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Long-Term Trends for Selected Iowa Weather Variables

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Introduction

In recent times, the state of climate earth is of concern to many people. Accounts of global warming, ozone holes, floods, droughts, and year-to-year variability of the weather in the decade of the 80's appear in popular media. Much attention has been focused on the possibility of growing crops in a changing environment (Rosenberg, 1981). Actual measurements of changing concentrations of trace gases in the atmosphere give credence to some of these fears (Schneider, 1990). Their actual impact on our weather is, however, controversial (Schneider, 1990). Computer models describing the atmosphere responding to these changes in gaseous composition predict a warmer earth with expected changes in precipitation. Some locations may experience weather patterns more favorable for crop production with others being exposed to more harsh weather (Manabe and Wetherald, 1986). There are great uncertainties with these models (Schneider, 1989), but most predict a warmer earth in future years.

Iowa possesses an invigorating climate for its inhabitants, but the economy is strongly tuned to this "weather machine." Because of these concerns, a study was conducted relative to Iowa's long-term weather resources. Parts of this research have been reported elsewhere (Carlson, 1990A; Carlson, 1990B)

Methods

Weather data, including daily values of maximum and minimum air temperature, were obtained for 9 stations from the U.S. Department of Commerce (1990). This covered the period from 1895-1990. Comparable data were collected for divisional precipitation for the period from 1890-1990. Monthly and seasonal summaries were computed using these data. In addition, an agriculturally important heat stress index was calculated from the air temperature data set. The index consists of an accumulation of the number of degrees above the 86F level each day for each year (Carlson, 1990A). Agricultural corn and soybean yield data were obtained from the Iowa Department of Agriculture (1990). Plant-available soil moisture data on 1 July for the period from 1954-1990 were obtained for R. H. Shaw (personal communication) for 9 sites throughout Iowa.
Although long-term changes at these weather stations can occur which may have an influence on observed air temperatures, no attempt was made to correct these data. Station histories were, however, examined for gross divergences. These details are reported in Carlson (1990B). The 9-station weather station set was formed to provide an Iowa average to reduce the "noise" commonly observed at single stations and to adequately represent Iowa geographically.

Results

The annual air temperature pattern for Iowa is shown in Fig. 1. Most striking, and typical for many weather data sets, is the large amount of year-to-year variation. This is a feature which makes detection of trends and, specifically changes in trends, difficult to detect statistically. For annual temperatures, Fig. 1 shows an increase from 1895 through the late 1930's with a decrease following through the late 1970's. Since that time considerable year-to-year fluctuations have been experienced and trends upward or downward are difficult to identify. The individual seasons are depicted in Fig. 2. The patterns for winter and summer temperatures have a tendency to follow the annual temperature pattern, but spring and fall reveal no temperature trends. Of recent interest is the four consecutive warm springs beginning in 1985. Both 1989 and 1990 spring temperatures have settled back to more normal values. Fig. 2 shows how extreme summer air temperatures were for years during the decade of the 1930's, but, also, the very cool year of 1915. From Fig. 2, does anyone remember the winter of 1936, or more recently the winters of 1978 and 1979?

Long-term patterns for annual precipitation totals are shown in Fig. 3 for all 9 divisions of Iowa. As with air temperatures, and from your own personal experience, considerable year-to-year variation is evident and expected. Extreme excesses and deficiencies can be noted, but there exists frequent "see-saw" motion from one year to the next year. Of interest is the recent dry years of 1987 until March and April of 1990 (1990 data are not shown in Fig. 3). Note that this pattern is not exactly alike over the 9 districts. In addition, note that runs of more than 2 consecutive dry years are not present for all districts. Cycles of length 18.6 years have been associated with these data, but more recently midwestern droughts have been associated with Equatorial Pacific Ocean sea-surface temperature anomalies. Since 1973, five droughts in the U.S. Corn Belt were in years following El Niño events, Equatorial Pacific warming. It appears that sea surface temperature fluctuations change atmospheric flow patterns leading to either dry or wet conditions in the U.S. Corn Belt (Trenberth et al., 1988). The impact of El Niños may be moderated by the 18.6 year cycle (Thompson, 1990). Fig. 4 is
closely associated with the weather patterns depicted in Figs. 2 and 3. In Fig. 4, corn and soybean yields are presented for all 9 districts in Iowa. Most notable from these figures is the trend upward for both corn and soybeans over this 60 year time period. This is related to the introduction of superior hybrids, or cultivars, and the implement of better all-around management practices by producers. Of interest is the fluctuations of yield over time (note in this figure that fluctuations of soybean yield appear diminished due to the scaling effect caused by inclusion with corn yields). The weather during the time period from about 1957 until the mid 1970's was very favorable for crop production with yields increasing each subsequent year. As we all know, however, since the mid 1970's Iowa has experienced both excellent production years, and frequent sub-normal years relative to yield expectations. For these reasons, the relationships between crop yields and weather variables were investigated. The weather variables used were restricted to those which would be available over long periods of time. This would allow for the analysis of the interannual (year-to-year) variability eluded to earlier and to determine if the weather experienced in Iowa since the mid 1970's is unusual. This work was reported by Carlson (1990A), but is summarized below.

In that research effort yield and weather related data were assembled beginning in 1954. Years before this date were excluded because plant-available soil moisture was not available. Regression analysis was used to fit the data in Fig. 5 to linear trends. These results are given in Table 1. After the time trend was established, residuals (actual yield-time trend yield \( y - \hat{y} \)) were calculated for each year and correlated with available weather data. This included monthly values of both temperature and precipitation, heat stress for each month from May through September and seasonal summations, and plant-available soil moisture on or near the following dates - April 15, July 1, and August 1. For corn in all districts and for six out of nine districts for soybeans, the heat stress summed over July and August was most highly correlated with these yield residuals.

Using the daily weather data set from 1900 through 1989, seasonal heat stress was computed and is depicted in Fig. 5 for all nine districts. Here one rural weather station was used for each district to represent the weather conditions for that district. This is probably a good assumption as temperature is spatially fairly conservative compared to precipitation.

Careful analyses of Fig. 5 shows that these patterns are not altogether consistent between districts, but major patterns emerge. The relatively benign period from 1957 through 1976 and the variation in the 1980's stand out for most districts. The
time period from 1900 until the late 1950's also reveals considerable year-to-year variation. It may be that the weather experienced in the 1980's is more normal than abnormal, at least based upon the patterns shown in Fig. 5.

The patterns for July 1 plant-available soil moisture in the 5-ft. profile are shown in Fig. 6. This variable is obviously related to both corn and soybean yields, and when used with the heat stress variable, was shown to be significantly related to corn yield (Carlson, 1990A). Of all figures presented here, this variable seems to show the most variation over the nine districts. It is unfortunate that this data does not extend back to earlier times, but it must be stated that this is unique data set in the world. The insights provided by Drs. Shaw and Pierre during the 1950's to even start such a laborious state survey, and the many individuals over the years who collect the necessary soil samples are to be commended.

From this figure, it is easy to see why the recent droughts in the eastern one third of Iowa are so unexpected. In addition, the benign period mentioned before is fairly evident in the eastern two thirds of Iowa. Certainly the western one third exhibits more ups and downs than the rest of the state. Although not shown here because of data unavailability, the recent levels for this variable, if placed onto Fig. 6, would show a welcome return to more normal levels.

Summary

In this report many facets of Iowa's diverse climate resource base were examined. Times of extremes were noted, but trends were difficult to identify because of "noisy" weather patterns. Prediction of future weather is obviously limited, but maybe this historical view can provide some insight relative to Iowa's weather to come.

References

Iowa Department of Agriculture, 1990. Agricultural statistics. Iowa Dept. of Ag., Des Moines, IA.


Table 1. Regression coefficients and correlations for both corn and soybean yield as a function of year for each district of Iowa for the period from 1954 until 1989.

<table>
<thead>
<tr>
<th>District</th>
<th>Corn</th>
<th></th>
<th>Soybeans</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$r^2$</td>
<td>$b_0$</td>
<td>$b_1$</td>
</tr>
<tr>
<td>1</td>
<td>0.76</td>
<td>49.8</td>
<td>2.2</td>
</tr>
<tr>
<td>2</td>
<td>0.80</td>
<td>58.0</td>
<td>2.2</td>
</tr>
<tr>
<td>3</td>
<td>0.68</td>
<td>57.9</td>
<td>2.0</td>
</tr>
<tr>
<td>4</td>
<td>0.68</td>
<td>52.7</td>
<td>1.9</td>
</tr>
<tr>
<td>5</td>
<td>0.68</td>
<td>62.3</td>
<td>1.9</td>
</tr>
<tr>
<td>6</td>
<td>0.48</td>
<td>69.2</td>
<td>1.5</td>
</tr>
<tr>
<td>7</td>
<td>0.62</td>
<td>49.6</td>
<td>1.9</td>
</tr>
<tr>
<td>8</td>
<td>0.43</td>
<td>49.3</td>
<td>1.6</td>
</tr>
<tr>
<td>9</td>
<td>0.36</td>
<td>62.3</td>
<td>1.5</td>
</tr>
</tbody>
</table>

1 The regression equation was of the form $\hat{y} = b_0 + b_1 \times \text{year}$ where $\hat{y}$ is the yield in bushels/acre and year is coded 1954 = 1, 1955 = 2 .... 1990 = 37.

2 $b_1$ represents the incremental yield increase in bushels/acre each year generally due to "technology."
Fig. 1  Annual air temperatures for Iowa based upon a 9-station average for the period from 1885 until 1989.
Fig. 2 Seasonal air temperatures for Iowa based upon a 9-station average for the period from 1895 until 1989.

Winter Temperature (°F)

Spring Temperature (°F)

Summer Temperature (°F)

Fall Temperature (°F)
Fig. 3 Annual precipitation totals for each of the nine districts of Iowa for the period from 1890-1989

DISTRICT PRECIPITATION TOTALS
NORTH WESTERN IOWA

DISTRICT PRECIPITATION TOTALS
WEST CENTRAL IOWA

DISTRICT PRECIPITATION TOTALS
SOUTH WEST IOWA

DISTRICT PRECIPITATION TOTALS
NORTH CENTRAL IOWA

DISTRICT PRECIPITATION TOTALS
CENTRAL IOWA

DISTRICT PRECIPITATION TOTALS
SOUTH CENTRAL IOWA

DISTRICT PRECIPITATION TOTALS
NORTH EAST IOWA

DISTRICT PRECIPITATION TOTALS
EAST CENTRAL IOWA

DISTRICT PRECIPITATION TOTALS
SOUTH EAST IOWA
Fig. 4 Corn and soybean yields for each of the nine districts of Iowa for the period from 1930 until 1989.
Fig. 5 Seasonal heat stress for one location from each of the nine districts of Iowa for the period from 1900 until 1989.
Fig. 6 July 1 plant-available soil moisture from a 5-ft. profile for one location from each of the nine districts of Iowa for the period from 1954 until 1989.