the importance of the lack of soil moisture in producing heat waves.

Similar to this study, many studies of droughts employ monthly or seasonal datasets. Madden and Williams (1978) analyzed seasonal mean station data for North America and found negative correlations between temperature and precipitation. Similar relationships have been observed by Karl and Quayle (1981) and Chang and Wallace (1987). They found that hot months were characterized by upper-level anticyclones over the central United States.

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