SOUTH DAKOTA MONTHLY PRECIPITATION TRENDS FROM LONG TERM COOPERATIVE OBSERVER STATIONS

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ABSTRACT

Over 70 years of monthly precipitation data, from 40 cooperative observer stations in South Dakota were analyzed to determine evidence of any long-term historical trend. Stations were selected by the length of period of record of data for each station. The selected stations have data extending to at least 1931 with some to 1893. While most stations selected have relatively complete data sets, some stations have missing data. R-squared values were determined from this regression (as the square of the correlation coefficient, it describes the variability in precipitation that can be explained by passage of time alone) for each station. Monthly regression data were also calculated for each climate division to identify any monthly precipitation trends for climate divisions.

For the annual trends all R-squared values in this analysis were less then 0.2 with only three station's R-squared value greater than 0.1. Lead was the station that had the highest annual trend, with an R-squared value of 0.17748. Positive sloping regression trends were evident in 75% of the stations, with negative trends for the remaining 25%. The highest positive annual trend was 0.04" of rainfall per year. In the monthly analysis, June and December were the only months with negative regression trends for most stations. Regression trends were positive during the other 10 months of the year for most stations. The relatively low R-squared values for all regressions indicate that a time-dependent trend in monthly and annual precipitation is not strongly evident in this data. But increases in precipitation are a general signal across the state over the last century. December precipitation decrease can possibly be attributed to undercatch issues associated with snowfall. The June decrease in precipitation is interesting and deserving of more scrutiny as it is the wettest month climatologically for the eastern part of the state. Changes in the timing of precipitation across the state could have agricultural, hydrological and subsequent economic impacts.

INTRODUCTION

Cooperative observer stations have collected daily high and low temperatures and precipitation across the state for over 100 years providing the state with several locations of long term observations of the climate and changes during the 20th Century. Despite some problems with the data, these stations give us the best long term view of climate of the state since settlement.

Despite recent drought conditions (ref), long term trends in precipitation indicate upward trends over the whole state. These are consistent with other studies across the Upper Midwest and the United States overall, indicating overall increasing precipitation over the area (Groisman et al. 2004). Much of the recent work has been devoted to examining extremes in precipitation (Kunkel et al., 1999) and diurnal changes in precipitation (Dai et al. 1999). What has not been well reported is what changes in the annual cycle may driving this increase. The warm season (April-September) gives the most precipitation by far over the state (~75%). But are increases confined to the warm season, cold season, or year-round. Is any part of the annual cycle driving the precipitation changes?

Agricultural production is large part of the economy of South Dakota. Crop types and management decisions are used to make best use of temperature and precipitation combinations in the state. Changes in agriculture have occurred in the last 15 years in response to some precipitation changes. Change in the timing and amount of precipitation, especially in combination with temperature changes, can change which crops are grown, how they are grown or when they are planted and mature.

The goal of this study was then to determine similarities or differences in the slope of trend lines in monthly precipitation for different months across regions in the state.

DATA

Monthly precipitation totals exist for over 150 locations in the state. The stations have periods of record of data varying from just a few years to over 100 years. Obviously, comparing a 10 year trend to a 100 year trend would not be appropriate. To be relatively consistent in time period, we used monthly total precipitation for cooperative observer stations across the state where data exist for at least 50 years. While the longest period of record would be provide the best trend, few stations have records of longer than 50 years. The Cooperative observer program added a large number of stations around 1950. Another jump in the data records exists starting in 1930. There has actually been a downward trend in the number of stations since the peak of the 1950s.

Stations also varied in the quality of their observations. Because these are human observers, many errors occur due to vacations, recording error and other situations. Typical problems with station histories are missing data. If a month had less than 20 days, it was coded as missing and eliminated from the monthly trend analysis to reduce the chance of an under-reported monthly precipitation value. Because we could not ascertain precipitation amounts for the missing days, the month was just eliminated from the analysis. Another problem was station moves, where the station was moved from one location to another for changes in observer and other reasons. Location changes lead to exposure changes for the gauge, which could affect the precipitation totals. We decided to ignore moves to have the largest database of stations from which to choose if the station maintained the same name. The lack of name change usually indicated a minor station move of a few miles or less.

After limiting the data based on the above criteria, 40 stations across the state were determined to have sufficient data to be used in the study. These stations were concentrated in two districts, the north central and southeast. The Black Hills contained only two stations (Lead and Hot Springs) sufficient for the study.

METHOD

The goal was to determine differences in monthly precipitation trends for each station in each month and between each station. Data for each station were downloaded from the National Climatic Data Center and sorted by month for each station. A linear regression was calculated for each station and month over the complete record of the station. For example, a trend for July precipitation in Brookings was calculated for the complete history of the station. For each station this provided a trend line with a specific slope for each month indicating the regression calculated change in precipitation over time. The slopes of these trend lines were compared between months at each station to determine the relative contribution of each month to the changes at each station. They were also compared among stations for each month to compare trends of precipitation across districts and across the state.

RESULTS

Several interesting features appeared in the monthly trends across the state for different months within each station and across stations. The general trend for most months for most stations was for a positive precipitation trend for nearly all months. This varied somewhat by station and time of year. The largest magnitude trend overall was in October, where some stations had a trend increase of precipitation of over 0.03" per year. The southeast district is typical of the trend over the whole state throughout the year (Fig. 1). All stations had a positive trend for October (Fig. 2). .

April, May and July were other months that had consistently positive trends across the state. Magnitudes were slightly lower and some stations had small negative trends during these months. The magnitudes of the negative anomalies tended to be rather small. Of the warm season precipitation (April-October) nearly all months at all stations had positive slopes of their regression trend.
Two monthly exceptions stand out. June precipitation had a consistently negative trend across the state (Fig. 3). Nearly 75% of the stations had a negative

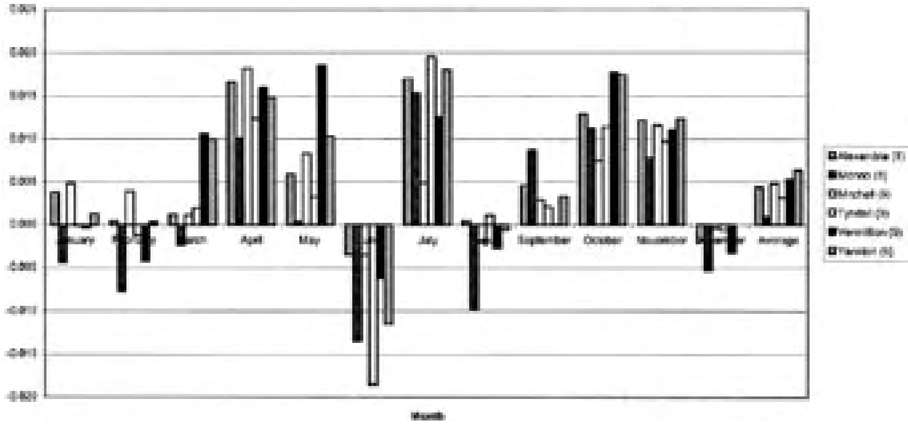

Figure 1. Slopes of regression line for six stations in the southeast district of South Dakota (District 9). Notice that the trends are consistent in sign for nearly all warm season months.

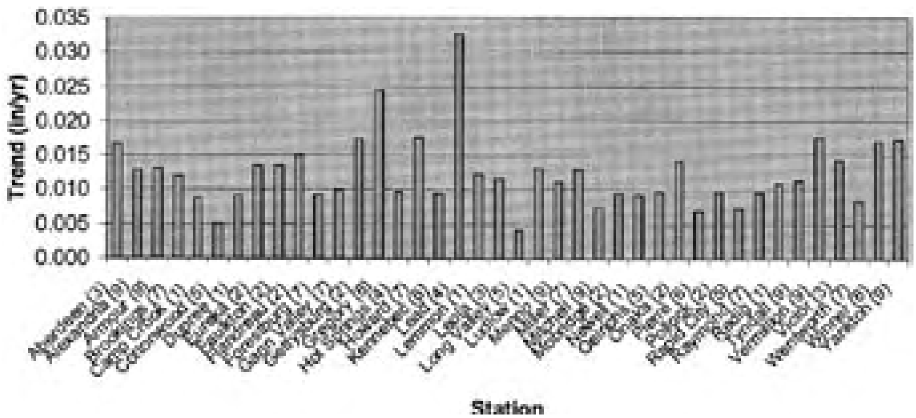

Figure 2. Slope of regression trend for October for the 40 stations included in the study. Numbers in parentheses indicate climate district.

precipitation trend during this month. This is interesting in its contrast to surrounding months and its consistency across the state. Generally, warm-season months showed a positive trend across nearly the whole state.

Winter precipitation typically provided a mixed result with a very small magnitude of the slope. Winter precipitation in South Dakota is much smaller than summer precipitation except for the northern areas of the Black Hills. We have only one station in this location for comparison. Thus, the magnitude of the slope will likely be smaller than seen in the warm season values. The second reason for mixed results in the winter is the concern with undercatch of winter precipitation (Groisman and Legates, 1994 and Yang et al. 1998). Snow in South Dakota is often accompanied by high winds, making catching of the snow very difficult. Undercatch will then lead to misrepresentation of the cold season

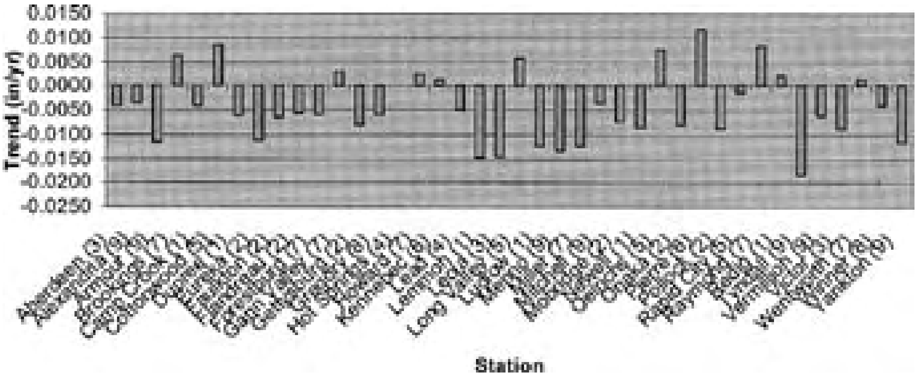

Figure 3. Slope of regression trend for June for the 40 stations included in the study. Numbers in parentheses indicate climate district.

precipitation. Because these trends are based on the raw data without attempting to account for such errors, the winter trends are basically ignored.

DISCUSSION

The negative trend in June precipitation seems to be least in the southwestern to central part of the state. The area east of the Black Hills to Pierre and into part of the east central part of the state does not indicate the negative precipitation trend. This negative trend in June is in stark contrast to the rest of the warm season. A decreasing trend indicates a reduction over time. Obviously, less precipitation is occurring in June except for the swath listed previously. We cannot determine a physical reason for this at this time. This trend bears further study. Because June is the wettest month over most of the eastern part of the state, a reduction in June precipitation is not serious agriculturally. Reduced precipitation in June is likely a benefit to small grains production in limiting the disease occurrence.

The increased precipitation during the wet season is significant agriculturally because of the additional precipitation available to grow crops. Typically South Dakota crop production is limited by rainfall, especially late in the season. The additional precipitation has allowed changes in the cropping system over the state by supporting the wider production of two crops, corn *(Zea maize)* and soybeans *(Glycine max)*, in areas that could usually only support small grain production. While the yield values of these crops are not as large as the main areas of the corn belt, the yields are large enough to make them economically viable even in marginal precipitation areas of the state.

The additional precipitation has been a large factor in the increased spatial extent of water and wetland areas in the eastern part of the state (Johnson et al. 2000). Recent inundation accompanied by lower summer evaporation has greatly expanded the area of many lakes in the closed basin areas of the northeast as well as expanding the size and number of wetland areas.

Precipitation has a cyclical nature over time. Thus, a linear trend may not necessarily the most accurate in depicting changes in precipitation changes over time (Fig. 4). The Aberdeen October precipitation trend indicates the inter-annual variability. The trend toward increasing precipitation during October is quite obvious. But the cyclical nature is not regular among stations or among years. Thus, there is not an accepted option for precipitation change over time. The R^2 values from the regression analysis typically were less than 0.1. Thus, less than 10% of the precipitation variability was explained by the regression model. This is typical of precipitation and its variable nature. Other regression methods should be tried to better explain the variability. But the main goal was to determine overall trends over time and to determine consistency of trends across the state. A linear model is acceptable in this situation. A more rigorous statistical approach should follow this initial study to determine the significance of the slopes and significant differences between months and stations.

Further work on understanding the June difference from the rest of the warm season should also occur. Relating the changes over time to specific times as compared to using the whole period of record for a slope calculation would also be beneficial.

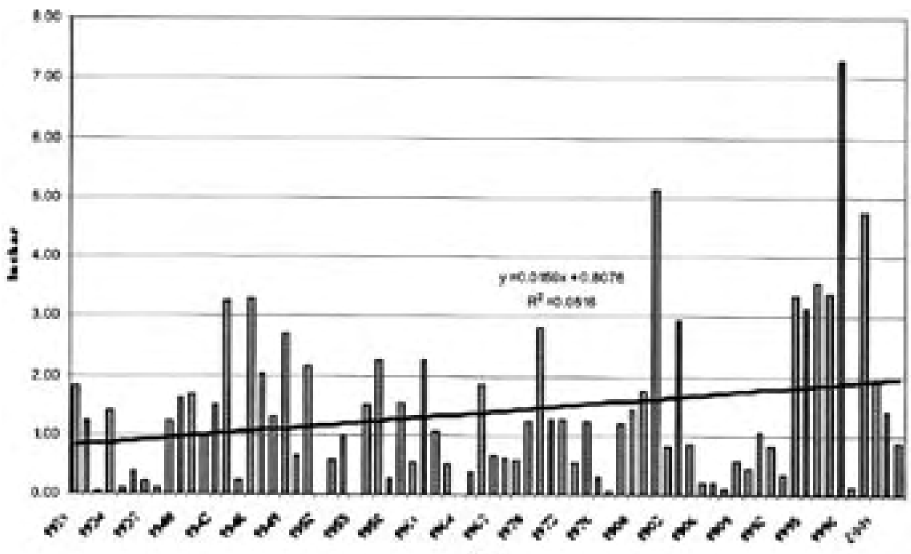

Figure 4. October precipitation for the Aberdeen station over the whole period of record. Regression line is indicated.

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