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# REGIONAL ANALYSIS OF PRECIPITATION AND TEMPERATURE TRENDS USING GRIDDED CLIMATE STATION DATA

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## ABSTRACT

During the development of a stochastic weather data generator CLIGEN as part of the Water Erosion Prediction Project (WEPP), a database of over 1000 climate stations in the conterminous 48 U.S. states was constructed on a 1- by 1- degree grid of latitude and longitude. This database represents daily precipitation and maximum and minimum air temperature in each grid cell generally for the period 1948 to 1990. Monthly time series analysis were computed from data for the station in each grid for the period of record with missing precipitation and temperature values estimated using CLIGEN and the generator parameter database. Trend analyses were performed on these gridded data sets for those stations with complete records from 1950 to 1990. Contour maps of seasonal and annual precipitation, maximum, minimum, and mean temperature were constructed and analyzed for significant change in the climate patterns across the U.S. Results from analyses of the 585 station contour patterns show a 1 to 8 mm/year trend increase in precipitation for the 40 year period. Temperature trends increased in the northwestern U.S. and decreased in the southeastern regions. Increasing mean temperature trends were associated with increases in minimum temperatures.

## INTRODUCTION

Detecting climate change has been clouded by uncertainties existing in the long term observational records. Most independent analysis of this data show a increase of 0.5 degree C in the mean global temperature over the past 100 years (Shiffer and Unninayar, 1992). Much of recent research efforts have been directed toward determining the cause of this increase. A consensus finding is that this change in observed climate is due to the enhanced greenhouse effect. Furthermore, these changes have been forecast by 3 dimensional state-of-the-art climate models run on sophisticated supercomputers (Hansen, et al., 1987).

However, these studies have presented uncertainties to water resources investigators and planners because of the various mathematical assumptions made and the scale of the changes depicted from the output of these models. For water resource investigators to use existing hydrologic models to predict changes in secondary or tertiary hydrologic cycle elements such

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as surface runoff and sediment transport, better estimates of the long term trends of not only temperature but precipitation are required. At present, the output from these models is at too large a scale to be of particular use for precipitation trends that could be used in hydrologic modeling.

This paper presents results of trend analysis for monthly temperature and precipitation data from approximately 1000 stations in the conterminous U.S. for a 40 year period from 1950 to 1990. Monthly, seasonal and annual trends calculated from these stations are combined by contour mapping to depict the regional climate changes for this period.

METHODS

The user requirements of the USDA Water Erosion Prediction Project (WEPP) dictated the need to stochastically generated weather elements on a daily time step for continuous simulation of erosion from agricultural lands (Foster, 1987). To meet this need, a weather generator, CLIGEN, (Nicks and Lane, 1989) was developed to generate daily storm precipitation amount, duration, time to peak intensity, maximum intensity, maximum, minimum, and dew point temperature, solar radiation, and wind speed and direction. The basic data required to calculate the parameters for these were derived from various National Weather Service (NWS) sources (Nicks, 1989).

For precipitation and temperature parameters, daily records were obtained from the National Climate Data Center, Ashville, NC. The archived data set records of all daily precipitation and temperature stations, including more than 25,000 stations, were obtained on magnetic tape. These data were inventoried and a set of nearly 1100 station spaced on a 1- by 1- degree grid of latitude and longitude were selected for the conterminous U.S. (one in each grid cell), Alaska, Hawaii, Puerto Rico, and 9 U.S pacific ocean islands. These station have records extending from 1896 until the present with the majority with digitized records from 1948. The distribution of these stations and the grid for the conterminous 48 states are shown in figure 1.

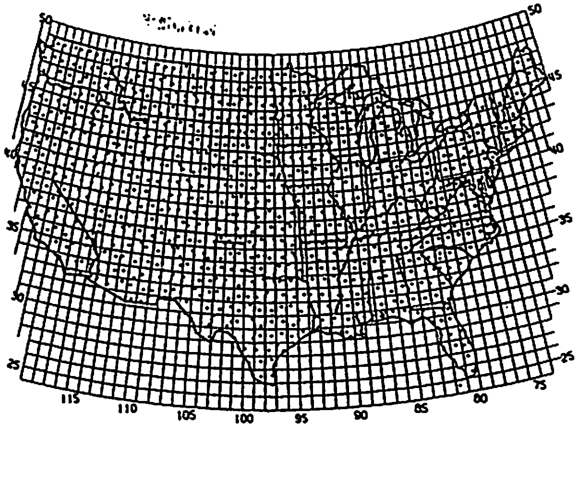


Figure 1. One Degree Grid of Precipitation and Temperature Stations.

Daily values of precipitation and maximum and minimum temperature were processed for nearly 1000 station shown in figure 1 by a two pass method to fill in missing daily values. First the data were read and generator parameters were calculated for estimating the occurrence and amount of precipitation, and the minimum and maximum temperature for each of 12 monthly periods. Then the data were read again and the missing data generated using the statistical parameter calculated in the first pass.

Precipitation occurrence is estimated using a two-state Markov chain. Two conditional probabilities are calculated; a, the probability of a wet day following a dry day, and b, a wet following a wet day. The two-state Markov chain for the combination of conditional probabilities is

$$P(W|D) = a \quad (1)$$
$$P(D|D) = 1 - a \quad (2)$$
$$P(D|W) = b \quad (3)$$
$$P(W|W) = 1 - b \quad (4)$$

where P(W|D), P(D|D), P(D|W), and P(W|W) are the probabilities of a wet day given a dry day, dry day given a dry day, dry day given a wet day, and a wet day given a wet day, respectively. Twelve monthly values of these probabilities are calculated and used to provide transition from one season to another. Random sampling of the monthly distributions is then used to determine the occurrence of a wet or dry day for missing records.

A skewed normal distribution is used to represent the daily precipitation amounts for each month. The form of this equation is

$$x = 6/g((g/2((X-u)/s)+1)^{1/3})-1)+g/6 \quad (5)$$

where x is a standard normal variate, X is the raw variable, u, s, and g, are the mean, standard deviation and skew coefficient of the raw variate. The mean, standard deviation, and skew coefficient are calculated for each month. Then to generate a missing value for each wet day event estimated from above, a random normal deviate is drawn and the raw variate X (daily amount) is calculated using equation (5).

Temperature values are generated from a normal distribution of the form given as

$$Tmax = Tmx + (STmx)(v)(B) \quad (6)$$
$$Tmin = Tmn + (STmn)(v)(B) \quad (7)$$

where Tmax and Tmin are generated maximum and minimum daily temperatures, Tmx and Tmn are the mean daily maximum and minimum temperature for a given month, STmx and STmn are the standard deviations of maximum and minimum temperature for the month, v is a random normal deviate, and B is a weighting function based on the wet-dry day probabilities. Values for B for a given month are

$$B(W|D) = 1 - P(W|D) /PF \quad (8)$$
$$B(W|W) = 1 - P(W|W) /PF \quad (9)$$
$$B(D|D) = P(D|D) \quad (10)$$
$$B(D|W) = P(D|W) \quad (11)$$

where PF is a probability factor based on the wet - dry day probabilities given by

$$PF = P(W|D)(1 - P(W|D)) + P(W|W)(1 - P(W|W) \tag{12}$$

The weighting function B is used to adjust generated temperatures for the dependency on precipitation state of the previous day.

TREND CALCULATION

Monthly total precipitation and mean maximum and minimum temperature were calculated from the stations shown in figure 1 for the entire length of record available at each station. Next, monthly, seasonal, and annual linear trends were calculated for each station with complete records, observed and estimated by the procedures given above, for the period from 1950 through 1989. Trend coefficients, a, were calculated from

$$Y = aX + b \tag{13}$$

where Y is the climate element (monthly total precipitation or minimum or maximum monthly temperature), X the number of the year, 1,2, ....., n = 40, and a and b constants calculated from the regression. Average monthly temperatures were calculated from the maximum and minimum monthly values and trends calculated in the same manner.

Limiting the station used in the analysis to those with complete records from 1950 through 1989 reduced the total number of stations to 585. The distribution of these stations are shown in figure 2. Trend coefficients a, calculated from equation (13), were plotted and contour maps constructed for each month and arbitrarily selected seasonal periods of January through March, April through June, July through September, and October through December. Annual values were also calculated and plotted.

Figure 2. Climate Stations with Complete Records 1950 - 1990.

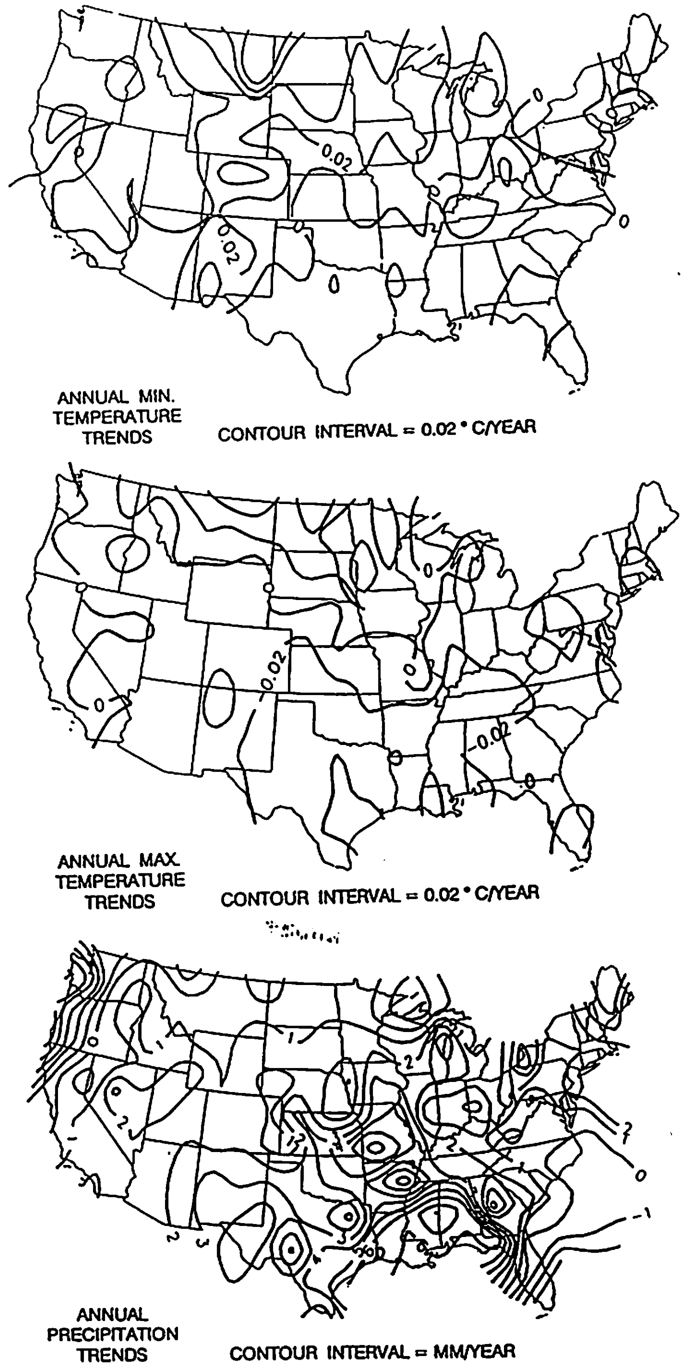


Figure 3. Contours of annual trends of precipitation and temperatures.

## RESULTS AND CONCLUSIONS

The trends for mean annual minimum and maximum temperature and precipitation plotted as contours of the coefficient a in equation 13, are shown in figure 3 with contour intervals of 0.02 degree C/year and 1.0 mm/year for temperature and precipitation, respectively. From these maps of the trends, minimum temperature have increased in northwestern regions and decreased in the southeastern U.S. as shown by the distribution of the contours about the 0 contour line located from the east coast in North Carolina to the Texas border near El Paso, TX. Maximum temperatures for this 40 year period have decreased in the south, east, and southwestern regions of the U.S. Average annual mean temperature (not shown) have, in general, increased north of a line from Lake Michigan to the Mexican border in southeastern Arizona and decreased southeast of this line to the Florida peninsula. Maximum increase of up to 0.07 degree C/year were calculated in the northern Great Plain in Montana. Most change in mean annual average temperatures are associated with increases in minimum temperature.

The annual precipitation map for the same period shows an increase of from 1 to 8 mm/year starting in the northwest in the states of Washington and Oregon and increasing to the gulf coast in Mississippi and Alabama. According to these data, an area encompassing nearly 90 per cent of the U.S. have experienced an increase in annual precipitation. Significant also, is the region of the gulf coast where the largest trends were noted that may be the result of the large number of tropical storms crossing the area during the 40 year period.

Water resource planners and investigators should be aware of the these types of trends which could be used to constructed scenarios of climate change that would be useful in hydrologic modeling studies. At least, the trends from these results reduce the amount of speculation as to magnitude and direction of climate change that are exhibited in historical data.

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