COMPARISON OF POINT AND AREAL ESTIMATES OF TEMPORAL FLUCTUATIONS OF CLIMATIC ELEMENTS: A CASE STUDY FOR TEXAS

A Thesis

by

DAVID MORRIS GAFFIN

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 1993

Major Subject: Meteorology

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December 1993

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ABSTRACT

Comparison of Point and Areal Estimates of Temporal Fluctuations
of Climatic Elements: A Case Study for Texas (December 1993).
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Chair of Advisory Committee: Prof. John F. Griffiths

Because of the accepted practice of using single point estimates to represent large areas of the world (especially in Africa and South America), an attempt was made to assess the amount of error involved in using a single point estimate (station) to represent a large area such as a climatic division, as well as the state of Texas.

Stations used in this study were selected on the basis of a long continuous record (preferably >50 years), minimal number of station moves (none over a mile), non-urbanized locations (populations <25,000), and adequate spatial coverage in order to evaluate the best possible data in terms of homogeneity.

It was determined that since a product-moment correlation coefficient of ≥ 0.86 causes at least a 50% reduction in the standard error of estimate, $\sqrt{(1-r^2)}$, this was a value that was practically significant in determining a 'representative' area. Station-to-station correlations versus distance graphs were then evaluated along with isopleth maps of correlations between a single point estimate and the statewide and divisional average areal estimates in order to further assess the size and seasonality of the 'representative' area for Texas.

The results indicated that January experienced the highest correlations with July the lowest for both temperature and precipitation series. This was attributable to the fact that synoptic scale systems dominate during the winter while isolated convection dominates during the summer. While temperature revealed a highly correlated and centered areal estimate, precipitation revealed that the area of highest correlations was biased towards areas of persistent and reliable rainfall.

Even when evaluating the results of this study with correlation thresholds of ≥0.50 and ≥0.33, as was done with earlier studies of annual temperature series, the size of the 'representative' area for Texas was not as large as would have been assumed by the earlier studies.

DEDICATION

To my parents. Although they will probably never read this manuscript or find it very interesting, their support and lessons of never leaving anything unfinished kept me going during the many times I doubted I would make it through graduate school.

ACKNOWLEDGEMENTS

I would like to thank the members of my committee, Drs. G. R. North and W. B. Smith, for their advice and assistance which added to the quality and scope of this thesis. But most of all, I would like to personally thank the chairman, Professor J. F. Griffiths, whose patience and direction was instrumental to the completion of this thesis.

Also, I would like to thank Mike Nelson, Trevor Wallis, and Larry Jacobs for their endless computer assistance which greatly aided and saved this computer-illiterate person.

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CHAPTER I

INTRODUCTION

A. The Problem

During the last two decades it has become accepted practice to present climatic anomaly data by magnitude versus time graphs. When such graphs appear to indicate trends, either by inspection or statistical analysis, these trends are often interpreted as evidence of climate change. These graphs, along with General Circulation Models, have led to the introduction of the term 'global warming'.

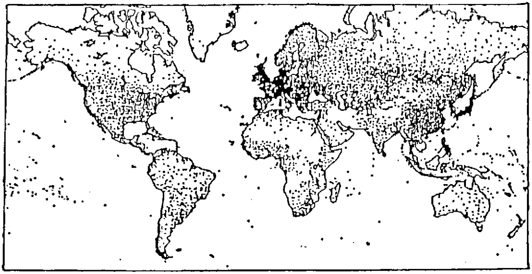
Because these graphs and computer models often present data averaged over large areas, for example, land area of the Northern Hemisphere or of the globe, they include data from regions in which data are very sparse. In such instances the covert assumption is made that data from some particular station accurately represents conditions over a large area, often hundreds of thousands of square kilometers. This assumption needs to be tested using actual data so that some idea of the error term can be included in future analyses, and conclusions can be made as to whether the reported climatic anomalies are actually significant.

The citations on this and following pages follow the style of the *Journal of Climate*.

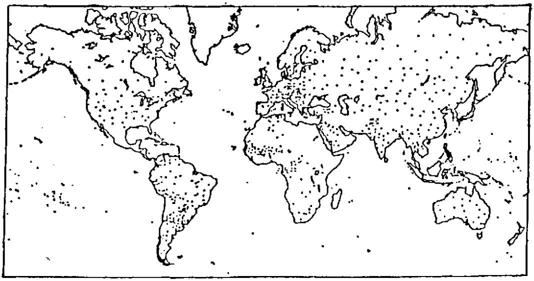
B. Background

The Climate System Monitoring (CSM) project of the World Climate Data and Monitoring Programme (WCDMP) was initiated in 1984 following a recommendation of the Ninth Congress of the World Meteorological Organization (WMO). The CSM project was designed to provide to the Meteorological Services and other national and international organizations synthesized information on the state of the climatic system and diagnostic insight into significant large-scale anomalies of regional and global consequence. The CSM Monthly Bulletins have included, as a routine feature, global analyses of temperature and precipitation anomalies and statistics which indicate the persistence of, among other things, circulation anomalies and drought-monitoring indices. The identification of anomalies requires the availability of statistics from long time-series of data from each individual observing station; however, anomalies cannot be accurately identified and monitored in data sparse areas (WMO, 1992).

These monthly bulletins, including the Climate Diagnostic Bulletin among others, are published using reported data over the Global Telecommunications System (GTS). These monthly and seasonal summaries are based on integrated synoptic reports as well as the monthly summaries, i.e., CLIMAT reports, prepared by the stations and transmitted over the GTS. Typical distributions in April 1984 of synoptic reports and CLIMAT receipts (Fig. 1) illustrate that although several



STATION REPORTS RECEIVED OVER THE GTS FOR APRIL 1984



CLIMAT REPORTS RECEIVED OVER THE GTS FOR APRIL 1984

FIG. 1. Typical distribution of station synoptic and CLIMAT reports received over the Global Telecommunications System (adapted from Ropelewski, et al., 1985).

thousand station reports are received monthly, portions of the world are not adequately represented (Ropelewski, et al., 1985). This is especially true today since the number of reporting stations has steadily decreased since 1987, mainly in Africa, Asia and South America (D. Miscus 1992, personal communication). In these areas of sparse coverage, the surface analysis will be particularly poor and subject to errors and oversimplifications.

Jones et al. (1986) constructed an objective and homogeneous series of monthly mean surface air temperatures (1851-1984) from station data that were analyzed for homogeneity in order to adequately represent the land areas of the Northern Hemisphere. Because of the changing station network through time, it was concluded that the hemispheric temperature series was reliable on a year-to-year basis after 1875. In their work, Jones et al. noted two main criticisms of previous constructions of mean surface air temperature data for the Northern Hemisphere. The first criticism dealt with the fact that the spatial coverage of the data was restricted, and hence, the representativeness of the hemispheric average would be uncertain especially in the nineteenth century when station data were limited. The second criticism was the fact that the original station data may have been affected by the inhomogeneities and other errors in the station time series. After evaluating stations for inhomogeneities such as changes in station location and urbanization changes, selected station data were used by Jones et al. and weighted by interpolation onto a 5° latitude by 10° longitude grid for all months from 1851 to 1984. One of their conclusions was that the monthly estimates calculated in their paper were subject to spatial sampling uncertainty which they recommended should be evaluated in future work.

Similar problems were noted by Folland et al. (1990) who pointed out, among other things, that errors in the global land air temperature record arise from the problems of spatial coverage of the global data being incomplete and varying greatly, stations having relocated, and changes in the environment, especially urbanization, having taken place around many of the stations. This thesis tries to minimize these inhomogeneities in the temperature and precipitation record for Texas by the careful selection of stations to be used.

Work done by Solow (1988), using a robust, locally weighted regression on Southern Hemisphere temperature records, revealed that the variance of the deviations in the temperature record did not change through time as more stations were added to the sampling network. Although the data used to estimate the variance were from gridded data similar to that calculated by Jones et al. (1986), the addition of more stations in order to increase coverage should have caused the variance to decrease through time. The fact that the variance did not decrease through time, as one might expect especially since the maritime stations were added later, helps support the assumption that estimating the variance in an area of dense station coverage, such as Texas, could also represent the conditions in an area of sparse areal coverage.

Methods for estimating the size of the surrounding area for which a given station's data may provide significant information on temperature change have been developed by several authors in the past. Hansen and Lebedeff (1987) graphed correlation coefficients, computed between the annual mean temperature variations for pairs of stations in their sample, against the corresponding distances between the stations. The results indicated that correlations fell below 0.50 at a station separation of about 1200 kilometers (km) for mid-latitude stations (23.6°-44.4°N). Although correlations in a similar study by Longley (1974) over the Canadian Prairies were found to be dependent on direction, Hansen and Lebedeff found no dependence between correlations and the direction of the line connecting the two stations for their stations in the United States and Europe.

More recently, Kim and North (1991), using a stochastic climate model, found that (1) the spatial correlation scale of the interannual variability is in the range of 1500-2000 km (for correlations $\geq 1/e$) and is shorter for higher frequency temporal fluctuations, and (2) the spatial correlation length scale is larger over the land than over the ocean due to the relaxation time of the surface medium, one month over land and five years over the open ocean. It will be shown later in Chapter IV that the length scales of 1200-1500 km are too large when evaluating Texas stations and that accepting a correlation as low as 0.50 or 1/e (0.33) will bring about a large error term.

C. Goal

The goal of this investigation is to determine the error inherent in assuming that climatic changes at a single point (station) accurately represent similar values over a large area. Also, it is relevant to study the change of the correlation coefficient (which determines the error term, $\sqrt{(1-r^2)}$) between the station and the selected area on a temporal scale. The threshold distance between two points will also be determined in order to evaluate the area that can be 'accurately' represented by a single point for both temperature and precipitation.

Since a reasonable *estimate* of temperature and precipitation over many areas of the world cannot be obtained, due to sparsity of data, error terms can be assessed only in areas, such as Texas, where a dense network of stations exist.

D. Objectives

To reach the goal of this thesis, a number of objectives must be accomplished:

1. Selection of areas that are climatically homogeneous, and stations that have a stable, long period of record.

2. Estimate the standard errors when assessing the relationship between both point-to-point and point-to-areal estimates (over annual and monthly intervals), so that the strength of these relationships can be determined.

3. Construct graphs of point-to-point correlations and isopleth maps of point-to-areal correlations in order to evaluate the magnitude and size of the 'representative' area for a single-point estimate and the seasonality of the corresponding areal patterns.

4. Investigate the items in objective 3 to attempt to relate these findings to the synoptic patterns which occur in the state and its climatic divisions.

CHAPTER II
DATA AND PROCEDURES

A. Reasons for Texas Study

Since Texas, the largest state in the continental United States, covers an area of 741,130 square kilometers and contains a relatively dense network of stations with detailed histories spanning close to a hundred years, the state is an ideal region of study in order to estimate errors in station representativeness. Recognizing the inherent errors in the temperature record due to changes in station location and environment, careful selection of stations is possible while retaining enough stations for a relatively representative coverage of the many climatic regions of Texas.

Also, it is known that Texas has a wide variety of weather regimes since part of it fringes on the tropics (26°N) and part of it lies along the southern boundary of the middle latitude westerlies (36°N). Throughout Texas there are many climatic regions ranging from humid temperate and sub-tropical areas along the coast to the dry continental areas of the western half of the state. This variability, coupled with the fact that Texas is relatively free of severe orographic effects, except in the Trans-Pecos region, will provide an ideal setting for an investigation of station representativeness and the inherent error of using values at a single point to represent values of a large area.

Because of its wide climatic variability, ten climatic divisions were set up for the state of Texas (Fig. 2) by the National Weather Service in the 1950s. This investigation will examine the variability of temperature and precipitation within each of these ten climatic divisions of Texas, as well as the state as a whole, and will show the degree of representativeness and accuracy of single point measurements with respect to the divisional averages.

B. Sources of the Data

The divisional data used in this study were extracted from the National Climate Information Disc: Volume One compiled by the National Climatic Data Center in Asheville, North Carolina. This disc contains divisional monthly and annual mean temperatures and precipitation totals calculated by averaging together all reporting stations in each respective division. Because of the fact that pre-1930 divisional data were calculated from the statewide average by a regression technique (R. Muller and G. Faiers 1993, personal communication), this period of record was eliminated from this study.

Individual station data were obtained through the use of the Summary of the Day CD-ROM from EarthInfo, Inc. This CD-ROM included monthly averaged maximum and minimum temperatures and precipitation records for Texas stations as recorded by the National Climatic Data Center. Since only the

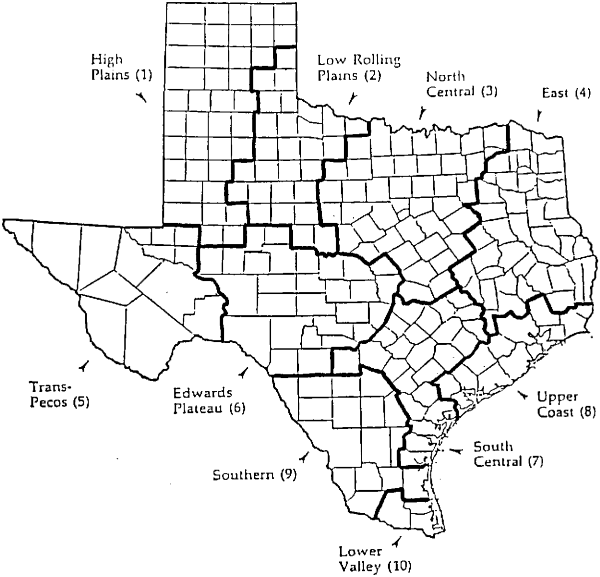


FIG. 2. Ten climatic divisions of Texas.

average maximum and minimum monthly temperatures were available from the Summary of the Day CD-ROM, the monthly mean temperatures were calculated by averaging together the maximum and minimum temperatures. Maximum and minimum temperatures were not correlated in this study because the divisional data from the National Climate Information Disc did not include these temperature values and most temperature studies focus only on mean values.

The statewide temperature and precipitation records were calculated using a FORTRAN program which areally weighted each divisional record. This was accomplished by multiplying each division's areal percentage weighting by the divisional values obtained from the National Climate Information Disc. The ten areally weighted divisional values were then added together in order to obtain the statewide total.

By transferring these monthly and annual totals to the Wylbur computing system, the SAS statistical program was then utilized in order to correlate the station, divisional, and statewide data.

C. Station Selection Criteria

In order to accomplish the objectives of the proposed study, an average of five stations from each climatic division in Texas were chosen (Fig. 3) based on the completeness of their record and the homogeneity of their climatic series to

FIG. 3. Selected stations used for study.

provide the most accurate analysis of natural, and not man-made, climatic variations. Some of the inhomogeneities that have been identified by Mitchell (1953) include changes in instrumentation, exposure and station location. However, Mitchell considers the effects of changes in instrumentation and exposure on monthly mean temperatures to be small for stations in the United States. Thus, this inhomogeneity is not considered here but station location inhomogeneities are to be minimized for this thesis.

Because of the observed 'urban heat island' warmings of 1-2°F in previous studies (Cayan and Douglas, 1984; Mitchell, 1953), urban influences are also minimized in this study by the exclusion of urbanized stations, defined here as having populations >25,000.

The criteria that were used for this study are summarized below:

(1) Long continuous record, preferably >50 years.

(2) Minimal number of station moves with no station moves of more than a mile.

(3) Non-urbanized locations (population <25,000).

(4) Use of stations that provide adequate spatial coverage of climatic divisions.

Most every station selected, 50 stations overall, met the above criteria with a few exceptions. Dalhart had a move in station location of over a mile in 1947, but was selected due to the fact that it was the only station in the northwest panhandle area to meet the other three criteria. Although San Angelo, Huntsville, and Lufkin are 'urbanized' stations with populations of roughly 100,000, 30,000, and 30,000, respectively, and although Sonora, Sanderson, and LaTuna are stations with records of only 40 years, on average, these stations were selected because they were the only stations in their respective areas that met the other three criteria. All other stations selected for this study adequately fulfilled the four criteria.

CHAPTER III
METHODS OF ANALYSIS

A. Correlation Coefficient

The principal index used in this thesis is the Pearson product-moment correlation coefficient which, according to Conrad and Pollak (1962), is 'a generally valid measure of the degree of association of two series'. As shown by Brooks and Carruthers (1953), the correlation coefficient can be represented by the following linear relationship:

$$r_{xy} = \Sigma[(x-X)(y-Y)]/\sqrt{[\Sigma(x-X)^2\Sigma(y-Y)^2]}$$

where x and y are paired values and X and Y their mean values. With the average sample in this investigation containing at least 50 pairs of observations, Brooks and Carruthers (1953) explains that the smallest correlation coefficient which could still be statistically significant is 0.452 at the 0.001 significance level (P(0.001)), 0.361 at P(0.01), and 0.279 at P(0.05). Thus, 'a coefficient of 0.30 based on 50 pairs of observations would be equaled or exceeded by chance in unrelated data between once and five times in 100 trials. An isolated coefficient of +0.30 or -0.30 based on 50 pairs of observations is therefore above the significance level of 5 percent and probably indicates a real relation between the two variables' (Brooks and Carruthers, 1953).

After obtaining the correlation coefficient between a point and areal estimate and determining the standard deviation of the areal estimate, the residual error, $\sigma_y\sqrt{(1-r_{xy}^2)}$, can then be calculated in order to evaluate the size of the error term involved when using a single point to represent an area. Although the correlation coefficient in this thesis is used to examine the relationship between both point-to-point and point-to-areal estimates, it has been remarked (Conrad and Pollak, 1962) that the *correlation coefficient* does not indicate anything about the causal association of two series of numbers representing the variations of two atmospheric variables. Thus, although this thesis suggests some possible causes of the observed correlations, but, because it is beyond the scope of this investigation, does not present definitive proof of the suggested causal relationships.

B. Potential Problems

When investigating the correlation between two series of meteorological variables, the series are assumed to contain random, independent observations with normal distributions. The problems of spurious correlations, 'persistence', and the interrelationship between temperature and precipitation are concerns that will be addressed now in order to further validate the later findings of this investigation.

Since the divisional averages are computed by averaging all the reporting stations in a particular division, the correlation of an individual station to the divisional average has a certain degree of spurious correlation involved.

has a certain degree of spurious correlation involved. However, since the number of stations used to calculate the divisional averages range from 12 in division ten to 134 in division 3 with an average of around 60 stations per division, the degree of spurious correlation is considered small enough to be ignored.

The term 'persistence' has been used by climatologists to explain that 'a meteorological observation is not usually independent of preceding conditions, though the dependence decreases with the length of the time interval between successive events' (Brooks and Carruthers, 1953). As noted by Thom (1966), a climatological series is 'a sample series of data consisting of one climatological value for each year of the record being considered' and is assumed 'to behave as if it were infinite in extent and having climatic properties such that the observed climatological series is a random sample from that infinite population, that is to say a sample drawn in a manner independent of the individual magnitudes of the members of the infinite population'. Since this study focuses on the correlation between two different series with one observation per year, it is assumed that there is little, if any, persistence between, for example, January of one year and January of the preceding year.

In regards to the interrelationship between temperature and precipitation, the divisional temperature and precipitation series used in this study (1930 through 1989) are correlated together and found to exhibit, consistent with previous findings for the state of Texas by Lyons (1990) and Bjornsen (1990), significant inverse correlations only during the summer months in Texas (Table 1). Outside of the summer months (June, July, and August), there are very few correlations greater than 0.40 with a high probability of being significant between temperature and precipitation series. Thus, it was decided that there would be no need for partial correlations in this study.

TABLE 1. Correlation coefficients of statewide precipitation versus temperature series (1930-1989). Prob>/R/ is the probability that the two series are unrelated and the coefficient is insignificant.

Division	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
One	-0.28	-0.24	-0.27	-0.27	-0.20	-0.57	-0.74	-0.62	-0.56	-0.20	-0.31	-0.28	-0.41
Prob>/R/	0.03	0.07	0.04	0.04	0.12	.0001	.0001	.0001	.0001	0.12	0.02	0.03	0.001
Two	-0.12	-0.16	-0.05	-0.16	-0.16	-0.65	-0.75	-0.70	-0.62	-0.22	-0.18	-0.05	-0.48
	0.35	0.21	0.70	0.21	0.22	.0001	.0001	.0001	.0001	0.09	0.17	0.73	0.0001
Three	-0.02	0.00	-0.13	-0.13	-0.27	-0.63	-0.68	-0.62	-0.44	-0.22	+0.03	+0.04	-0.47
	0.86	1.00	0.33	0.34	0.04	.0001	.0001	.0001	.0004	0.09	0.84	0.78	0.0001
Four	+0.10	+0.09	-0.03	-0.05	-0.20	-0.43	-0.51	-0.57	-0.33	-0.06	+0.05	-0.02	-0.25
	0.46	0.51	0.83	0.72	0.13	.0008	.0001	.0001	0.01	0.65	0.69	0.90	0.06
Five	-0.36	+0.11	-0.31	-0.13	-0.19	-0.41	-0.71	-0.52	-0.53	-0.31	-0.32	-0.24	-0.35
	0.005	0.40	0.02	0.33	0.16	0.001	.0001	.0001	.0001	0.02	0.01	0.06	0.007
Six	+0.07	-0.16	-0.33	-0.31	-0.38	-0.57	-0.60	-0.65	-0.47	-0.25	-0.14	+0.06	-0.34
	0.59	0.22	0.01	0.02	0.003	.0001	.0001	.0001	.0002	0.06	0.30	0.68	0.008
Seven	-0.16	-0.26	-0.21	-0.24	-0.37	-0.57	-0.68	-0.57	-0.41	-0.17	-0.13	-0.16	-0.56
	0.22	0.05	0.11	0.07	0.004	.0001	.0001	.0001	0.001	0.20	0.34	0.22	0.0001
Eight	-0.17	-0.15	-0.14	-0.13	-0.13	-0.33	-0.62	-0.46	-0.14	+0.14	+0.03	-0.16	-0.34
	0.21	0.26	0.29	0.32	0.32	0.01	.0001	0.002	0.29	0.30	0.83	0.24	0.009
Nine	-0.24	-0.34	-0.10	-0.29	-0.41	-0.63	-0.66	-0.61	-0.47	-0.20	-0.35	-0.21	-0.54
	0.07	0.01	0.46	0.02	.001	.0001	.0001	.0001	.0002	0.13	0.006	0.12	0.0001
Ten	-0.34	-0.32	-0.17	-0.11	-0.25	-0.60	-0.71	-0.55	-0.50	-0.13	-0.19	-0.29	-0.39
	0.008	0.01	0.19	0.43	0.05	.0001	.0001	.0001	.0001	0.32	0.14	0.03	0.002
State	-0.09	-0.13	-0.19	-0.14	-0.33	-0.64	-0.71	-0.66	-0.53	-0.21	-0.14	-0.11	-0.48
	0.51	0.33	0.14	0.28	0.01	.0001	.0001	.0001	.0001	0.10	0.28	0.40	0.0001

C. Error Estimation

The main focus of this thesis is to estimate the error in using values at a single point to estimate values of a given area the size of a division or the state of Texas. Previous evaluations of the distance one can travel from a point and still maintain a 'accurate' representation of the area covered (Hansen and Lebedeff, 1987) have maintained that a correlation of 0.50 and, more recently, 1/e (Kim and North, 1991) will suffice in defining the term 'accurate'. However, if one postulates, using statistical analysis by Brooks and Carruthers (1953), that one needs a 50% reduction of the standard error of estimate ($\sqrt{(1-r^2)}$) for practical significance, then a correlation coefficient of ≥ 0.86 must be obtained (Fig. 4). In other words, when one attempts to regress y on x (Fig. 5), the error of prediction of y from x is $\sigma_y\sqrt{(1-r_{xy}^2)}$ where $d=\sigma_y$ and $D \sim 0.7d$ when $(1-r_{xy}^2)$, the proportion of the variance of y which is due to factors other than x, equals 0.50. Thus, by decreasing the 'representative' correlation coefficient from 0.86 to 0.50 or 1/e, the size of D, the standard deviation of y when the portion attributed to variations in x have been eliminated, will increase to larger values. With these ideas in mind, the representativeness of individual stations for an area the size of Texas will be examined in the following chapter.

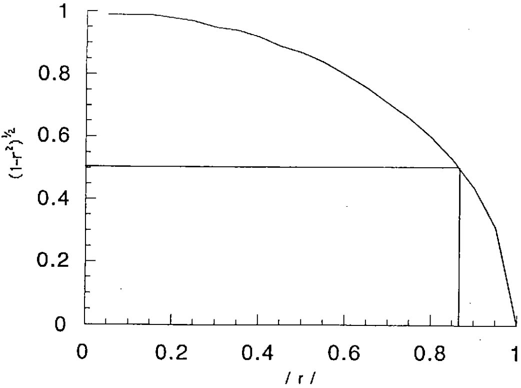


FIG. 4. Correlation coefficient (/r/) versus standard error of estimate $\sqrt{(1-r^2)}$.

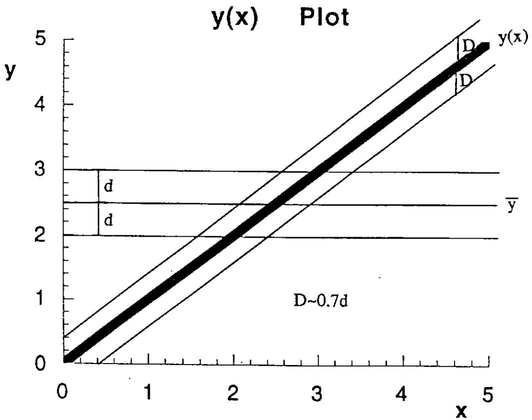


FIG. 5. Plot of y series versus x series showing the standard deviations (D,d) between y(x) and y, the mean value of y.

CHAPTER IV
PRESENTATION OF RESULTS

In order to evaluate the size of an area that a single point can represent, and its corresponding seasonal fluctuations, three different diagrams are constructed so as to represent the correlation patterns between point and areal estimates in Texas. The first diagram to be constructed is that of the station-to-station correlations versus distance graph which was used by Hansen and Lebedeff (1987) and Longley (1974). This graph yields a quantitative measure of the size of the surrounding area for which a given station's data may provide significant information on temperature and precipitation change. For this investigation, twenty stations in Texas, two from each division, were correlated against each other and then plotted against the distance between the respective pairs of stations.

The next diagram to be constructed is an isopleth map of Texas showing the correlation pattern between individual stations and the statewide average. This was done in order to reveal the actual symmetry of the area in Texas where a reliable point estimate of the state could be found and to note any seasonal patterns that developed.

The next step was to display isopleth maps of the ten divisions of Texas in order to evaluate the correlation patterns between climatic series of values at a single point and its corresponding divisional average. This final figure reveals a more realistic representativeness since it is most likely for the divisional average, rather than the statewide average, to be similar in value to the point estimate.

In all diagrams, the mid-seasonal months of January, April, July, and October are selected to be evaluated, along with annual figures, in order to observe the temporal fluctuations of the correlation patterns. The results in this chapter are presented in two different categories describing the results for both temperature and precipitation correlations.

A. Temperature

When evaluating the size of an area that a single point can 'accurately' represent, the distance of around 700 kilometers from any one point in Texas, using an annual temperature series, is the threshold from which one can expect to obtain a correlation of ≥ 0.50 (Fig. 6), which is the definition of 'accurately' adopted by Hansen and Lebedeff (1987). Kim and North (1991) used a correlation point of decay of 1/e as the threshold in order to evaluate reliable estimates of an area, which would indicate that around 1150 km is the threshold distance. However, if the threshold value of $r \geq 0.86$ is used, the distance of around 200 km, when both categories are considered together, becomes the farthest distance one can travel from a single point in Texas and still maintain an 'accurate' representativeness of the area. Because this thesis has shown that one should not use a correlation of less than 0.86 in order to obtain an areal estimate with at least a 50% reduction in the standard error of estimate, this correlation value will be used from here on to evaluate the graphs and maps.

Since the Trans-Pecos region (division 5) is known to have variable topography which could cause additional scatter in the graphs, stations that are correlated with a division 5 station are designated by a diamond in the graphs (Figs. 6-10) in order to determine the effect that division five has on the r^2 value, the proportion of the total variability of the y-values that are accounted for by the independent variable x. The exclusion of division 5 when computing r^2 for each graph did increase its value, especially during the months of January (for both temperature and precipitation) and July (only significantly for temperature). This indicates that division five experiences different climatic conditions during January and July than the rest of the state. The annual R^2 values for both temperature and precipitation show only a marginal improvement with the exclusion of division 5 correlations. However, precipitation r^2 values for October reveal a significant decrease with the exclusion of division 5 correlations which is quite surprising with no real explanation available.

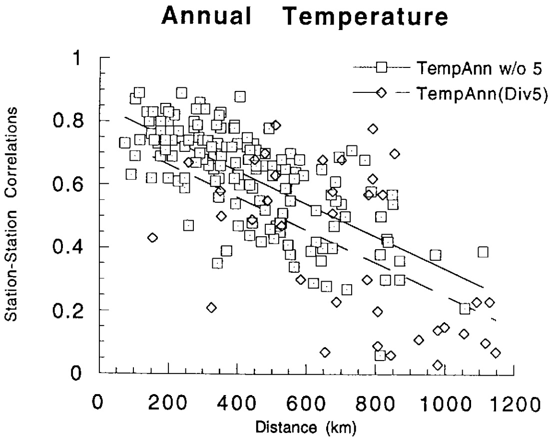


FIG. 6. Scatterplot of station to station correlations versus distance using annual temperature series (stations correlated with division 5 stations are represented by diamonds).

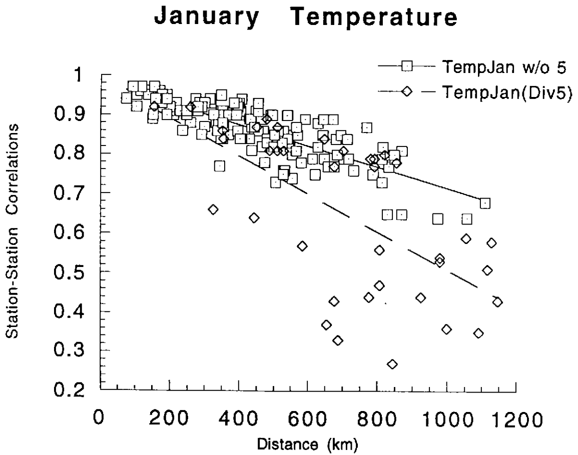


FIG. 7. Same as FIG. 6 but for January.

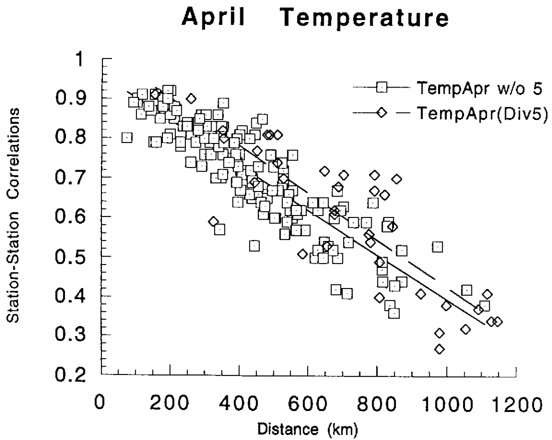


FIG. 8. Same as FIG. 6 but for April.

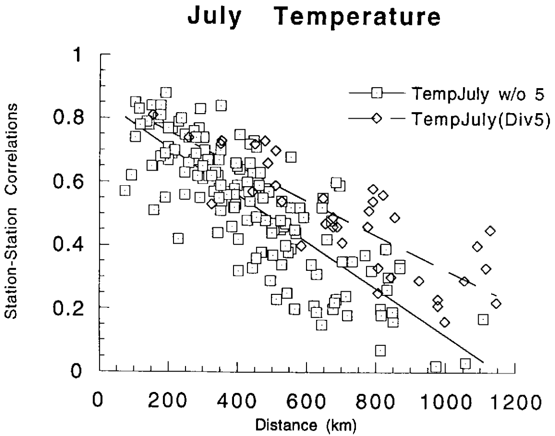


FIG. 9. Same as FIG. 6 but for July.

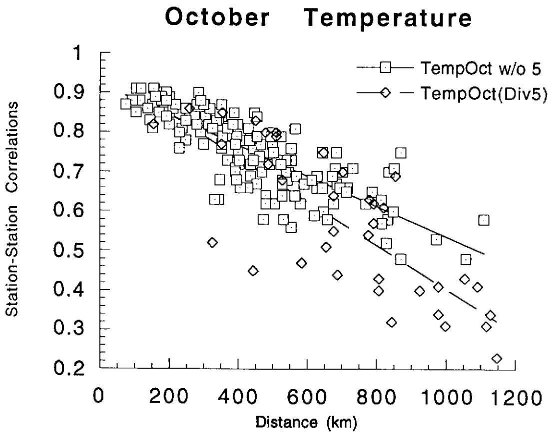


FIG. 10. Same as FIG. 6 but for October.

These station-to-station versus distance graphs are next grouped into three categories according to whether the correlations were from inland-to-inland, coastal-to-coastal, or inland-to-coastal correlated stations. This is done in order to observe the effect of the coast on the slope of the graphs. A coastal station is defined here as being within 200 km of the coastline with all other stations being defined as an inland station.

Using three different symbols on the graphs to represent the three different categories, some significant patterns are noticed (Figs. 11-15). In January, the inland-to-inland station temperature correlations decrease more rapidly with distance than the other two categories, while in July the coastal-to-coastal station temperature correlations are the least correlated category with distance. No significant differences in other months are noticed for temperature correlations. The decreases in inland-to-inland correlations are attributed to the outliers caused by division 5, as seen earlier.

Overall, the month with the highest station-to-station correlations is January with most correlations found to be above 0.80, while July is the month with the lowest station-to-station correlations with very few correlations above 0.80. The threshold distance for correlations above 0.85 is found to be roughly 500 kilometers in January, when ignoring the outlying inland-to-inland station correlations, and 0 kilometers for all categories during July. The distances for the transitional months of April and October are roughly 200 kilometers for all categories.

As is noted in the graphs, lines of best fit are determined by the least-squares method for each category used in the graphs. Although the lines do not intercept the y-axis at a correlation of one, as one might expect, the reason can be attributed to the standard error of estimate of the slope and to instrumentation error of the data used for correlation. For example, the error of the slope of the annual temperature series line of best fit (without division 5 stations) creates a y-intercept error of ± 0.02. The remaining difference between the y-intercept and the expected value of one can be attributed to instrumentation error and possible linear bias. Although a linear line of best fit is applied to the graphs in this thesis, it should also be noted that a straight line might not necessarily be the best fit for some graphs which would also explain the observed discrepancies in the expected y-intercept of one.

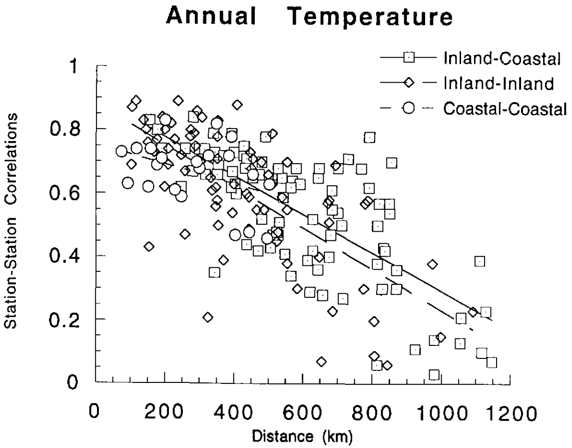


FIG. 11. Scatterplot of 3 different types (inland to coastal, inland to inland, and coastal to coastal) of station to station correlations versus distance using annual temperature series.

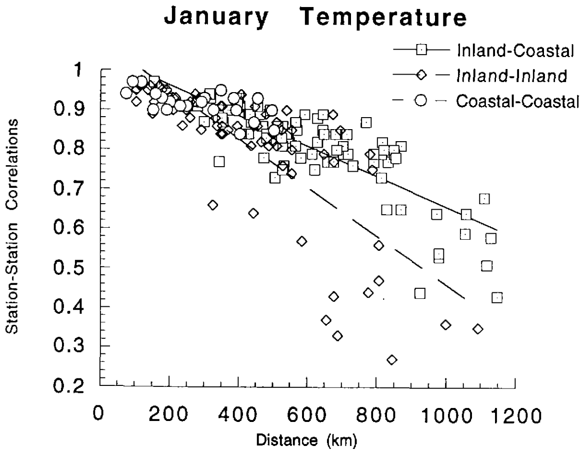


FIG. 12. Same as FIG. 11 but for January.

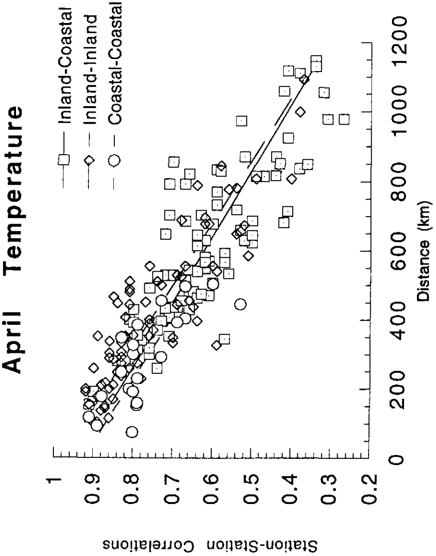


FIG. 13. Same as FIG. 11 but for April.

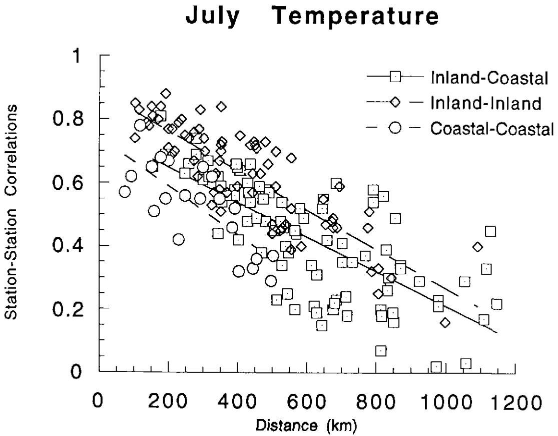


FIG. 14. Same as FIG. 11 but for July.

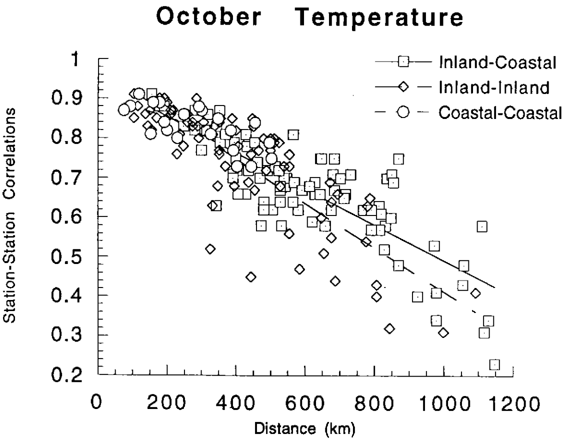


FIG. 15. Same as FIG. 11 but for October.

When observing the correlation coefficient table (Table 2) and the isopleth maps displaying the correlation patterns of individual stations versus the statewide temperature average (Figs. 16-20), one notices a wide range of contrasts among the seasons. The annual map reveals that only the Trans-Pecos region and the southern tip of Texas encounter correlations below 0.85. January is even better with only the far western tip of the state experiencing correlations below 0.85. However, April reveals no stations above 0.85 which indicates that during mid-spring, no one station can accurately represent an area the size of Texas in terms of temperature. July displays a large area of ≥ 0.85 correlations with the western, southern and coastal areas experiencing the lowest correlations. This was expected for the coastal areas since the sea breeze effect, which significantly alters the coastal temperatures, is prevalent during the summer months. Another surprising result is the fact that the entire state, except for the Rio Grande Valley, had correlations of at least 0.85 for October.

TABLE 2. Correlation coefficients of selected stations versus statewide monthly and annual temperature series (1930-1988).

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Alpine	0.86	0.82	0.87	0.75	0.79	0.82	0.78	0.82	0.85	0.89	0.89	0.81	0.70
Angleton	0.93	0.94	0.95	0.71	0.76	0.76	0.75	0.78	0.81	0.87	0.92	0.93	0.86
Beeville	0.98	0.97	0.96	0.81	0.87	0.90	0.83	0.90	0.91	0.95	0.97	0.96	0.92
Blanco	0.99	0.98	0.99	0.83	0.91	0.93	0.93	0.96	0.97	0.97	0.97	0.98	0.96
Bonham	0.97	0.96	0.98	0.78	0.95	0.96	0.93	0.95	0.96	0.98	0.97	0.97	0.94
Cameron	0.97	0.97	0.98	0.80	0.95	0.96	0.93	0.95	0.96	0.97	0.97	0.97	0.96
Canyon	0.94	0.92	0.94	0.68	0.87	0.89	0.93	0.92	0.89	0.88	0.92	0.88	0.90
Carrizo Sps	0.95	0.95	0.94	0.88	0.77	0.77	0.66	0.79	0.77	0.91	0.94	0.94	0.89
Childress	0.95	0.94	0.97	0.81	0.92	0.93	0.93	0.94	0.93	0.94	0.95	0.93	0.92
Clark'ville	0.95	0.97	0.96	0.75	0.85	0.87	0.88	0.88	0.88	0.91	0.95	0.95	0.92
Coleman	0.95	0.95	0.97	0.81	0.92	0.93	0.93	0.95	0.93	0.94	0.95	0.93	0.94
Crosbyton	0.93	0.92	0.95	0.74	0.83	0.86	0.88	0.92	0.90	0.88	0.90	0.91	0.89
Dalhart	0.93	0.92	0.95	0.73	0.83	0.86	0.88	0.92	0.90	0.88	0.90	0.91	0.89
Dilley	0.95	0.95	0.93	0.79	0.76	0.79	0.71	0.82	0.83	0.90	0.95	0.96	0.89
Dublin	0.97	0.97	0.97	0.80	0.95	0.96	0.93	0.95	0.96	0.97	0.97	0.97	0.95
Encinal	0.95	0.95	0.93	0.76	0.76	0.77	0.72	0.81	0.82	0.90	0.95	0.95	0.87
Falfurrias	0.95	0.95	0.93	0.79	0.76	0.78	0.67	0.80	0.80	0.91	0.94	0.94	0.84
Goliad	0.98	0.97	0.96	0.80	0.87	0.89	0.85	0.91	0.90	0.94	0.96	0.97	0.93
Graham	0.97	0.97	0.98	0.80	0.95	0.96	0.93	0.95	0.96	0.97	0.97	0.97	0.95
Haskell	0.94	0.94	0.97	0.79	0.92	0.93	0.93	0.95	0.93	0.94	0.95	0.93	0.92
Henrietta	0.97	0.97	0.98	0.80	0.96	0.96	0.93	0.95	0.95	0.97	0.97	0.97	0.95
Hillsboro	0.97	0.97	0.98	0.79	0.95	0.96	0.93	0.95	0.96	0.97	0.97	0.97	0.95
Huntsville	0.95	0.97	0.95	0.74	0.85	0.87	0.90	0.89	0.90	0.91	0.94	0.95	0.92
Lamesa	0.93	0.92	0.95	0.73	0.82	0.87	0.88	0.91	0.90	0.89	0.89	0.92	0.92
Lampasas	0.99	0.98	0.99	0.83	0.91	0.93	0.93	0.95	0.96	0.97	0.97	0.98	0.96
La Tuna	0.82	0.84	0.87	0.74	0.80	0.81	0.86	0.88	0.87	0.89	0.89	0.79	0.79
Liberty	0.93	0.94	0.95	0.73	0.78	0.76	0.72	0.77	0.83	0.89	0.92	0.93	0.84
Llano	0.99	0.98	0.99	0.83	0.90	0.93	0.94	0.96	0.96	0.97	0.97	0.98	0.95
Lufkin	0.95	0.96	0.96	0.76	0.85	0.86	0.89	0.88	0.87	0.91	0.95	0.95	0.92
Luling	0.98	0.97	0.96	0.82	0.88	0.90	0.83	0.90	0.91	0.95	0.97	0.97	0.92

TABLE 2. (Continued)

Marshall	0.95	0.96	0.96	0.77	0.85	0.86	0.89	0.88	0.88	0.92	0.95	0.95	0.93
Matagorda	0.93	0.94	0.95	0.73	0.77	0.76	0.74	0.78	0.82	0.88	0.92	0.93	0.86
Memphis	0.95	0.94	0.97	0.81	0.92	0.93	0.93	0.94	0.94	0.94	0.95	0.93	0.92
Mexia	0.97	0.95	0.98	0.80	0.93	0.96	0.87	0.95	0.93	0.96	0.97	0.96	0.95
Miami	0.93	0.92	0.95	0.74	0.83	0.86	0.88	0.91	0.90	0.89	0.90	0.91	0.89
Mt. Locke	0.83	0.83	0.87	0.73	0.80	0.81	0.80	0.82	0.82	0.87	0.90	0.79	0.63
Muleshoe	0.93	0.92	0.95	0.74	0.83	0.86	0.88	0.91	0.90	0.89	0.90	0.91	0.89
Pierce	0.93	0.94	0.95	0.73	0.78	0.76	0.74	0.78	0.82	0.89	0.91	0.94	0.85
Port Isabel	0.90	0.91	0.89	0.64	0.49	0.53	0.43	0.47	0.52	0.83	0.89	0.87	0.72
Presidio	0.84	0.83	0.88	0.75	0.79	0.81	0.77	0.82	0.85	0.90	0.89	0.80	0.69
Ray'ville	0.90	0.90	0.88	0.67	0.53	0.52	0.47	0.52	0.56	0.80	0.90	0.91	0.71
San Angelo	0.99	0.99	0.98	0.81	0.90	0.93	0.94	0.97	0.97	0.97	0.98	0.99	0.97
Sanderson	0.87	0.82	0.92	0.73	0.82	0.79	0.83	0.91	0.92	0.91	0.89	0.84	0.75
Sealy	0.98	0.97	0.97	0.81	0.86	0.89	0.81	0.89	0.89	0.94	0.95	0.96	0.91
Smithville	0.98	0.97	0.97	0.82	0.87	0.89	0.83	0.89	0.89	0.95	0.97	0.97	0.91
Sonora	0.99	0.99	0.99	0.80	0.90	0.93	0.95	0.97	0.97	0.97	0.99	0.99	0.98
Uvalde	0.99	0.98	0.99	0.82	0.92	0.93	0.93	0.96	0.96	0.98	0.98	0.97	0.96
Weath'ford	0.97	0.97	0.98	0.80	0.95	0.96	0.93	0.95	0.96	0.97	0.97	0.96	0.94
Wills Pt.	0.96	0.97	0.95	0.74	0.85	0.85	0.88	0.89	0.89	0.90	0.95	0.95	0.90
Wink	0.84	0.83	0.89	0.71	0.82	0.84	0.80	0.84	0.84	0.86	0.90	0.77	0.67

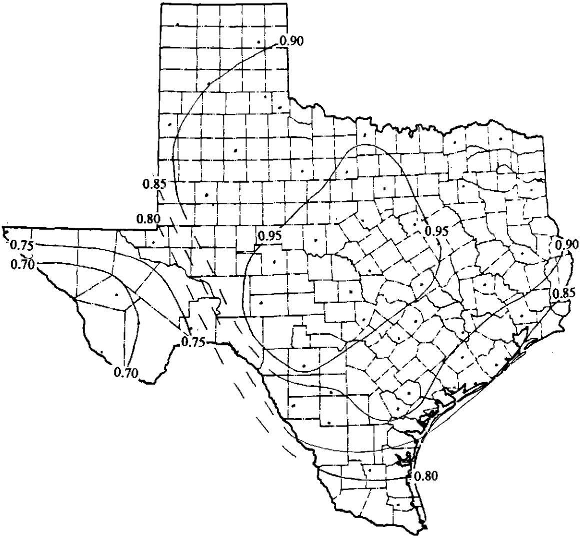


FIG. 16. Correlation pattern of station versus statewide annual temperature series.

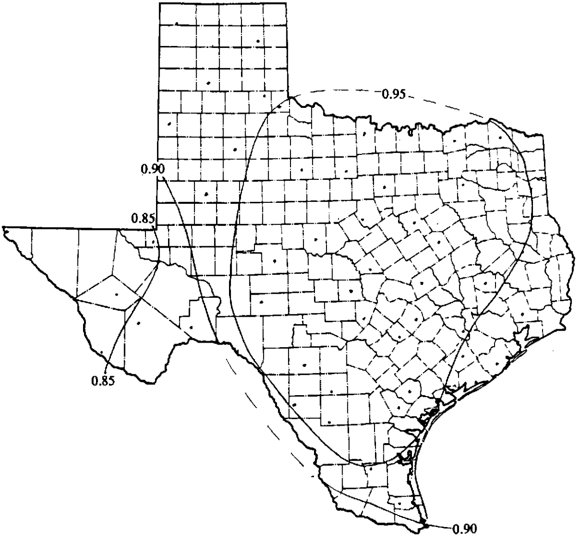


FIG. 17. Same as FIG. 16 but for January.

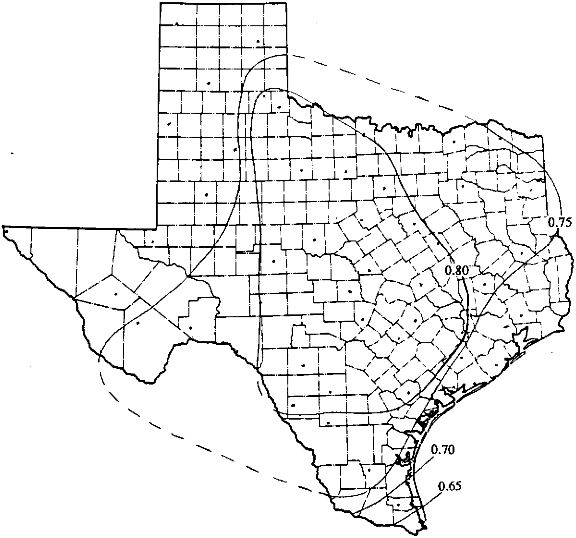


FIG. 18. Same as FIG. 16 but for April.

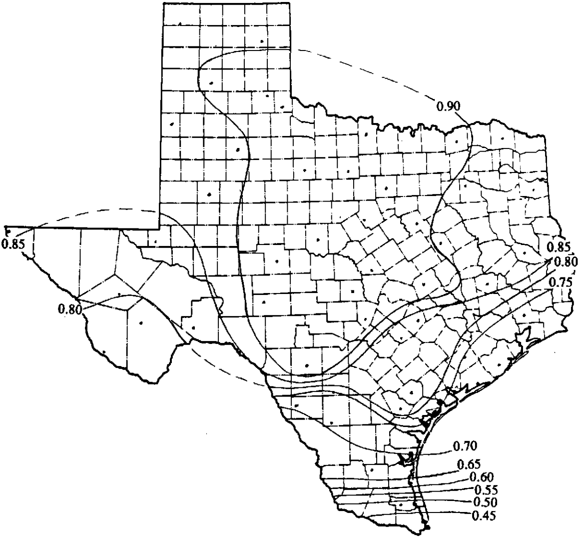


FIG. 19. Same as FIG. 16 but for July.

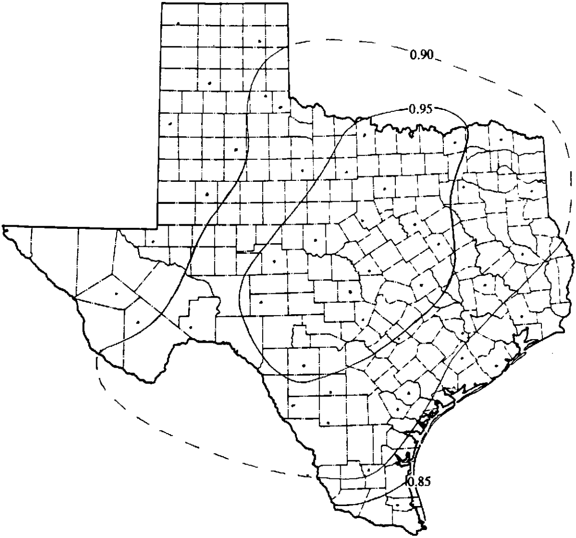


FIG. 20. Same as FIG. 16 but for October.

When observing a smaller area, such as the climatic divisions of Texas, similar patterns for temperature series emerge as with the statewide maps. Divisions one, six, and eight are chosen to be discussed in this chapter because they are the most interesting divisions in terms of variability. The other divisions in Texas did not reveal any unexpected results and thus, will not be discussed here but can be found in the appendix.

Similar to the statewide maps, patterns of highest correlations occurring in January and lowest correlations occurring in July, and sometimes annually, are seen in the divisional maps. However, April in the divisions did not reveal the low correlations that were seen in the statewide map.

When examining each division separately, the assumption that the best point to represent an area is the center point can not be justified. In division one (Table 3; Fig. 21), the highest correlations tend to be in the northern half of the division throughout the year. While in division six (Table 4; Fig. 22), the highest correlations are usually found in the eastern part of the division, and division eight (Table 5; Fig. 23) reveals that the highest correlations are near the coast in every month except for October. It is known that each division has a relatively even distribution of stations, so the calculation of the divisional average could not contribute to these findings because the average is not biased by any particularly densely populated region of the division.

TABLE 3. Correlation coefficients from temperature series of individual stations versus division one averages.

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Canyon	0.97	0.96	0.97	0.96	0.92	0.87	0.90	0.90	0.90	0.89	0.94	0.93	0.82
n=40													4 missing
Crosbyton	0.96	0.97	0.98	0.95	0.90	0.90	0.89	0.91	0.93	0.93	0.94	0.97	0.82
n=60													4 missing
Dalhart	0.94	0.94	0.94	0.96	0.92	0.92	0.92	0.92	0.91	0.91	0.93	0.94	0.89
n=60													3 missing
Lamesa	0.91	0.87	0.92	0.92	0.75	0.84	0.80	0.83	0.85	0.86	0.89	0.93	0.72
n=60													16 missing
Muleshoe	0.95	0.96	0.97	0.96	0.91	0.92	0.91	0.94	0.95	0.92	0.95	0.93	0.86
n=60													1 missing
Miami	0.96	0.96	0.95	0.97	0.93	0.94	0.94	0.91	0.93	0.93	0.93	0.95	0.90
n=60													8 missing
Wink	0.91	0.87	0.91	0.88	0.83	0.77	0.82	0.83	0.88	0.84	0.90	0.82	0.76
n=47													10 missing

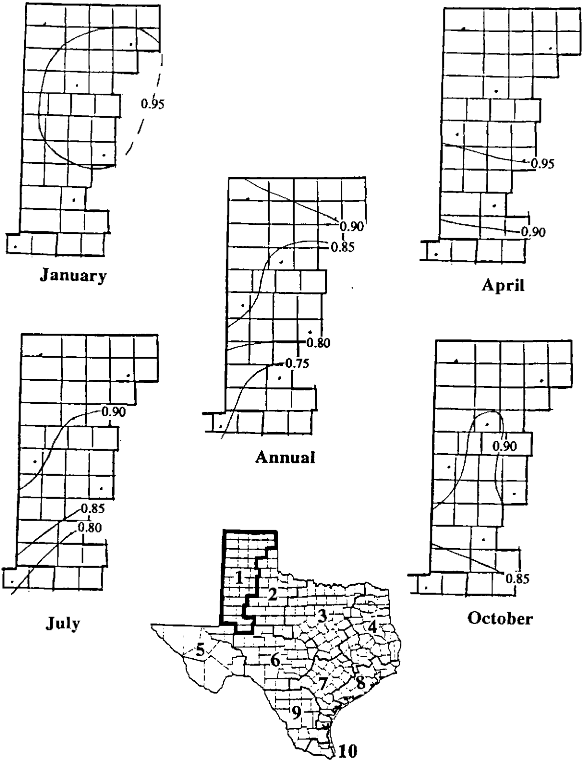
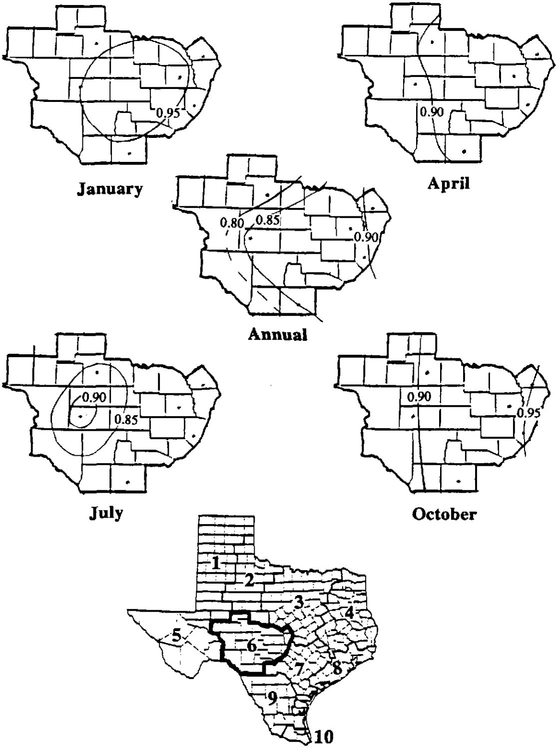


FIG. 21. Correlation pattern between temperature series of stations versus divisional averages for division one.

TABLE 4. Same as Table 3 but for division six.

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Blanco	0.98	0.97	0.96	0.94	0.84	0.85	0.84	0.88	0.88	0.95	0.96	0.96	0.89
n=60												2 missing	
Lampasas	0.98	0.95	0.95	0.93	0.86	0.87	0.81	0.84	0.91	0.95	0.97	0.96	0.93
n=60												4 missing	
Llano	0.93	0.93	0.96	0.92	0.88	0.84	0.83	0.85	0.94	0.94	0.94	0.92	0.87
n=60												7 missing	
San Angelo	0.96	0.96	0.94	0.93	0.87	0.83	0.86	0.89	0.92	0.93	0.93	0.95	0.79
n=44												3 missing	
Sonora	0.95	0.92	0.93	0.88	0.89	0.88	0.92	0.94	0.88	0.89	0.91	0.94	0.86
n=41												17 missing	
Uvalde	0.94	0.95	0.95	0.92	0.87	0.87	0.83	0.89	0.93	0.93	0.93	0.90	0.85
n=56												5 missing	



January

April

Annual

July

October

FIG. 22. Same as FIG. 16 but for division six.

TABLE 5. Same as Table 3 but for division eight.

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Angleton	0.98	0.98	0.97	0.95	0.91	0.77	0.87	0.83	0.92	0.93	0.96	0.97	0.89
n=60												8 missing	
Liberty	0.97	0.97	0.94	0.92	0.90	0.88	0.87	0.87	0.90	0.95	0.96	0.96	0.78
n=60												6 missing	
Matagorda	0.99	0.99	0.98	0.95	0.92	0.88	0.77	0.81	0.92	0.94	0.98	0.97	0.85
n=60												5 missing	
Pierce	0.97	0.97	0.97	0.92	0.86	0.81	0.70	0.84	0.87	0.96	0.96	0.94	0.80
n=60												7 missing	

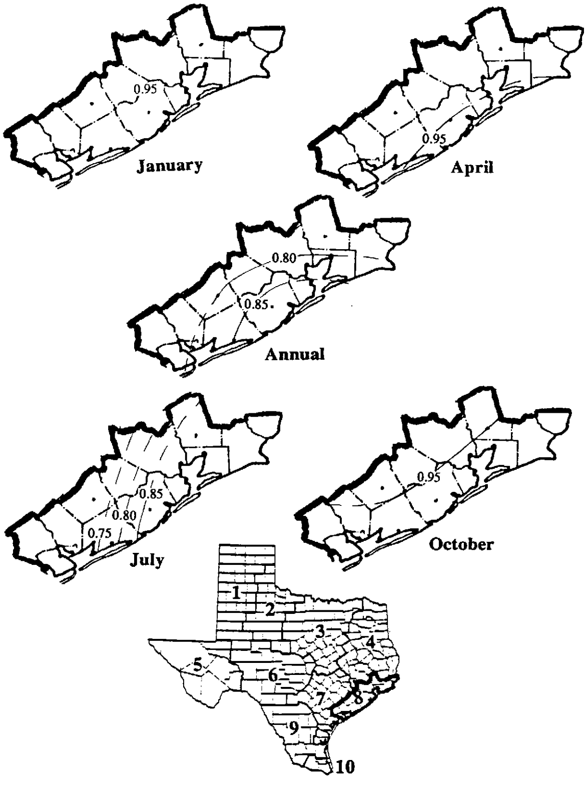


FIG. 23. Same as FIG. 16 but for division eight.

B. Precipitation

Since it is known that monthly precipitation in Texas does not follow a normal or Gaussian distribution, the monthly precipitation data in this study must first be normalized in order to satisfy the conditions of normality for a Pearson product-moment correlation coefficient. Tucker (1965), while investigating the distributions of monthly and annual precipitation data from 34 selected stations throughout Texas, utilized a square-root transformation of the monthly precipitation data and found that 88 percent of the distributions of the square-root of monthly precipitation were not significantly different from normal. The untransformed distributions of annual precipitation data for Texas were found not to be significantly different from normal for 71 percent of the distributions. Thus, a square-root transformation is utilized in this study in order to normalize the monthly precipitation data.

The precipitation correlation results indicate that representing an area in terms of precipitation is more difficult than with temperature, which is expected since it is known that precipitation is highly variable. The graphs of station-to-station correlations versus distance (Figs. 24-33) reveal that the threshold distance when correlating two different point annual precipitation series in Texas is roughly 200 kilometers (r=0.50) when ignoring the scatter caused by division 5 stations. Since a threshold distance for correlations of at least 0.85 can not be determined from the precipitation graphs, the threshold distances are evaluated for correlations of ≥ 0.50 which (as noted from Fig. 4) have only a 15% reduction in the standard error of estimate. The largest threshold distance found for precipitation correlations of ≥ 0.50 is around 400 kilometers in January and October (without division 5 stations), while July experiences the lowest threshold distance at roughly 50 kilometers. This is consistent with an earlier evaluation of Texas precipitation by Lyons (1990) where it was concluded that January precipitation had a higher correlation among stations because of the prevalence of synoptic weather systems during the winter and that July had the lowest correlations because of the isolated convection that typically occurs during the summer in Texas.

It is interesting to note that stations correlated with division five stations (Figs. 24-28) show a slower decrease in precipitation series correlations with distance especially in January and annually. This indicates that precipitation patterns during these periods in the Trans-Pecos region (division five) follow the patterns of other stations throughout Texas better with distance than any other stations.

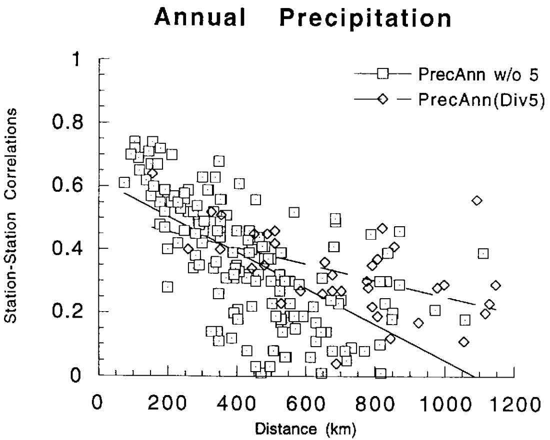


FIG. 24. Scatterplot of station to station correlations versus distance using annual precipitation series (stations correlated with division 5 stations are represented by diamonds).

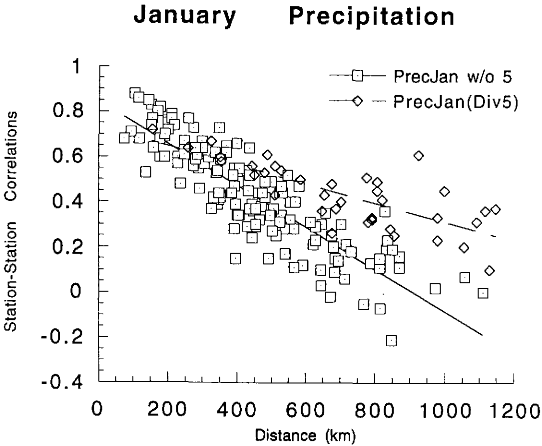


FIG. 25. Same as FIG. 24 but for January.

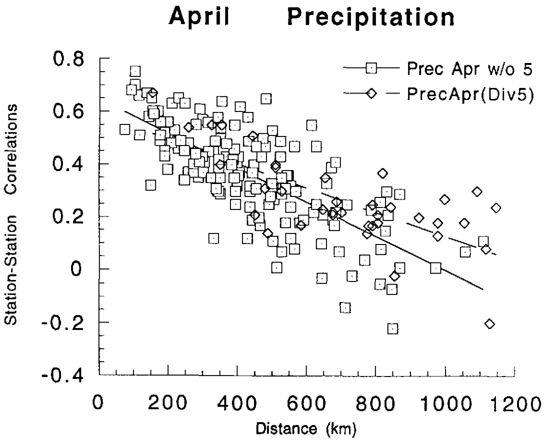


FIG. 26. Same as FIG. 24 but for April.

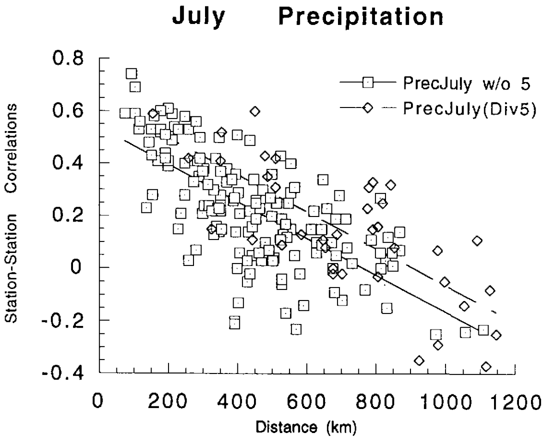


FIG. 27. Same as FIG. 24 but for July.

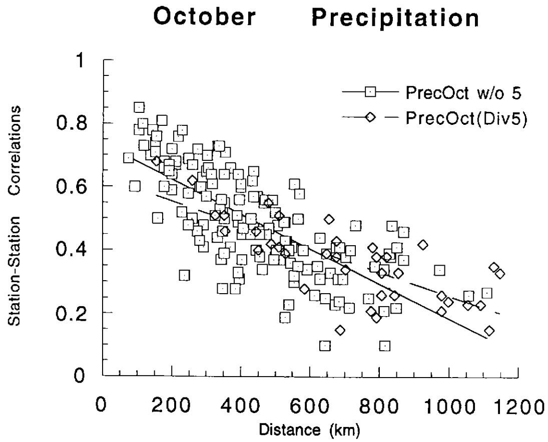


FIG. 28. Same as FIG. 24 but for October.

When separating the station-to-station correlations by coastal influences (Figs. 29-33), it is noted that coastal-to-coastal and inland-to-coastal correlated stations tend to exhibit a lower correlation than the other two categories of station-to-station correlations especially annually and in January. This is most likely due to the idea that precipitation is highly variable along the coast when compared to inland stations, especially in July, when the sea breeze effect provides a source of precipitation found only along the coast.

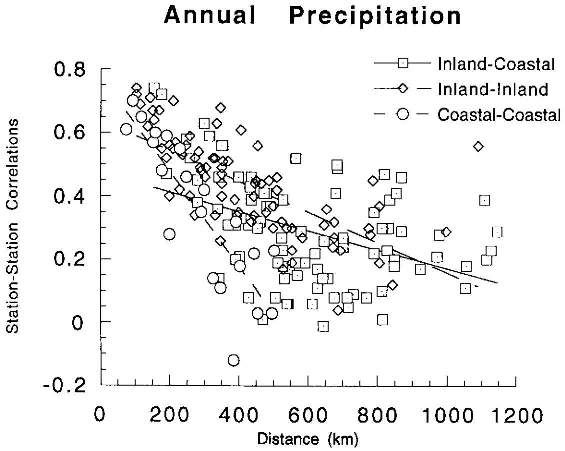


FIG. 29. Scatterplot of 3 different types (inland to coastal, inland to inland, and coastal to coastal) of station to station correlations versus distance using annual precipitation series.

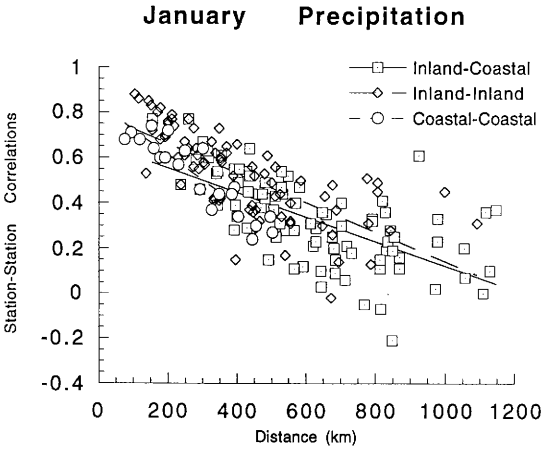


FIG. 30. Same as FIG. 29 but for January.

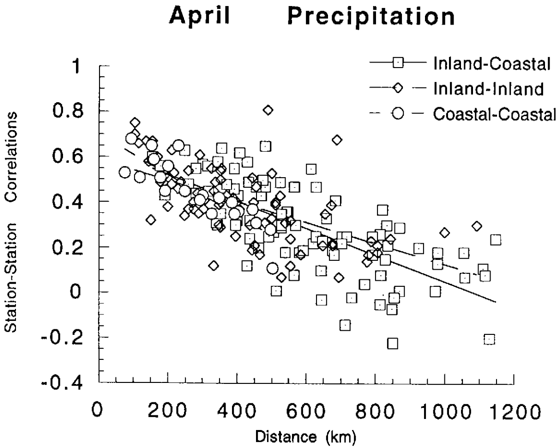


FIG. 31. Same as FIG. 29 but for April.

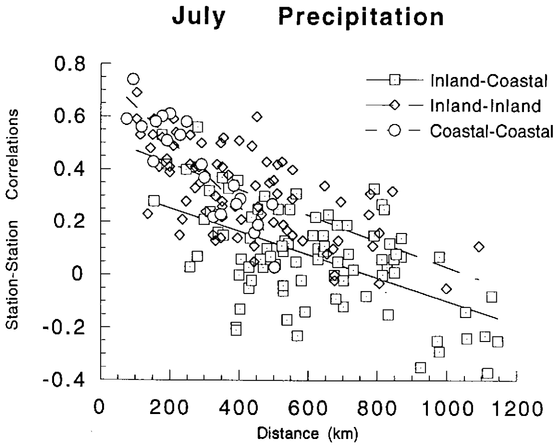


FIG. 32. Same as FIG. 29 but for July.

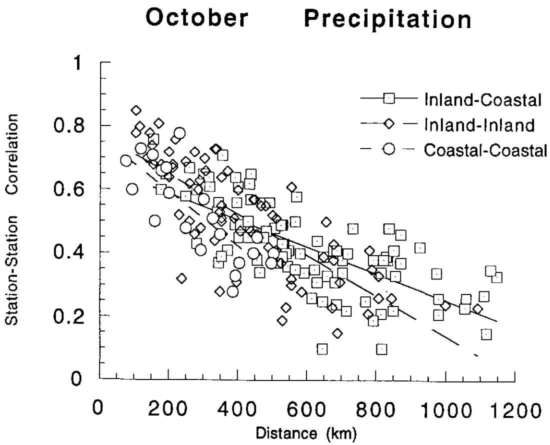


FIG. 33. Same as FIG. 29 but for October.

When observing the correlations of individual stations versus the statewide average, Table 6 and Figures 34 through 38 reveal that January and October are the only months in which one can expect to find correlations ≥ 0.85, with January revealing the greatest area of correlations above 0.85. Unlike the temperature maps, these precipitation isopleth maps reveal that a centralized point in Texas is not the best estimator of its area. The area of highest precipitation correlations is consistently found slightly to the east of the center of the state which can be attributed to the fact that the highest precipitation totals are found in the eastern part of the state. However, in July the area of highest correlations ($r \geq 0.65$) moves to the west which most likely can be attributed to the dry line phenomena which occurs in west Texas and is a more reliable rain-maker during the summer than the isolated thunderstorms which dominate the rest of the state in July.

TABLE 6. Correlation coefficients of selected stations versus statewide monthly and annual precipitation series (1930-1988).

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Alpine	0.47	0.53	0.40	0.24	0.31	0.30	0.51	0.64	0.71	0.54	0.61	0.76	0.65
Angleton	0.69	0.55	0.67	0.57	0.47	0.70	0.46	0.51	0.52	0.69	0.68	0.72	0.34
Beeville	0.69	0.59	0.56	0.68	0.51	0.54	0.45	0.65	0.53	0.71	0.56	0.62	0.66
Blanco	0.86	0.85	0.77	0.82	0.69	0.70	0.65	0.74	0.56	0.80	0.87	0.87	0.76
Bonham	0.56	0.73	0.61	0.68	0.57	0.67	0.58	0.65	0.62	0.71	0.74	0.73	0.56
Cameron	0.86	0.77	0.81	0.80	0.70	0.76	0.62	0.67	0.72	0.77	0.82	0.82	0.79
Canyon	0.64	0.48	0.61	0.49	0.29	0.34	0.46	0.32	0.53	0.68	0.59	0.53	0.50
Carrizo Sps	0.63	0.70	0.52	0.56	0.42	0.38	0.61	0.61	0.67	0.63	0.55	0.72	0.56
Childress	0.69	0.70	0.71	0.65	0.50	0.50	0.49	0.47	0.65	0.68	0.69	0.63	0.74
Clark'ville	0.47	0.65	0.59	0.63	0.59	0.66	0.35	0.46	0.49	0.67	0.71	0.71	0.64
Coleman	0.82	0.72	0.68	0.74	0.60	0.67	0.58	0.68	0.77	0.81	0.78	0.78	0.74
Crosbyton	0.70	0.66	0.62	0.62	0.52	0.50	0.66	0.46	0.63	0.68	0.64	0.65	0.68
Dalhart	0.27	0.39	0.53	0.27	0.48	0.28	0.11	0.14	0.23	0.54	0.58	0.49	0.46
Dilley	0.67	0.74	0.63	0.73	0.58	0.56	0.60	0.68	0.62	0.68	0.52	0.76	0.74
Dublin	0.89	0.80	0.79	0.74	0.57	0.75	0.55	0.57	0.76	0.82	0.87	0.80	0.71
Encinal	0.59	0.58	0.30	0.63	0.48	0.47	0.42	0.53	0.57	0.56	0.45	0.75	0.62
Falfurrias	0.43	0.48	0.28	0.32	0.47	0.51	0.23	0.35	0.51	0.62	0.48	0.58	0.30
Goliad	0.76	0.64	0.65	0.66	0.55	0.54	0.27	0.71	0.62	0.74	0.74	0.60	0.61
Graham	0.75	0.73	0.71	0.62	0.69	0.76	0.53	0.69	0.65	0.78	0.76	0.78	0.77
Haskell	0.75	0.72	0.67	0.64	0.68	0.66	0.67	0.47	0.74	0.78	0.74	0.71	0.62
Henrietta	0.67	0.72	0.62	0.62	0.66	0.63	0.48	0.60	0.63	0.77	0.79	0.72	0.65
Hillsboro	0.86	0.77	0.83	0.77	0.70	0.81	0.61	0.68	0.76	0.78	0.78	0.75	0.79
Huntsville	0.85	0.66	0.68	0.75	0.49	0.69	0.54	0.48	0.62	0.83	0.84	0.60	0.75
Lamesa	0.70	0.54	0.56	0.58	0.48	0.44	0.73	0.50	0.64	0.69	0.60	0.62	0.58
Lampasas	0.87	0.88	0.86	0.75	0.71	0.73	0.65	0.58	0.68	0.87	0.78	0.76	0.81
La Tuna	0.58	0.36	0.37	0.35	0.47	0.06	0.12	0.16	0.38	0.42	0.35	0.59	0.44
Liberty	0.72	0.62	0.64	0.76	0.43	0.73	0.43	0.56	0.41	0.74	0.71	0.65	0.64
Llano	0.86	0.87	0.81	0.80	0.72	0.71	0.61	0.71	0.59	0.79	0.82	0.82	0.68
Lufkin	0.73	0.59	0.66	0.61	0.54	0.71	0.55	0.54	0.51	0.71	0.83	0.57	0.65
Luling	0.84	0.84	0.83	0.78	0.74	0.63	0.53	0.67	0.66	0.79	0.79	0.76	0.77

TABLE 6. (Continued)

Marshall	0.67	0.64	0.61	0.64	0.63	0.74	0.42	0.55	0.39	0.63	0.71	0.68	0.62
Matagorda	0.62	0.52	0.56	0.60	0.49	0.51	0.31	0.50	0.53	0.74	0.68	0.66	0.65
Memphis	0.66	0.58	0.67	0.60	0.38	0.43	0.54	0.42	0.61	0.65	0.64	0.60	0.60
Mexia	0.85	0.76	0.73	0.81	0.56	0.74	0.54	0.59	0.61	0.82	0.85	0.78	0.79
Miami	0.42	0.53	0.58	0.42	0.48	0.42	0.35	0.41	0.56	0.62	0.50	0.55	0.52
Mt. Locke	0.63	0.48	0.34	0.17	0.28	0.11	0.53	0.58	0.65	0.59	0.52	0.69	0.48
Muleshoe	0.61	0.33	0.61	0.58	0.36	0.28	0.41	0.56	0.59	0.68	0.61	0.64	0.59
Pierce	0.72	0.62	0.72	0.70	0.62	0.62	0.53	0.47	0.53	0.71	0.69	0.69	0.69
Port Isabel	0.29	0.32	0.14	0.20	0.24	0.42	0.19	0.34	0.38	0.50	0.28	0.62	0.49
Presidio	0.43	0.48	0.18	0.22	0.32	0.21	0.43	0.50	0.59	0.61	0.47	0.60	0.50
Ray'ville	0.42	0.42	0.25	0.35	0.51	0.31	0.40	0.33	0.38	0.46	0.38	0.61	0.36
San Angelo	0.76	0.71	0.72	0.63	0.59	0.59	0.60	0.64	0.65	0.83	0.66	0.76	0.70
Sanderson	0.55	0.66	0.42	0.33	0.31	0.37	0.68	0.59	0.70	0.73	0.56	0.74	0.57
Sealy	0.84	0.63	0.68	0.73	0.71	0.68	0.54	0.60	0.59	0.73	0.82	0.65	0.76
Smithville	0.87	0.74	0.80	0.77	0.69	0.69	0.54	0.53	0.63	0.84	0.73	0.74	0.83
Sonora	0.76	0.66	0.78	0.73	0.57	0.45	0.69	0.70	0.67	0.77	0.70	0.79	0.72
Uvalde	0.74	0.76	0.66	0.69	0.62	0.35	0.57	0.70	0.62	0.63	0.52	0.73	0.76
Weath'ford	0.78	0.74	0.75	0.74	0.69	0.71	0.36	0.61	0.78	0.79	0.80	0.83	0.77
Wills Pt.	0.74	0.68	0.75	0.75	0.46	0.68	0.58	0.55	0.63	0.72	0.72	0.76	0.67
Wink	0.67	0.61	0.54	0.49	0.10	0.16	0.62	0.43	0.70	0.65	0.64	0.64	0.63

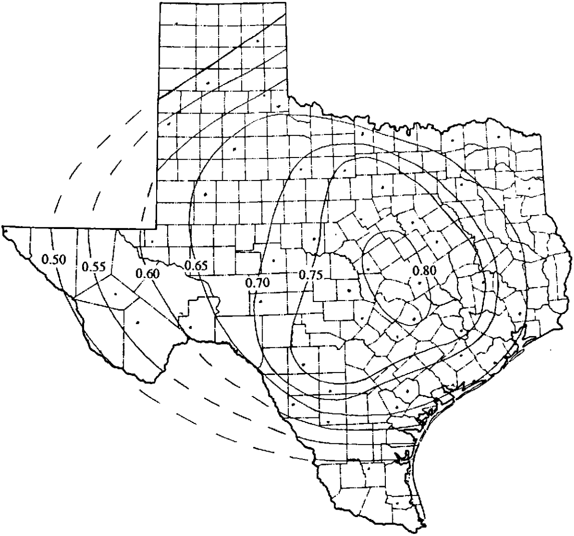


FIG. 34. Correlation pattern of station versus statewide annual precipitation series.

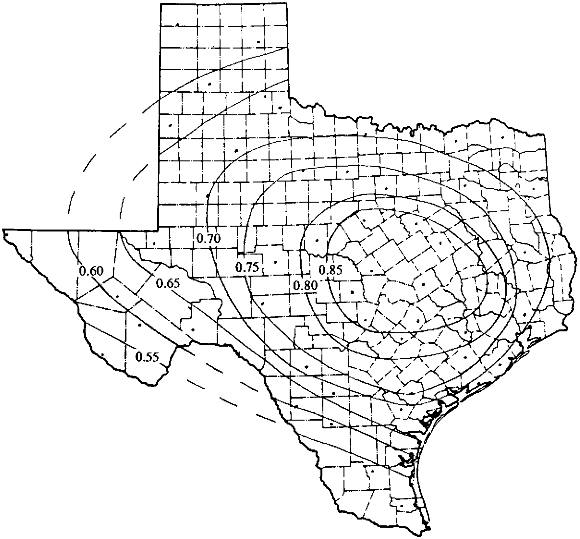


FIG. 35. Same as FIG. 34 but for January.

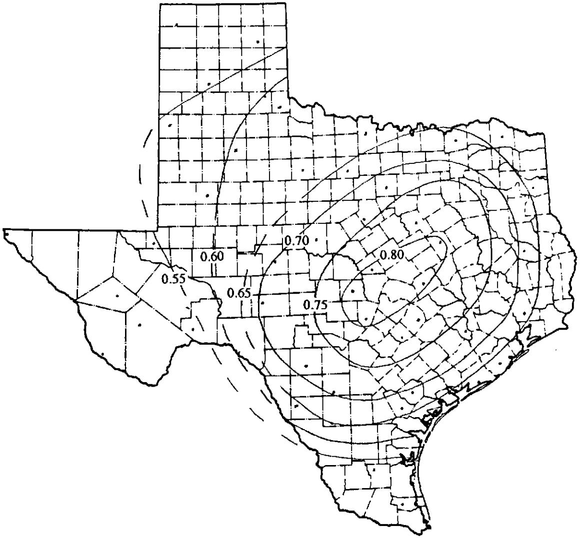


FIG. 36. Same as FIG. 34 but for April.

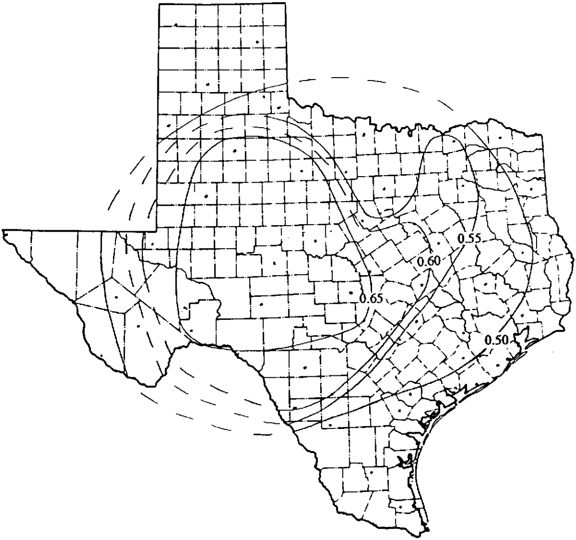


FIG. 37. Same as FIG. 34 but for July.

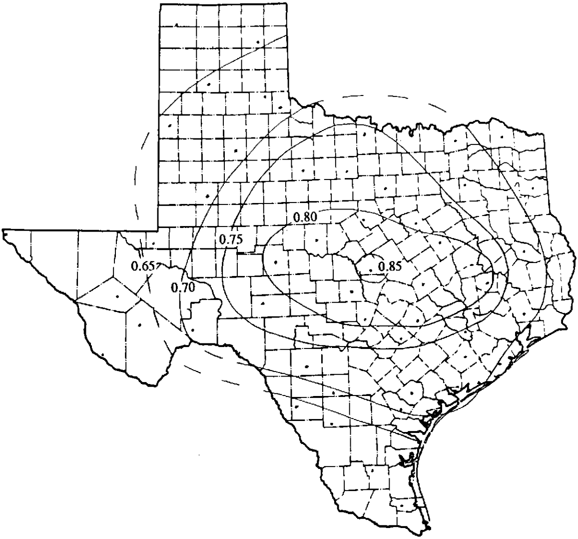


FIG. 38. Same as FIG. 34 but for October.

When observing the correlations between individual stations and the divisional averages of divisions one, six and eight (Tables 7-9), it can be seen that the greatest area of correlations ≥ 0.85 is found in January with July experiencing the lowest correlations for all three divisions. Although these correlation patterns are consistent with the earlier findings, the correlation coefficients themselves are higher for divisional averages than when compared to the statewide average. This is expected of course since a divisional average covers a significantly smaller area.

Although most areas of high correlations are centralized for precipitation in division one throughout the year (Fig. 39), division six (Fig. 40) reveals that the area of highest correlations is to be found in the eastern part of the division annually but this area varies significantly throughout the seasons. During April and July, the western section of the division displays the highest correlations while, in October, the northern section reveals the highest correlations.

In division eight (Fig. 41), the highest correlations are found inland on an annual basis and for the months of April and July. This can be attributable to the fact that the sea breeze effect is prevalent in the late spring and summer months which contributes to a more variable precipitation pattern along the immediate coast and thus, lower correlations can be expected.

TABLE 7. Correlation coefficients from precipitation series of individual stations versus division one averages.

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Canyon	0.86	0.83	0.88	0.81	0.78	0.78	0.82	0.66	0.81	0.90	0.89	0.85	0.80
n=60													6 missing
Crosbyton	0.90	0.85	0.74	0.80	0.75	0.71	0.66	0.79	0.82	0.89	0.82	0.83	0.85
n=60													3 missing
Dalhart	0.68	0.65	0.79	0.68	0.79	0.72	0.58	0.47	0.57	0.77	0.82	0.74	0.75
n=60													2 missing
Lamesa	0.74	0.69	0.69	0.63	0.71	0.58	0.54	0.72	0.80	0.79	0.72	0.74	0.71
n=60													14 missing
Miami	0.81	0.80	0.85	0.75	0.79	0.70	0.79	0.63	0.72	0.79	0.84	0.86	0.80
n=60													6 missing
Muleshoe	0.86	0.76	0.83	0.76	0.80	0.63	0.75	0.80	0.76	0.88	0.87	0.89	0.85
n=60													2 missing
Wink	0.78	0.50	0.53	0.55	0.26	0.41	0.59	0.58	0.64	0.62	0.55	0.70	0.65
n=48													4 missing

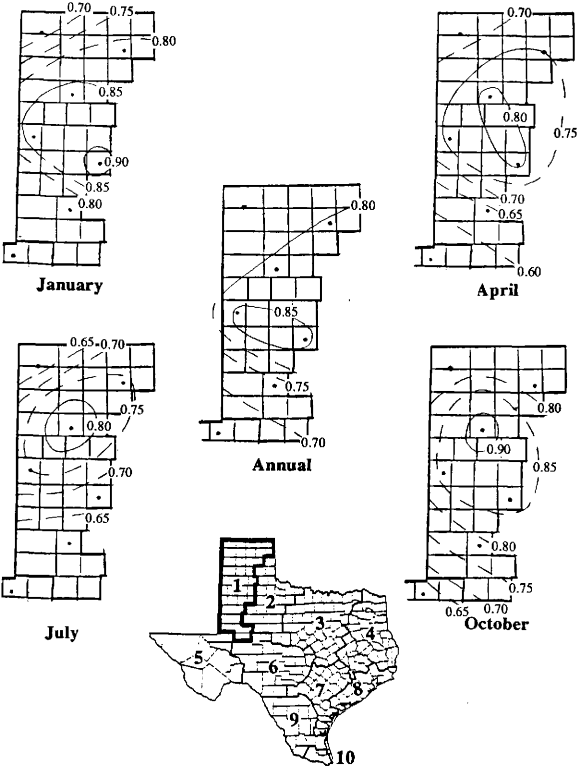


FIG. 39. Correlation pattern between precipitation series of stations versus divisional averages for division one.

TABLE 8. Same as Table 7 but for division six.

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Blanco	0.89	0.85	0.85	0.82	0.76	0.75	0.63	0.78	0.73	0.87	0.82	0.91	0.79
n=60													2 missing
Lampasas	0.90	0.90	0.80	0.75	0.76	0.64	0.76	0.57	0.76	0.89	0.81	0.85	0.84
n=60													4 missing
Llano	0.94	0.89	0.85	0.84	0.72	0.73	0.74	0.80	0.78	0.85	0.89	0.92	0.82
n=60													3 missing
San Angelo	0.86	0.82	0.80	0.78	0.76	0.60	0.64	0.74	0.68	0.86	0.88	0.85	0.75
n=44													3 missing
Sonora	0.91	0.79	0.87	0.88	0.72	0.73	0.84	0.80	0.70	0.88	0.87	0.88	0.74
n=41													14 missing
Uvalde	0.86	0.85	0.81	0.78	0.72	0.66	0.79	0.79	0.72	0.77	0.74	0.83	0.82
n=56													5 missing

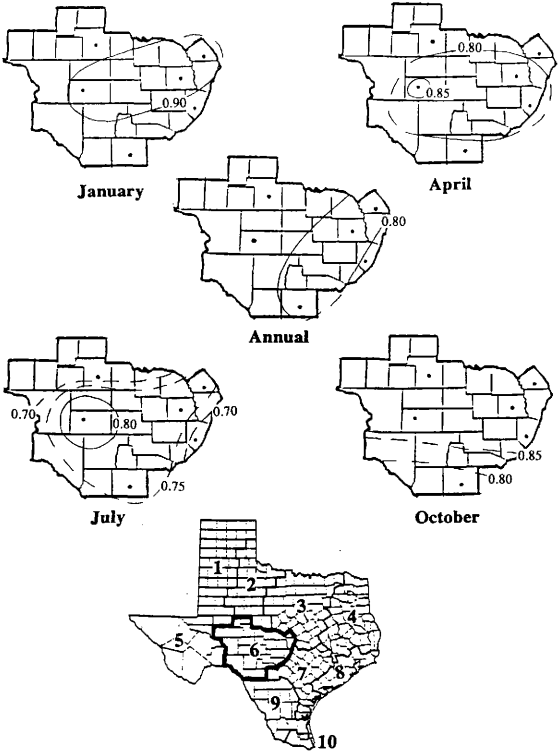


FIG. 40. Same as FIG. 39 but for division six.

TABLE 9. Same as Table 7 but for division eight.

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Angleton n=60	0.90	0.92	0.87	0.82	0.84	0.88	0.84	0.81	0.89	0.90	0.92	0.91	0.44 6 missing
Liberty n=60	0.83	0.87	0.89	0.81	0.85	0.84	0.75	0.79	0.79	0.89	0.89	0.78	0.83 4 missing
Matagorda n=60	0.85	0.84	0.85	0.80	0.78	0.82	0.79	0.80	0.83	0.88	0.84	0.86	0.86 2 missing
Pierce n=60	0.88	0.93	0.90	0.90	0.84	0.84	0.82	0.76	0.82	0.88	0.85	0.80	0.91 6 missing

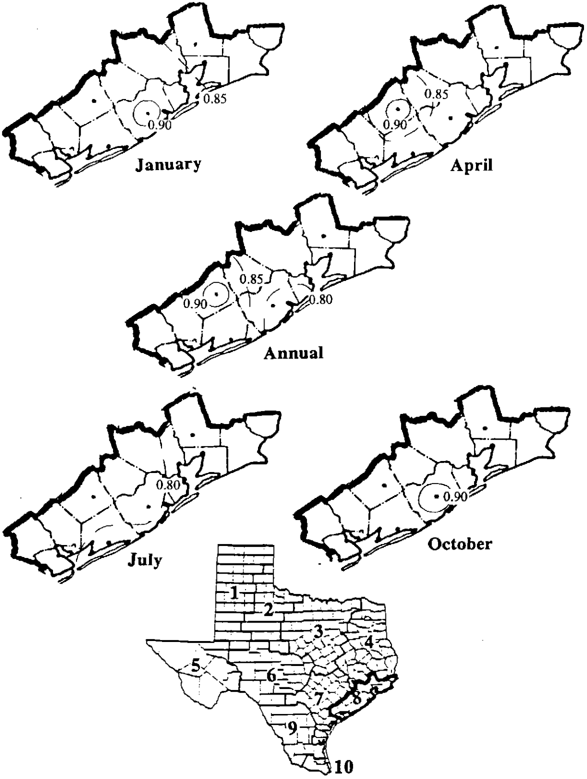


FIG. 41. Same as FIG. 39 but for division eight.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

As stated earlier, the goal of this thesis is to determine the error inherent in assuming that climatic changes at a single point (station) accurately represent similar values over a large area, and to investigate the change of the correlation coefficient between a station and a given area on temporal and spatial scales.

Fifty stations from across the state of Texas are chosen based upon the criteria of a long continuous record (preferably >50 years), minimal number of station moves, non-urbanized locations, and adequate spatial coverage. The state of Texas is chosen for this study because the dense and large station network allows for specific selection criteria and also because of the fact that Texas is relatively orography-free (with the exception of the Trans-Pecos region). The ten climatic divisions of Texas, as defined by the National Weather Service, are also used in order to evaluate the seasonality of the correlation patterns of single stations versus the divisional average.

A. Conclusions

Some conclusions that could be determined from this thesis are as follows:

1. When assessing the strength of both a point-to-point and point-to-areal relationship, the lowest correlation which should be considered is found to be 0.86. This allows at least a 50% reduction in the standard error of estimate $\sqrt{(1-r^2)}$, thus significantly decreasing the error in prediction of y from x. It is noticed that the standard deviations (σ_y) of mean monthly temperatures for areal *estimates used in this study* are on the order of 4-5°F (in January), 2-3°F (April and October), 1-2°F (July), and ~1°F (annually). Thus, the standard deviation of y not associated with variation in x, $\sigma_y\sqrt{(1-r^2)}$, is roughly ±2.0-2.5°F (in January), ±1.0-1.5°F (April and October), ±0.5-1.0°F (July), and ±0.5°F (annually) when using a correlation of 0.86. If a smaller threshold correlation value of 0.50 (Hansen and Lebedeff, 1987) or 1/e (Kim and North, 1991) is used, a standard error of estimate reduction of only 13% and 5% occurs, respectively. The standard deviation of y not associated with variation in x, for correlations of 0.50 increases to ±3.4-4.3°F (in January), ±1.7-2.6°F (April and October), ±0.9-1.7°F (July), and ±0.9°F annually for a study of temperature in Texas.

In terms of precipitation, the annual standard deviation is on the order of ±4.0-8.0". Thus, the standard deviation of y not associated with variation in x for precipitation is ±2.0-4.0" for the annual series with a correlation of 0.86. If one uses a correlation of 0.50 as the threshold value, the standard deviation of y not associated with variation in x increases to ± 3.4-6.8" for the annual series.

2. When evaluating graphs and isopleth maps in order to evaluate the magnitude and size of the 'representative' area for a single point estimate and its seasonality, some interesting results occurred. The graphs of station-to-station correlations versus distance reveal that a distance of roughly 200 kilometers for an annual temperature series and 0 kilometers for an annual precipitation series is the threshold from which an accurate ($r \geq 0.86$) representation of an area can be made. This distance covers an area of roughly 125,600 km^2 (for temperature) which is roughly one-sixth the size of Texas.

This conclusion indicates a smaller 'representative' area for temperature than was obtained from the isopleth maps of a station versus the statewide average. An explanation could be the idea that the distances determined from the graphs vary significantly for different directions in Texas. One would expect the 'representative' distances from a station directed towards the center of the state to be longer than those directed elsewhere, especially when orographic and coastal influences are included. Thus, when evaluating the isopleth maps of a station correlated to a centralized value, the statewide average, one should expect a higher correlation.

When evaluating the seasonal fluctuations of station-to-station correlations versus distance in terms of both temperature and precipitation, January is found to have the highest correlations between stations with distance, while July is found to have the lowest station-to-station correlations with distance. This conclusion reveals that a greater area can be represented by a single station during the winter while the area of station representativeness significantly shrinks during the summer. The influence of the coast on station-to-station correlations was also examined and it was found that coastal-to-coastal and coastal-to-inland correlated stations have significantly lower correlations with distance in July than inland-to-inland stations, especially in terms of precipitation.

Since the Trans-Pecos region exhibits extreme variations in topography, stations that are correlated with stations in the Trans-Pecos region (division 5) were removed in order to evaluate the change in r^2, the proportion of the total variability of the y values that are accounted for by the independent variable x. The r^2 values significantly improved for the months of January and July while the improvements in r^2 during April, October and annually were only slight. This reveals that the winter and summer months experience a greater disruption in correlations with topography than do the transitional months and annual values.

When evaluating the correlations of a single point estimate to the statewide average estimate, it is noted that, for temperature series, a single point can represent the majority of Texas during the months of January and October

($r \geq 0.86$). Annual and July correlations reveal that roughly two-thirds of the state can be represented by a single point estimate with the coastal regions experiencing the lowest correlations, which is consistent with the coastal influences results uncovered by the station-to-station correlations.

In terms of precipitation, the isopleth maps of a single point estimate correlated to the statewide average estimate reveals that only during the month of January can a single point estimate accurately represent ($r \geq 0.85$) the state of Texas. However, unlike temperature series, a station in the center of the state is not necessarily the optimal location for this single point estimate of the statewide precipitation average as the east-central area appears to show the highest correlations.

When a smaller areal average, the size of a climatic division in Texas, is correlated to a single point, the results for both temperature and precipitation series reveal higher correlations than the correlations with the statewide average (as expected). But the results also indicate that not all climatic divisions exhibit a centralized point as being the best estimator for their respective areas, especially in terms of precipitation. Divisional correlations also reveal the earlier determined conclusions of January having the highest correlations with July showing the lowest correlations. However, the three divisions chosen for study (divisions 1, 6, and 8) indicate that the area of highest correlations shifts from season-to-season with some significant changes observed for precipitation series correlations. Thus it appears that determining a single point estimate to use to represent a small area, such as a climatic division, is not as easy of a task as one might expect.

3. The previous conclusions can be evaluated with an attempt to relate these findings to the known synoptic patterns for the state of Texas. When evaluating both temperature and precipitation correlations, January was found to reveal the highest correlations while July revealed the lowest correlations. This is attributable to the fact that synoptic systems prevail during the winter in Texas while mesoscale systems predominate during the summer, which is consistent with earlier precipitation studies of Texas (Lyons, 1990). Synoptic scale systems provide a more consistent pattern of precipitation across the entire state than the isolated mesoscale convective systems of July.

The findings of low correlations between coastal and inland stations, especially during July, is likely to be attributable to the sea breeze effect, strongest during the summer, which can significantly alter the temperature and precipitation patterns along Texas coastal areas when compared to the rest of the state.

Unlike temperature correlations, the area of highest precipitation correlations, when comparing a point estimate to the statewide average estimate, was found to be located slightly to the east of the center of the state. This is consistent with the known strong east-to-west precipitation gradient in Texas, with the eastern part of the state experiencing the greatest precipitation amounts. However, the area of highest correlations shifts to the west during July which can be attributed to the dry line phenomenon occurring in the western part of the state. This dry line phenomenon creates a more reliable precipitation pattern than the isolated convection which the rest of the state experiences during the summer. Thus, when attempting to represent an area in terms of precipitation, it appears one should choose a point estimate that is slightly biased, from the central point, towards the area where the predominant (most reliable) monthly rainfall patterns occur. This concept can also explain the observed fluctuations in the correlations of a single point estimate to its divisional areal estimate.

B. Recommendations

Recommendations for future research include a need to evaluate correlations of climatic series that have been 'smoothed' by five year averages or even ten year averages. The technique of averaging climatic series into five to ten year intervals has become a common practice in order to smooth and better visualize climatic trends. The effect of this practice on correlations between point and areal estimates should be analyzed in order to note any significant changes in the representativeness of a point estimate to an areal estimate.

There is also a need to understand whether station-to-station correlations or correlations of individual stations versus statewide averages are better for determining the representativeness of a station to a given area. When estimating the size of a representative area, this thesis reveals a conflict between results obtained from graphs of station-to-station correlations versus distance and those obtained from correlations of point estimates to the statewide average.

It is also pertinent to expand this study to other areas of the United States where reliable station records with extensive histories are obtainable. The magnitude and seasonal variability of correlations should be evaluated between isolated continental and maritime areas in order to examine further the effect of nearby oceans and orography when attempting to represent an area with a single point.

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APPENDIX

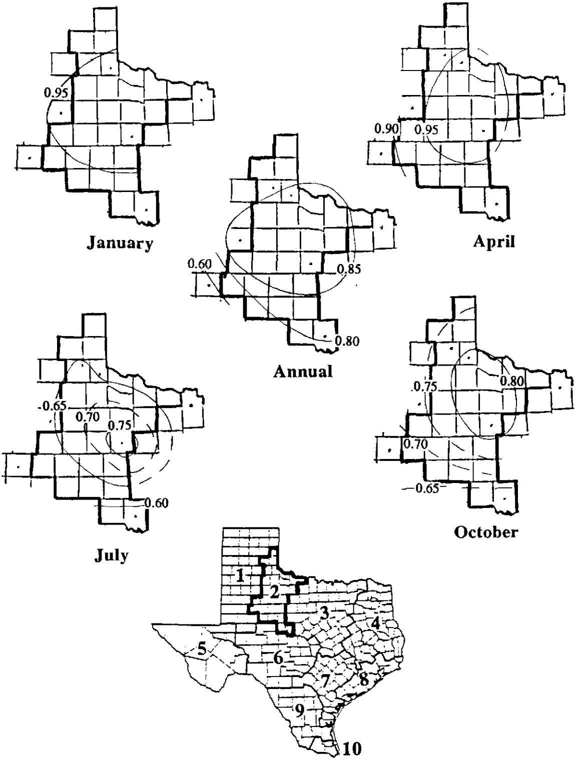
TEMPERATURE AND PRECIPITATION CORRELATION COEFFICIENTS BETWEEN INDIVIDUAL STATIONS AND THEIR DIVISIONAL AVERAGES

Correlation Coefficients: Division Two Temperature

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Childress	0.97	0.98	0.97	0.96	0.91	0.94	0.91	0.93	0.95	0.94	0.92	0.97	0.89
n=59													6 missing
Coleman	0.93	0.94	0.95	0.93	0.73	0.87	0.88	0.93	0.91	0.89	0.91	0.92	0.82
n=60													13 missing
Crosbyton	0.97	0.96	0.97	0.94	0.91	0.94	0.92	0.93	0.95	0.93	0.96	0.96	0.88
n=60													4 missing
Haskell	0.97	0.96	0.97	0.95	0.92	0.95	0.93	0.89	0.96	0.96	0.95	0.96	0.89
n=60													17 missing
Henrietta	0.96	0.96	0.96	0.92	0.88	0.91	0.86	0.88	0.91	0.92	0.91	0.94	0.80
n=60													6 missing
Lamesa	0.90	0.83	0.89	0.86	0.76	0.87	0.82	0.78	0.84	0.88	0.84	0.89	0.57
n=60													16 missing
Memphis	0.95	0.94	0.93	0.92	0.85	0.92	0.91	0.94	0.93	0.90	0.89	0.94	0.84
n=60													15 missing

Correlation Coefficients: Division Two Precipitation

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Childress	0.80	0.88	0.83	0.83	0.75	0.75	0.68	0.70	0.81	0.88	0.85	0.90	0.83
n=59													3 missing
Coleman	0.87	0.77	0.71	0.61	0.61	0.65	0.63	0.77	0.76	0.74	0.81	0.84	0.73
n=60													5 missing
Crosbyton	0.90	0.85	0.74	0.80	0.75	0.71	0.66	0.79	0.82	0.89	0.82	0.83	0.85
n=60													3 missing
Haskell	0.94	0.93	0.86	0.80	0.83	0.78	0.82	0.74	0.84	0.91	0.92	0.94	0.78
n=60													9 missing
Henrietta	0.81	0.85	0.76	0.73	0.72	0.76	0.57	0.80	0.78	0.83	0.85	0.87	0.73
n=60													5 missing
Lamesa	0.85	0.74	0.71	0.72	0.66	0.46	0.68	0.73	0.83	0.77	0.77	0.77	0.73
n=60													14 missing
Memphis	0.83	0.64	0.77	0.73	0.71	0.60	0.71	0.66	0.66	0.83	0.74	0.77	0.73
n=60													16 missing


January

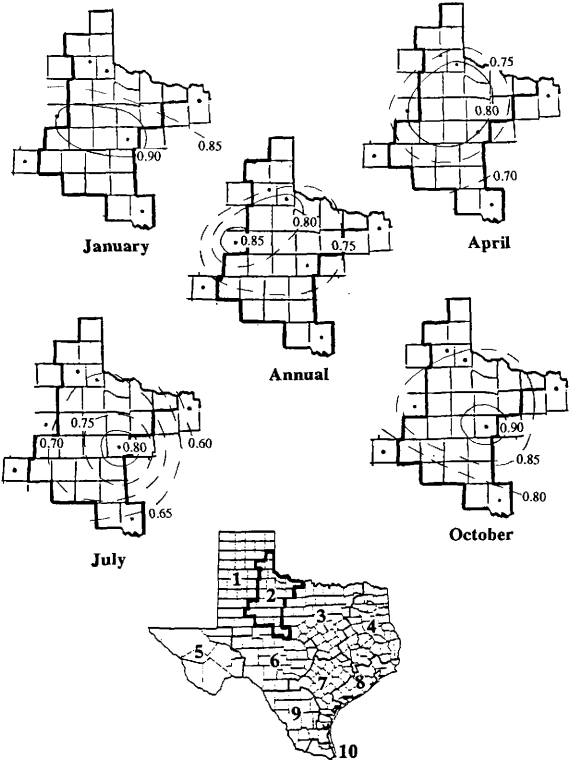
April

Annual

July

October

Division two temperature correlation patterns.



January

April

Annual

July

October

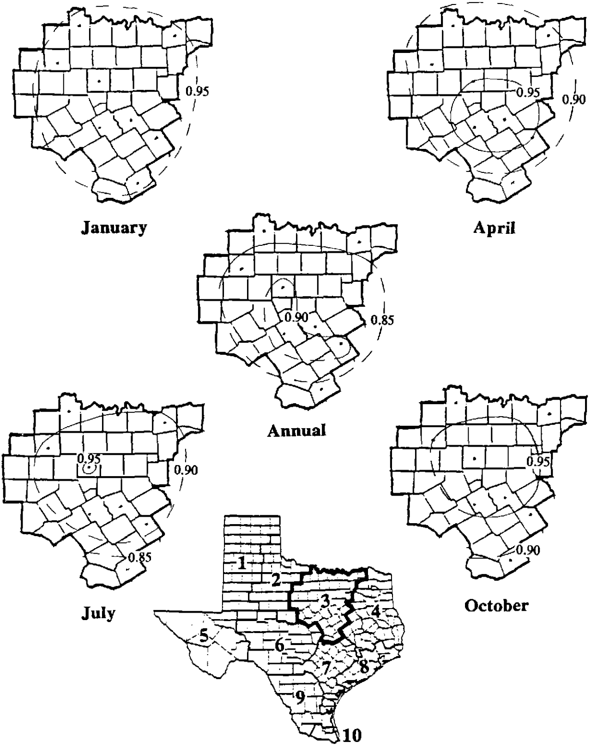
Division two precipitation correlation patterns.

Correlation Coefficients: Division Three Temperature

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Bonham	0.96	0.95	0.96	0.91	0.86	0.85	0.91	0.90	0.91	0.94	0.92	0.95	0.84
n=58													18 missing
Cameron	0.96	0.95	0.93	0.89	0.84	0.88	0.80	0.85	0.90	0.89	0.92	0.94	0.82
n=60													8 missing
Dublin	0.98	0.98	0.99	0.96	0.94	0.94	0.94	0.93	0.94	0.96	0.97	0.97	0.94
n=60													4 missing
Graham	0.96	0.95	0.96	0.93	0.92	0.93	0.93	0.89	0.94	0.95	0.95	0.94	0.88
n=60													4 missing
Henrietta	0.96	0.97	0.97	0.93	0.91	0.90	0.88	0.88	0.89	0.92	0.92	0.94	0.80
n=60													6 missing
Hillsboro	0.97	0.96	0.96	0.94	0.91	0.91	0.94	0.92	0.94	0.97	0.95	0.94	0.86
n=60													8 missing
Mexia	0.98	0.96	0.98	0.95	0.91	0.90	0.92	0.90	0.90	0.94	0.97	0.96	0.92
n=58													5 missing
Weatherford													
n=60	0.98	0.96	0.98	0.95	0.95	0.95	0.95	0.95	0.97	0.98	0.97	0.97	0.92
													3 missing

Correlation Coefficients: Division Three Precipitation

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Bonham	0.76	0.86	0.84	0.80	0.76	0.78	0.78	0.71	0.81	0.83	0.85	0.83	0.75
n=58													6 missing
Cameron	0.82	0.70	0.70	0.77	0.70	0.70	0.46	0.64	0.70	0.75	0.81	0.74	0.75
n=60													2 missing
Dublin	0.92	0.89	0.90	0.75	0.65	0.84	0.68	0.72	0.84	0.91	0.91	0.89	0.77
n=60													2 missing
Graham	0.87	0.78	0.84	0.75	0.79	0.83	0.70	0.77	0.75	0.87	0.82	0.88	0.79
n=60													2 missing
Henrietta	0.73	0.76	0.80	0.74	0.70	0.70	0.67	0.64	0.77	0.81	0.85	0.84	0.75
n=60													5 missing
Hillsboro	0.93	0.89	0.93	0.82	0.78	0.87	0.65	0.72	0.82	0.85	0.88	0.84	0.81
n=60													7 missing
Mexia	0.84	0.82	0.74	0.82	0.72	0.75	0.51	0.66	0.58	0.81	0.87	0.77	0.81
n=58													4 missing
Weatherford													
n=60	0.93	0.90	0.92	0.87	0.86	0.83	0.72	0.79	0.88	0.90	0.91	0.93	0.92
													2 missing



January

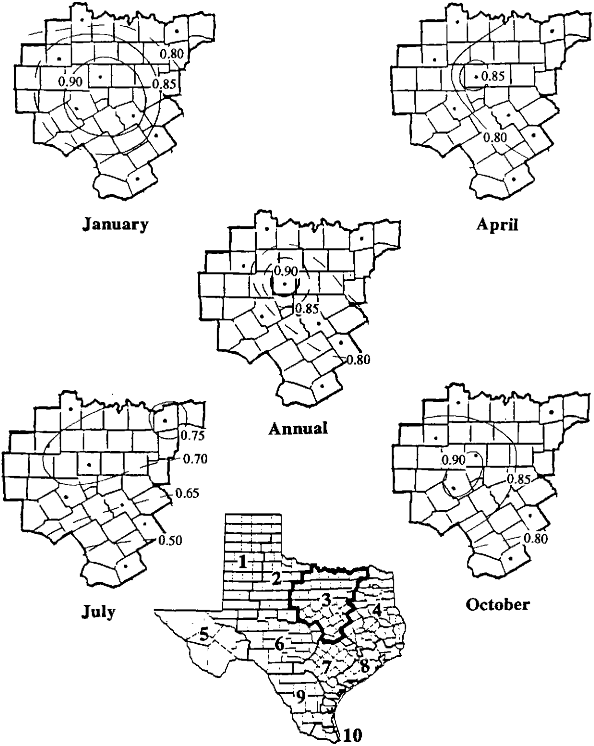
April

Annual

July

October

Division three temperature correlation patterns.



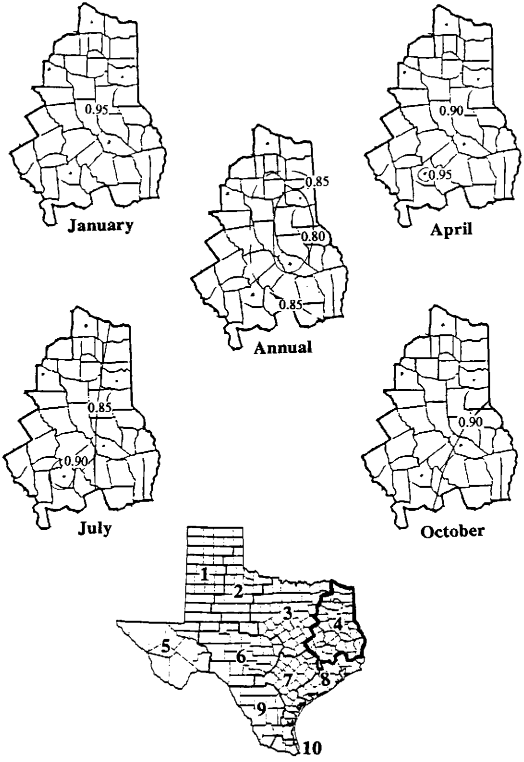
Division three precipitation correlation patterns.

Correlation Coefficients: Division Four Temperature

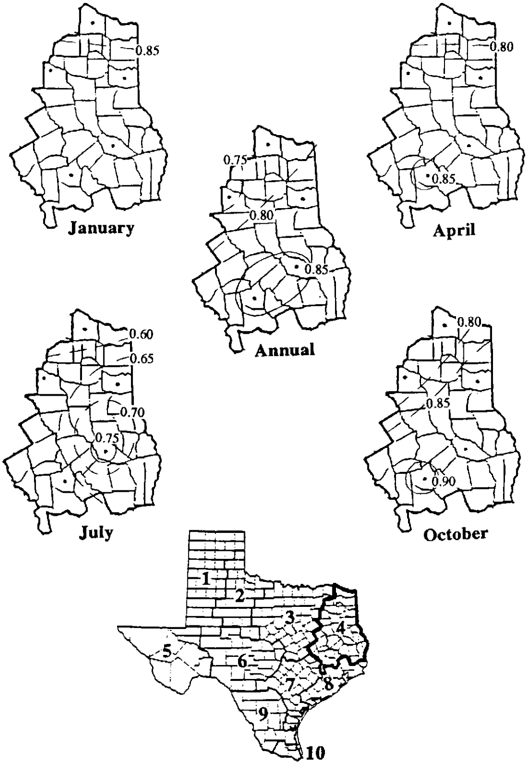
Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Clarkesville	0.97	0.97	0.95	0.90	0.90	0.92	0.88	0.89	0.89	0.91	0.90	0.95	0.90
n=59												14 missing	
Huntsville	0.99	0.98	0.98	0.95	0.92	0.92	0.92	0.92	0.94	0.94	0.97	0.98	0.89
n=44												2 missing	
Lufkin	0.97	0.95	0.96	0.92	0.88	0.86	0.84	0.88	0.90	0.89	0.95	0.96	0.78
n=60												3 missing	
Marshall	0.96	0.97	0.95	0.90	0.89	0.83	0.81	0.81	0.88	0.91	0.90	0.93	0.79
n=60												8 missing	
Wills Point	0.95	0.94	0.94	0.92	0.91	0.92	0.88	0.88	0.92	0.94	0.94	0.95	0.89
n=51												13 missing	

Correlation Coefficients: Division Four Precipitation

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Clarkesville	0.62	0.75	0.64	0.75	0.75	0.76	0.36	0.68	0.61	0.77	0.82	0.81	0.74
n=59												10 missing	
Huntsville	0.88	0.82	0.78	0.85	0.78	0.77	0.61	0.68	0.80	0.90	0.88	0.73	0.89
n=44												2 missing	
Lufkin	0.89	0.78	0.80	0.82	0.78	0.83	0.75	0.75	0.83	0.89	0.88	0.82	0.86
n=60												3 missing	
Marshall	0.86	0.83	0.84	0.84	0.87	0.87	0.68	0.65	0.75	0.89	0.86	0.90	0.84
n=60												6 missing	
Wills Point	0.87	0.81	0.76	0.81	0.75	0.75	0.62	0.64	0.72	0.78	0.84	0.81	0.69
n=51												3 missing	



Division four temperature correlation patterns.



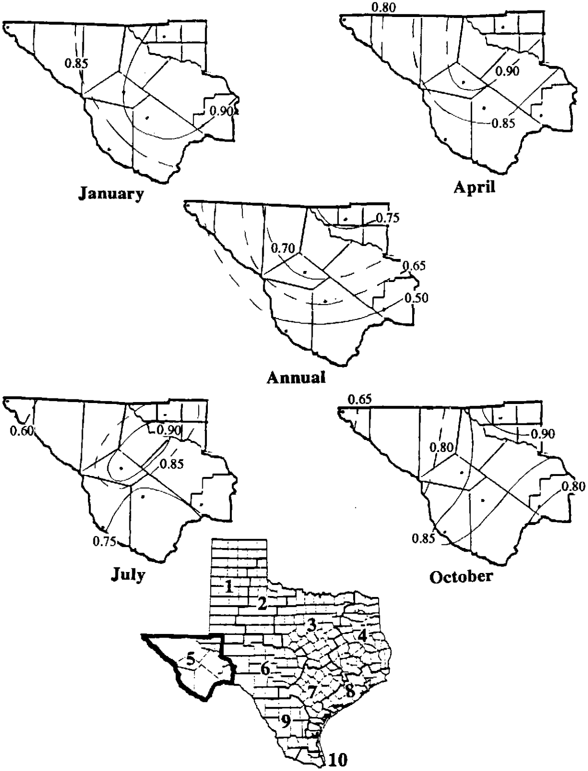
Division four precipitation correlation patterns.

Correlation Coefficients: Division Five Temperature

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Alpine	0.94	0.91	0.91	0.88	0.78	0.83	0.75	0.76	0.83	0.85	0.84	0.92	0.68
n=59												18 missing	
La Tuna	0.83	0.83	0.83	0.75	0.52	0.59	0.58	0.61	0.61	0.64	0.73	0.80	0.45
n=47												18 missing	
Mount Locke													
n=55	0.90	0.93	0.92	0.91	0.86	0.86	0.93	0.91	0.81	0.82	0.86	0.89	0.72
												5 missing	
Presidio	0.81	0.87	0.85	0.82	0.77	0.81	0.81	0.86	0.85	0.86	0.79	0.71	0.47
n=60												13 missing	
Sanderson	0.90	0.83	0.87	0.83	0.75	0.70	0.81	0.86	0.89	0.80	0.77	0.87	0.50
n=35												7 missing	
Wink	0.91	0.93	0.92	0.93	0.86	0.90	0.89	0.89	0.89	0.91	0.91	0.91	0.78
n=47												10 missing	

Correlation Coefficients: Division Five Precipitation

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Alpine	0.90	0.88	0.80	0.84	0.67	0.55	0.72	0.76	0.89	0.86	0.94	0.94	0.83
n=59												13 missing	
La Tuna	0.77	0.64	0.65	0.38	0.40	0.62	0.37	0.37	0.58	0.62	0.64	0.76	0.58
n=47												12 missing	
Mount Locke													
n=55	0.89	0.89	0.80	0.69	0.74	0.77	0.73	0.83	0.86	0.89	0.89	0.92	0.85
												2 missing	
Presidio	0.81	0.75	0.63	0.63	0.67	0.70	0.69	0.68	0.82	0.79	0.83	0.79	0.81
n=60												10 missing	
Sanderson	0.84	0.82	0.76	0.79	0.63	0.53	0.60	0.56	0.76	0.84	0.88	0.90	0.85
n=49												6 missing	
Wink	0.89	0.87	0.77	0.81	0.68	0.70	0.71	0.50	0.84	0.81	0.86	0.84	0.86
n=48												10 missing	



January

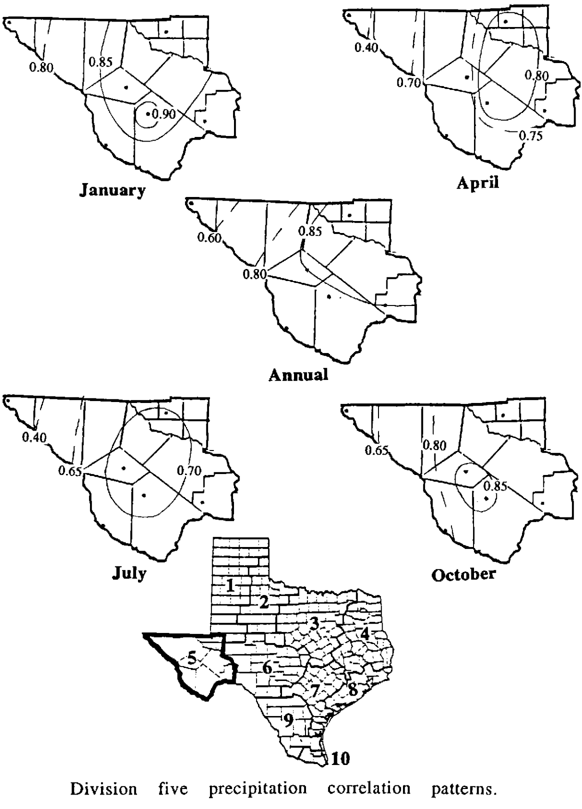
April

Annual

July

October

Division five temperature correlation patterns.



January

April

Annual

July

October

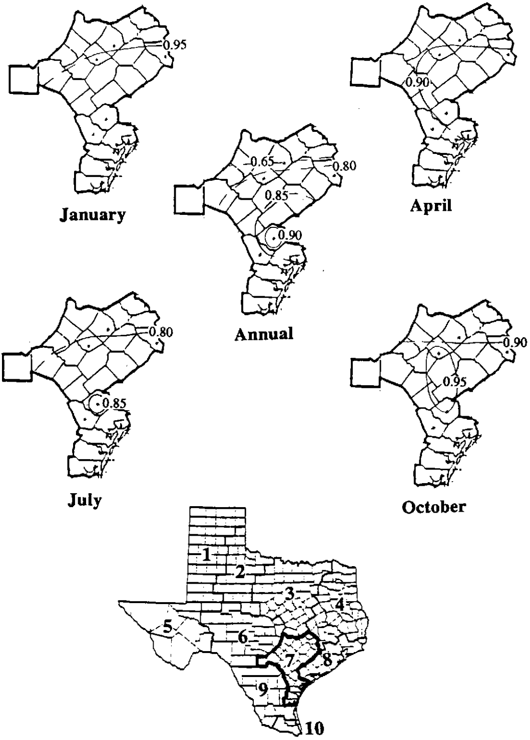
Division five precipitation correlation patterns.

Correlation Coefficients: Division Seven Temperature

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Beeville	0.96	0.96	0.94	0.87	0.94	0.86	0.82	0.84	0.86	0.94	0.94	0.95	0.81
n=59												2 missing	
Goliad	0.99	0.98	0.99	0.94	0.93	0.88	0.88	0.89	0.92	0.95	0.97	0.97	0.93
n=53												4 missing	
Luling	0.98	0.97	0.96	0.94	0.92	0.86	0.84	0.91	0.93	0.97	0.96	0.98	0.81
n=60												4 missing	
Sealy	0.97	0.96	0.96	0.91	0.82	0.81	0.82	0.80	0.88	0.92	0.90	0.94	0.83
n=55												8 missing	
Smithville	0.92	0.91	0.90	0.88	0.80	0.80	0.77	0.73	0.73	0.88	0.88	0.90	0.65
n=59												9 missing	

Correlation Coefficients: Division Seven Precipitation

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Beeville	0.87	0.78	0.75	0.85	0.69	0.79	0.78	0.79	0.78	0.81	0.74	0.82	0.80
n=59												2 missing	
Goliad	0.91	0.88	0.79	0.83	0.75	0.79	0.73	0.78	0.85	0.83	0.87	0.82	0.81
n=60												3 missing	
Luling	0.92	0.91	0.88	0.90	0.84	0.81	0.81	0.79	0.83	0.89	0.90	0.92	0.89
n=60												2 missing	
Sealy	0.84	0.63	0.74	0.45	0.69	0.52	0.60	0.52	0.63	0.58	0.72	0.60	0.68
n=55												7 missing	
Smithville	0.88	0.81	0.86	0.88	0.83	0.85	0.78	0.71	0.75	0.89	0.86	0.90	0.84
n=59												7 missing	


January

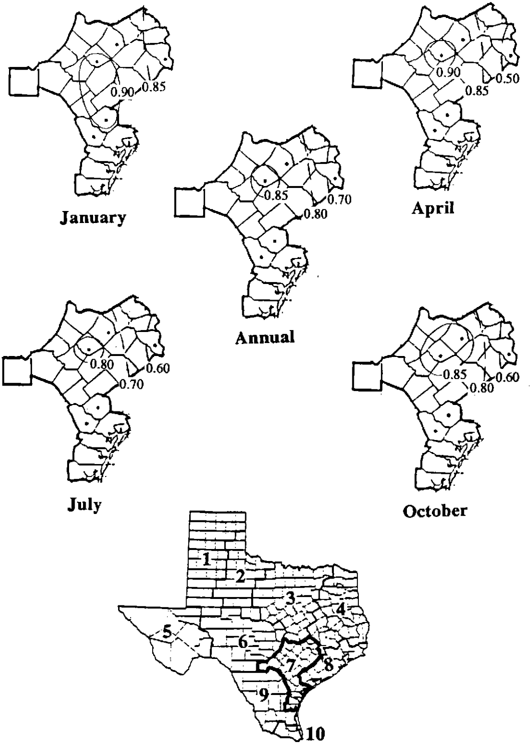
Annual

April

July

October

Division seven temperature correlation patterns.



January

Annual

April

July

October

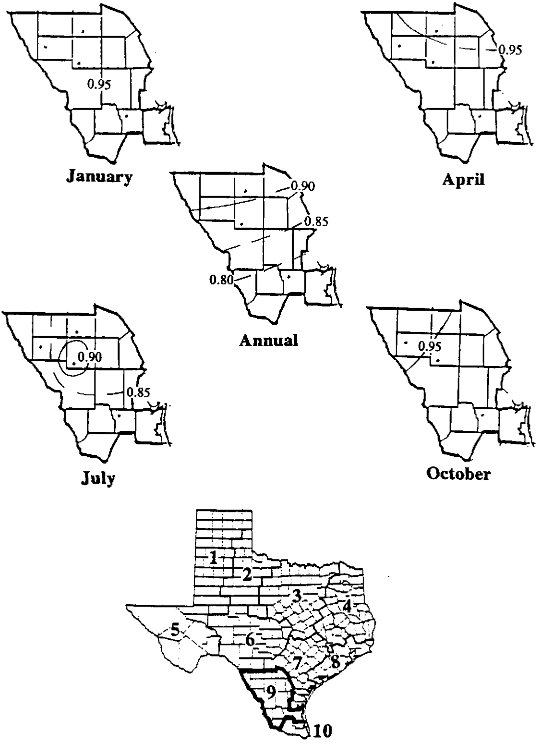
Division seven precipitation correlation patterns.

Correlation Coefficients: Division Nine Temperature

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Carrizo Springs n=58	0.96	0.95	0.96	0.94	0.94	0.93	0.81	0.90	0.95	0.97	0.91	0.96	0.90 11 missing
Dilley n=58	0.97	0.98	0.97	0.96	0.94	0.93	0.89	0.92	0.95	0.95	0.96	0.97	0.91 4 missing
Encinal n=60	0.98	0.97	0.97	0.93	0.95	0.91	0.90	0.93	0.91	0.94	0.91	0.94	0.89 9 missing
Falfurrias n=60	0.96	0.94	0.95	0.92	0.89	0.84	0.82	0.84	0.76	0.92	0.89	0.94	0.77 10 missing

Correlation Coefficients: Division Nine Precipitation

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Carrizo Springs n=58	0.90	0.87	0.79	0.81	0.79	0.74	0.82	0.78	0.78	0.88	0.92	0.89	0.79 5 missing
Dilley n=58	0.92	0.90	0.82	0.83	0.81	0.86	0.81	0.82	0.81	0.89	0.85	0.94	0.90 2 missing
Encinal n=60	0.86	0.87	0.84	0.82	0.79	0.84	0.79	0.82	0.72	0.89	0.85	0.94	0.88 8 missing
Falfurrias n=60	0.76	0.84	0.71	0.72	0.69	0.77	0.61	0.74	0.71	0.75	0.78	0.83	0.66 8 missing



January

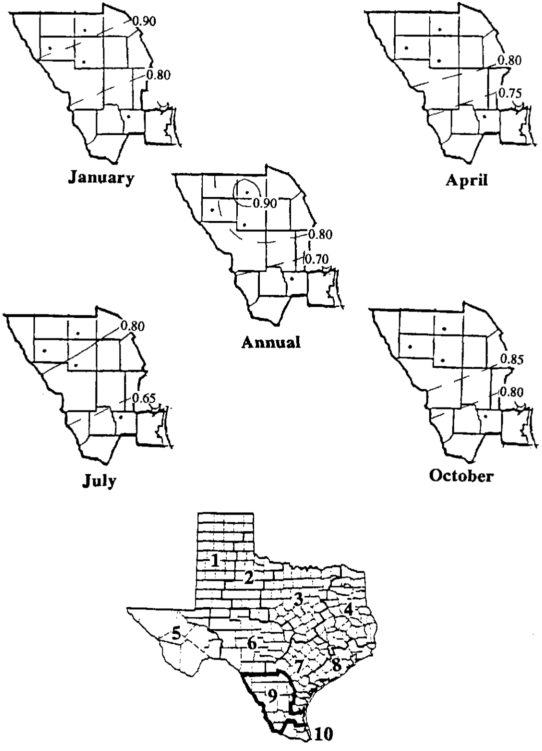
April

Annual

July

October

Division nine temperature correlation patterns.



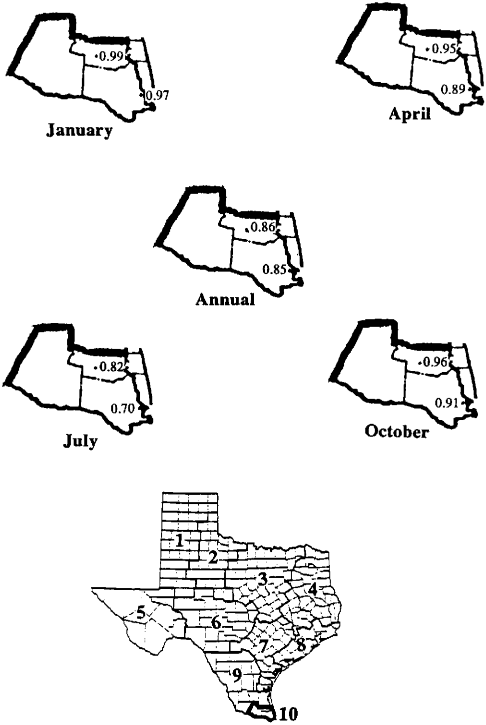
Division nine precipitation correlation patterns.

Correlation Coefficients: Division Ten Temperature

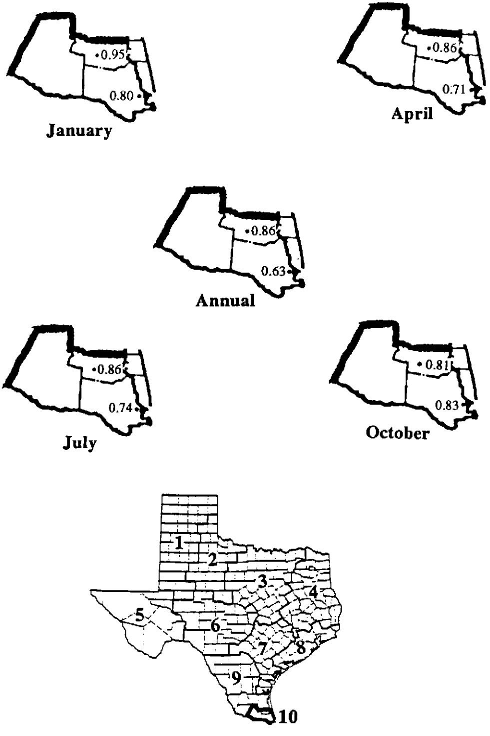
Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Port Isabel n=55	0.97	0.94	0.96	0.89	0.82	0.57	0.70	0.69	0.84	0.91	0.92	0.96	0.85
												18 missing	
Raymondville n=60	0.99	0.98	0.98	0.95	0.96	0.92	0.82	0.79	0.91	0.96	0.97	0.98	0.86
												11 missing	

Correlation Coefficients: Division Ten Precipitation

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Port Isabel n=55	0.80	0.85	0.84	0.71	0.71	0.72	0.74	0.84	0.75	0.83	0.73	0.90	0.63
												11 missing	
Raymondville n=60	0.95	0.93	0.90	0.86	0.83	0.82	0.86	0.86	0.89	0.81	0.76	0.93	0.86
												8 missing	



Division ten temperature correlation patterns.



Division ten precipitation correlation patterns.

VITA

David Morris Gaffin was born on May 16, 1968 in Fayetteville, Tennessee. After graduating in June 1986 from Plano Senior High School in Plano, Texas, he enrolled at the University of Tennessee-Knoxville where, in December 1990, he obtained a Bachelor of Arts degree in economics. He then enrolled at Texas A&M in the spring of 1991 where, after completing a semester of undergraduate meteorology courses, he was accepted as a graduate student in the fall of 1991. Subsequent assistantship assignments included being a teaching assistant for Meteorology 203 and more recently, assistant to the State Climatologist.

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