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The Climate of the Great American Desert: Reconstruction of the Climate of Western Interior United States, 1800-1850

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1. Introduction

HISTORIANS HAVE CONCLUDED that two conceptions of the West were held during the incipient stages of settlement of the plains region of the Western Interior *(sensu latu)*. They have labeled these conceptions the "myth of the desert," supposedly prevalent during the first half of the nineteenth century,[1] and the "myth of the garden," a notion widely held during the latter decades of that century.[2]

It has been assumed by students of the American frontier that the former—in its extreme form the concept of the Great American Desert—was derived from the notions of a few men rather than from the probable *reality* of the environmental conditions.[3]

In a sense the *reality* of the desert has not concerned western historians. Some have undoubtedly assumed that the environment was described accurately by first-hand observers before 1850. Others have assumed that plains of the past environment was no different from that of recent time. Others would seem to feel that the geographic reality is identical to man's contemporary conception, agreeing with Morton that "geography . . . is man's *concept* of his environment at any given time."[4] While others may assume that the geographic reality of the plains before 1880 is unknowable, these and other assumptions about the past reality of the plains environment have rarely been questioned by the writers who hold them. They have been the building blocks for most, if not all, interpretations of plains history and past geography. And yet each of these assumptions appears to be false.

The past reality of the plains environment, particularly the vegetation and climate, can be reconstructed from palynological, dendrochronological, and other records using recently developed techniques. There are strong indications from the partial environmental reconstructions pieced together in recent years that at least some of the observers of the plains misconstrued the environment, and particularly the climate, which was somewhat different from that of recent record. Furthermore, it is clear that there are two "geographies": those of conception (cognition) and of scientific objective reality, and that the two "plains" geographies of the first half of the nineteenth century were quite different.

Kraenzel is a good example of a writer guilty of the "past and present environments are identical" fallacy, which in turn leads him to an equally false conclusion that the Great American Desert became a reality in the American mind. He writes: "It goes without saying that Long's report and map confirmed the observations of previous explorers from Coronado to Pike. It did even more: it prejudiced the American reading public. The 'Great American Desert' became a reality in the minds of the American people."[5] The accusation of *prejudice* might be substantial if knowledge of the region were based on more than a supposition of a temporally uniform climate or vegetation or both. The fact that the area is not now a desert does not mean that extended drought conditions could not have made the region appear as a desert, especially if the effects of drought had been augmented by pressures of overgrazing by buffalo. Numerous studies document considerable changes in vegetational composition as well as of vegetational cover during a thirty-year period in grassland communities of Kansas.[6] Studies following the drought of the 1950s demonstrate a 90 percent loss of grass cover in portions of the Great Plains under pressures of grazing.[7]

Incredibly, then, the illusion of the Great American Desert has not been considered from a climatological perspective, that is, no serious attempts have been made using historical methods and techniques to establish the actual climate of the region during the period of formation of the desert image.[8]

The problem of the past plains climate was posed as early as 1935 by Isaiah Bowman, who emphasized that a climatic boundary (particularly in the plains) is but a mean position of a transition belt rather than a rigidly placed line. "All our climatic belts expand and contract with yearly variation. In individual years, a third of the United States may be 'desert.' It was once the fashion to laugh at the extension of the phrase 'Great American Desert' printed in large block letters upon our maps across the High Plains."[9] The drought of the 1930s suggests "that in Long's day (1819–20) and in Fremont's day (1842–44) it may not have been so foolish."[10]

The overriding purpose of this study is, therefore, to establish whether there was any justification for the belief held in the early nineteenth century (and subsequently by some historians) that there was a *real* desert west of the Missouri River and east of the Rocky Mountains. Did any or all of the explorers who were the sources of the desert image pass through the plains region when it was a desert? Was the plains region a real desert in any year between 1800 and 1850, and particularly in 1849 when most people crossed it?

The first objective of the study is to establish the range and the effectiveness of the sources, methods, and techniques available for the reconstruction of the plains climate before the period of meteorological record. To this end four different "sources"—dendrochronological evidence, fort records, diaries and letters, and deductive models of long-period climatic change—will be examined and utilized in successive chapters (II through V).

The substantive objective is to reconstruct the real climate of the plains area in 1849, the year for which the sources are most comprehensive before 1850. An attempt will be made (Chapter IV) to recreate the synoptic situations experienced by the Forty-Niners as they crossed personal *terrae incognitae.* The results of this reconstruction are crosschecked by those derived from the early meteorological records of military forts scattered mainly on the eastern periphery of the plains (Chapter III).

Reconstructions from quite different viewpoints will be provided by the tree-ring records from eight locations in the plains and contiguous territories (Chapter II) and by extrapolations from two eclectic models of climatic change (Chapter V). Both of these reconstructions will shed light on the climate of the plains between 1800 and 1850 and further check the results derived from the diaries and fort records. In addition, the tree-ring record will give some indication of the broad climatic trends in various sections of the plains from 1600 onward.

To know the reality of the plains in the nineteenth century is to provide a standard against which to measure the discrepancy between the real world and the images of the many individuals who saw the region: It is to know if the notions of the West held in the East were erroneous, whether they were products of semantic difficulties or products of eyes only able to see through humid-land spectacles. To know the varying realities of the plains before 1880 is to enable us ultimately to examine the process by which the conceptions of an unknown region gradually begin to approximate reality. The plains region is partitcularly important in furthering

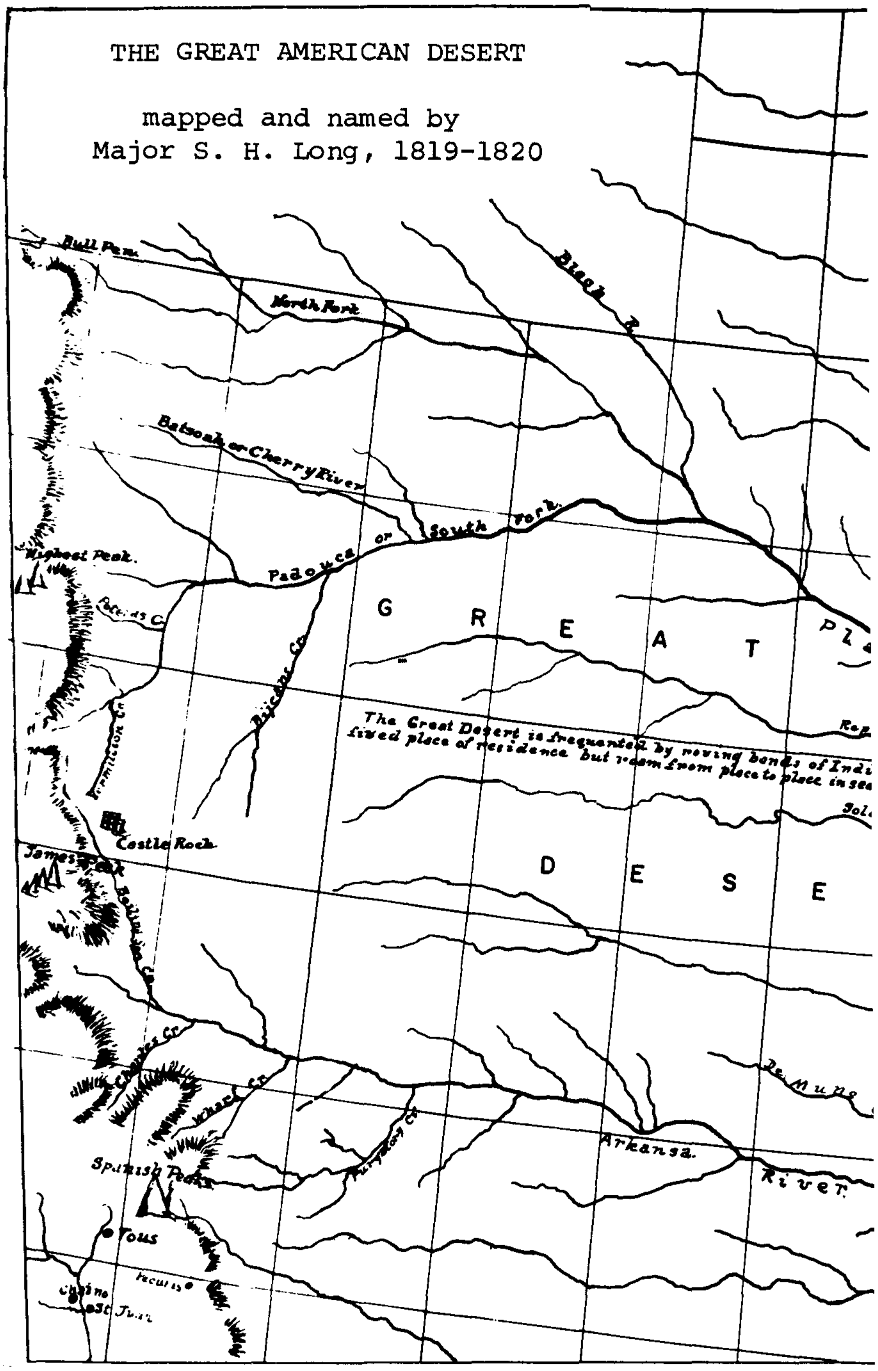
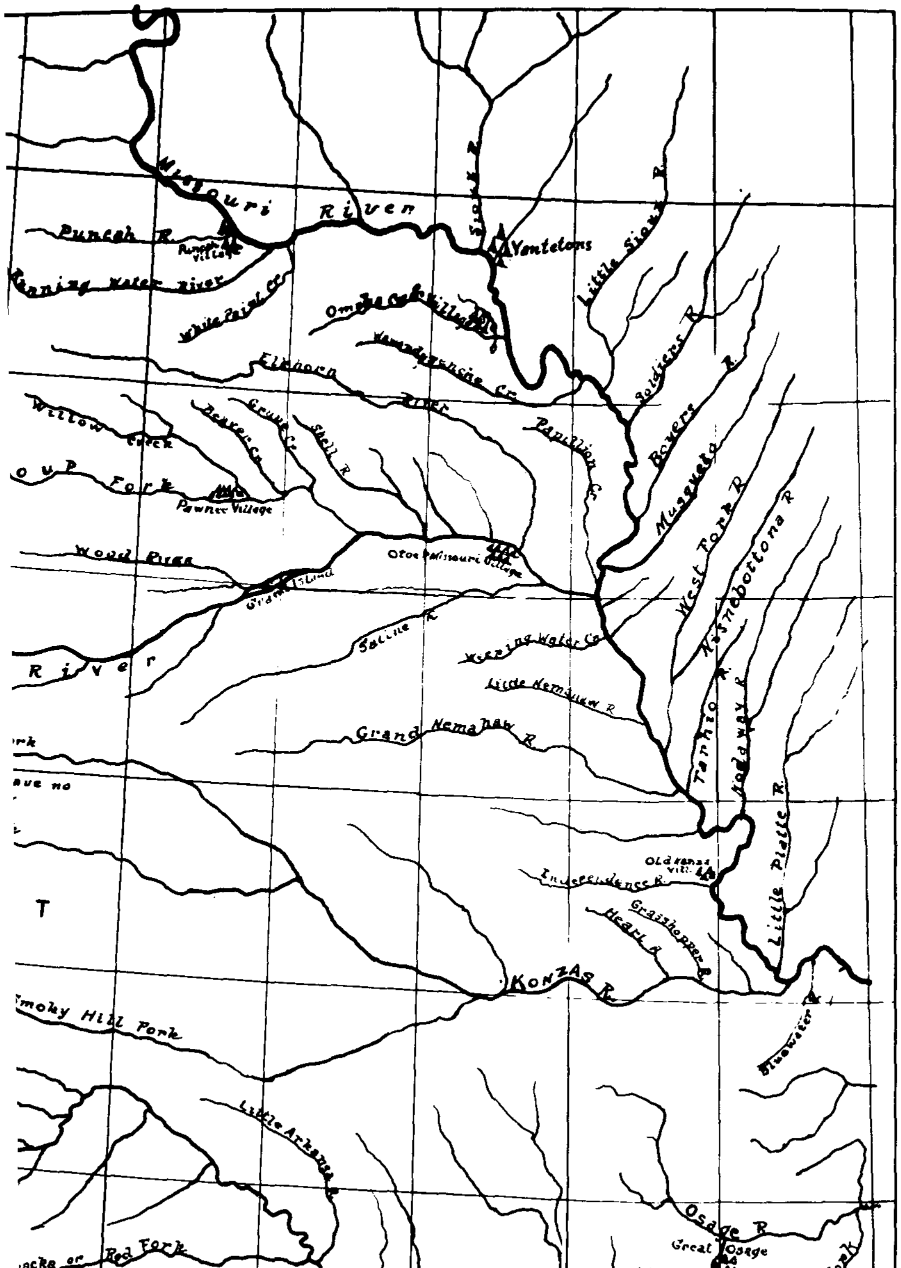

THE GREAT AMERICAN DESERT
mapped and named by
Major S. H. Long, 1819-1820
North Fork
Castle Rock
G R E A T
D E S E
Arkansa
River

Figure 1



Missouri River
Puncah R.
Puncah Village
Running water river
White Paint Cr.
Omaha Village
Yantetons
Little Sioux R.
Elkhorn River
Papillion Cr.
Soldiers R.
Boyers R.
Musqueto
West Fork R.
Nishnebottona R.
Willow Creek
Beaver Cr.
Shell R.
Loup Fork
Pawnee Village
Wood River
Grand Island
Otoe & Missouri Village
Saline R.
Weeping Water Cr.
Little Nemahaw R.
Grand Nemahaw R.
River
Tarkio R.
Nodaway R.
Little Platte R.
Old Kanzas Vill.
Independence R.
Grasshopper R.
Heart R.
T
Konzas R.
Smoky Hill Fork
Blue water
Little Arkansaw
Red Fork
Strong Saline R.
Osage R.
Great Osage
Little Osage
Grand Fork

our understanding of the process, for, initially in the plains, the gap between conception and reality was very broad. The process is obvious and possibly measurable. Furthermore, and probably a corollary of this, we know more about the geographical conceptions of the plains region in the half century before settlement than about any other region in North America.

It is hoped that this *reconstruction of the climate* of the Great American Desert will begin to redress the imbalance in our knowledge between the poorly known geography and the now well-known geosophy[11] of the plains before 1851.

2. A Dendroclimatological Interpretation of the Great American Desert

ISAIAH BOWMAN recognized the importance of climatic changes in marginal areas often stricken by drought.[1] He appealed to investigators to use such records as lake-level fluctuations and tree-ring analysis. Citing work done in the Great Basin by Antevs,[2] Bowman saw the importance of understanding dry-period recurrence so that land planning in marginal lands could be attempted.

Bowman's inference that the past is the key to the future may be contested. However, the utilization of tree-ring analysis by the historical geographer in attempting to understand the environmental past should be given every possible consideration. The assumption of climatic constancy must be tested before interpretational theories of behavioral implication can be considered by researchers attempting to explain the manifested perceptions of landscapes. One such attempt is that of G. Malcolm Lewis, who has sought to determine the reasons for the emergence of the concept of the Great Plains as a region.[3] Unfortunately, the climatic regime of the present century has been adopted by most students of the trans-Mississippi West as representing the "normal" climate. Such historical meteorological observations do not necessarily depict accurately the climatic regime concurrent with exploratory penetration into the West.

To understand the environmental conditions observed by explorers, trappers, or incipient settlers of the Western Interior, the student of western history must attempt to reconstruct the contemporary reality of those conditions rather than extrapolate the present into the past by assuming a constancy of processes affecting the landscape. With the use of tree-ring analysis, or dendrochronology, the researcher is capable both of defining environmental changes and of dating those changes. Thus, in this chapter an investigation is made as to the feasibility of using dendrochronological analysis in the central United States. The first part of the chapter will review the problems facing the user of dendrochronological sources in interpreting the past climates of the plains region. The work of tree-ring analysts operating in the plains and on its margins during this century will be examined critically, and adopted, where appropriate, for further analysis in the second part of the study. Here, tree-ring data from eight selected source areas in and around the plains are plotted on an annual basis, and statistically modified *t*-test values are computed to determine if short-term variations in the data significantly exceed a value compatible with random deviation. This analysis is the basis for a dendroclimatological interpretation of the plains region (1600–1950) in the third part of the chapter. In this final section, interregional and temporal assessments are considered for the entire period of record (1600–1950); a detailed analysis is made of the climate prior to the explorations of Pike, Long, and Fremont; and finally, the tree-ring record of 1849 and the preceding decade in the locales of the Oregon and Santa Fe trails is interpreted.

Dendrochronology

Dendrochronology is that science devoted to the systematic analysis of tree rings in an effort to date past events and evaluate certain associated climatic parameters. The origin and application of the science was originally restricted to the lower forest border of the western United States.[4] Subsequently, the value of climatic interpretation through utilized tree-ring series has been demonstrated in four major *regions* of the world: the subarctic of Scandinavia and Alaska, the semiarid regions of North America, Europe among drought-sensitive trees, and the equatorial region among drought-sensitive tropical trees.[5]

The science is founded on the principle that variations of widths of annual rings of woody species can be utilized to determine fluctuating precipitation and/or temperature conditions during the life of a plant.[6]

For purposes of this study, it is not necessary to include a technical discussion of dendrochronological techniques or site selection of species, or to cite physiological models of the relationship between plants and climate. This information is peripheral to the interest of the study, but must be considered by researchers concerned with validity of specific projects.[7]

Physiological Factors in Tree Growth

Before one can accurately attempt to determine the influence of climatic factors on the growth characteristics of trees, precautions must be taken to account for physiological trends or variations which may be misinterpreted by the researcher. For example, the increments of growth from year to year in a tree are actually a series of superposed conical surfaces and a function of heredity, environment, and age.[8] Generally, a transverse section will show rings to be wide near the center of a tree and narrow toward the periphery. This characteristic seems to reflect the distance from the crown to the base and is a function of competition within the tree for carbohydrates and hormones produced in the crown.

To relate properly the climatic environment of the tree as opposed to its physiological growth characteristics, it is necessary to "standardize" the growth curve of tree rings by age. A regression line can be fitted to each ring-width series. The yearly tree ring is then divided by that year's value on the regression curve to obtain an index of relative departure from the expected growth.[9] The resulting index is a valid expression of a tree's growth regardless of sample location within the tree or its absolute rate of growth.

It is crucial to the validity of interpretation of tree-ring series that a researcher standardize the series. A geographer seeking to use dendrochronological studies must be familiar with the possible interpretational errors arising from research conclusions based on nonstandardized measurements. The derivation of tree-ring indices has been greatly expedited by the use of computer techniques in the past decade.[10]

Relation of Tree Rings to Environment

Numerous studies concerned with the correlation of environment with tree rings have led to a formidable volume of literature. Douglass, the first to analyze systematically environmental relationships, early deduced that ring widths varied as climate fluctuated.[11] As researchers continued to compile data in dendroclimatic investigations, they were often challenged. Friesner held that too many "unsolved problems" still existed to allow conclusions to be stated as to the relation of climate and annual tree-ring growth.[12] Hustich made a plea for "deeper knowledge of the physiological processes" in search for an understanding of the relations between climate and growth.[13]

In response to the claims and counterclaims in dendroclimatological research, Glock conducted exhaustive studies in the topics of tree growth as well as growth rings and climate.[14] Today, highly integrated models have been hypothesized denoting the relationship between low precipitation and high temperature as they combine to produce a narrow tree ring.[15] For this reason, the indiscriminate application of dendroclimatic studies can be misleading if not false, as will be shown below.

Fritts, hoping to correlate ring-width variation with climatic factors, ran stepwise multiple regression analyses on numerous rings or species from the southwestern and central United States.[16] The results showed that the primary climatic factors, precipitation and temperature, did not necessarily correlate with the period of cambial activity. A logical fallacy appears evident. One cannot assume that the yearly period of tree growth correlates with the meteorological conditions existing at that time. The complexity of valid dendroclimatological conclusions is increased by the findings that conifer growth at high elevations correlates best with summer climatic parameters, while low-elevation conifer growth seems to reflect winter climatic conditions. Thus, not only the physiological variations of species, but also their elevations are significant in the designation of climatic influence.

As an aid to the valid climatic interpretation of tree rings, there follows a review of those studies which have sought to measure the influence of certain climatic elements on species used in tree-ring studies associated with the Western Interior of the United States.

Rocky Mountain Front

The Douglas fir was used by Schulman as one of the major species in his dendrochronological analyses of the semiarid West. Therefore, it is critical to relate its physiological reaction to climatic factors.

The Douglas fir initiates its radial growth season in late April and culminates growth during the month of June.[17] A researcher interested in understanding the weather situations encountered by explorers or pioneers crossing a region at this time might well become enthusiastic about the possibilities.

To establish an approximation between ring width and precipitation, Schulman undertook a systematic correlation analysis by region from Jasper, Alberta, to the Guadalupe Mountains of southern New Mexico.[18] He chose sixteen rainfall intervals ranging from three months to two years. The most sensitive local ring sequences in the Rocky Mountains were compared with the best reliable rainfall series near each "tree station." These correlations of growth in the Douglas fir versus rainfall by regions are presented in table 1.

TABLE 1

GROWTH-PRECIPITATION RELATIONS FOR DOUGLAS FIR[a]

Location	July / June	Oct. / June	Mar. / July
Upper Missouri, Montana	.65	.53	—
South Platte R. Basin, Colo.	.58	.49	—
Santa Fe, New Mexico	.69	.68	.44

[a] Schulman, *Dendroclimatic Changes,* pp. 41–43

It appears from an inspection of the data that growth-precipitation coefficients increase as temporal intervals increase. This is probably a result of error cancellation produced by larger areas and many weather stations. The correlation coefficient for the period March through July calculated for Santa Fe, New Mexico, is unfortunately only .44.

In northern New Mexico, Glock sought to measure the trend agreement of conifer tree-ring growth with precipitation from March to July of 1909–41.[19] He was able to establish a trend agreement of 96.5 percent with a rain station located at a distance of five miles.

Fritts has analyzed Douglas fir chronologies in Arizona and southwestern Colorado.[20] He concludes that relationships between tree-ring widths in Douglas fir and climate become greater as the aridity of the site increases. Precipitation relates to ring-width variation during the period August–May, with the immediate preceding ring being highly significant, but showing no relationship to previous years of growth. Fritts therefore concludes:

> Conditions of low moisture and high temperature during March through May relate most significantly to narrow rings. Moisture and temperature during the current June, previous October through November, and previous December through February are next in importance. Moisture and temperature conditions during the previous June and August through September appear to follow in importance, while climatic factors during the previous and current July exhibit no clear relationship to the annual ring increment.[21]

In an attempt to investigate various statistical problems regarding the use of tree-ring chronologies as a technique in climatic reconstruction, Julian and Fritts selected tree cores from twelve forest stands in the lower foothills of the Front Range of the Rocky Mountains for statistical analysis.[22] Four of these were stands of Douglas fir. The multiple correlation coefficients for Douglas fir ring indices with certain antecedent climatic variables are presented in table 2. Highest correlations are obtained when ring width is compared with the precipitation of the previous twenty-four months. When the twelve previous months' precipitation as well as twelve previous months' temperature are correlated with growth, coefficients do not drop significantly. Using serial regression coefficients, Julian and Fritts were also able to demonstrate that precipitation during the spring and previous September and October is most important in explaining the variability in the growth of the Douglas fir.

As perhaps the most significant of their findings, Julian and Fritts discovered a high relationship between ring growth in the Douglas fir and the Palmer drought index.[23] The Palmer drought index, which employs the actual and potential parameters of evapotranspiration as an index of meteorological drought, appears to

TABLE 2

SUMMARY OF CORRELATION COEFFICIENTS FOR DOUGLAS FIR WITH VARIOUS CLIMATIC INDICES[a]

Location along Front Range	R_1	R_2	R_3	R_4	R_5
Horsetooth	0.72	0.72	0.72	0.50	—
Big Thompson	0.81	0.81	0.77	0.63	0.67
Eldorado Canyon	0.82	0.86	0.84	0.57	—
Kassler	0.80	0.84	0.86	0.63	0.71

Correlation coefficient between ring index and
R_1: 12 previous months' precipitation, 12 months' temperature
R_2: 24 previous months' precipitation
R_3: 12 previous months' precipitation, 3 previous rings
R_4: Precipitation index
R_5: Palmer drought index

[a] After Julian and Fritts, "On the Possibility of Quantitatively Extending Climatic Records."

represent satisfactorily the complex interaction of precipitation and temperature on the physiological processes of tree growth. Column R_5 in table 2 presents the correlation of the July value of the Palmer index with the growth chronologies for nearby tree stands.

Western Nebraska

In the North Platte area of western Nebraska, Weakly sought the climatic significance for the growth of the red cedar and ponderosa pine.[24] Precipitation records for a sixty-four-year period produced a correlation of .63 ± .05 between ring width and annual rainfall, and of .73 ± .05 between the cross-sectional area of individual tree rings and annual rainfall. Ponderosa pine revealed coefficients which were practically identical. In both species, the relationship improved when the correlation was based on rainfall from October 1 to September 30 rather than for the calendar year. Unfortunately, Weakly did not attempt to measure the serial regression coefficients for each of the twelve months.

A question arises, however, as to the *regional extent* to which a reasonable correlation exists between ring growth and precipitation. A scatter diagram depicting the covariation from 1876 to 1938 between Weakly's juniper tree-ring values for the lower North Platte and *annual* precipitation for the western climatic division of Nebraska (fig. 2) demonstrates the futility of any attempts to make *vast* regional interpretations, considering the calculated correlation coefficient of 0.14. When the two forms of data are smoothed using five-year moving scores,[25] extreme events such as drought for a broad area are reasonably represented by the regionally restricted collection of tree-ring observations (fig. 3).

Central Oklahoma

In his investigations with post oak trees in central Oklahoma, Harper found a higher correlation between tree-ring widths and drought years than with years with average or above average precipitation.[26] By ranking years into rainfall groups of low, moderate, high, and very high precipitation totals, he realized a coefficient of correlation increase from .55 to .73 by excluding the very high rainfall years from the comparison. In accordance with the findings of Weakly,[27] Harper designated October 1 to September 30 of the following year as the hydrological period of best correlation.

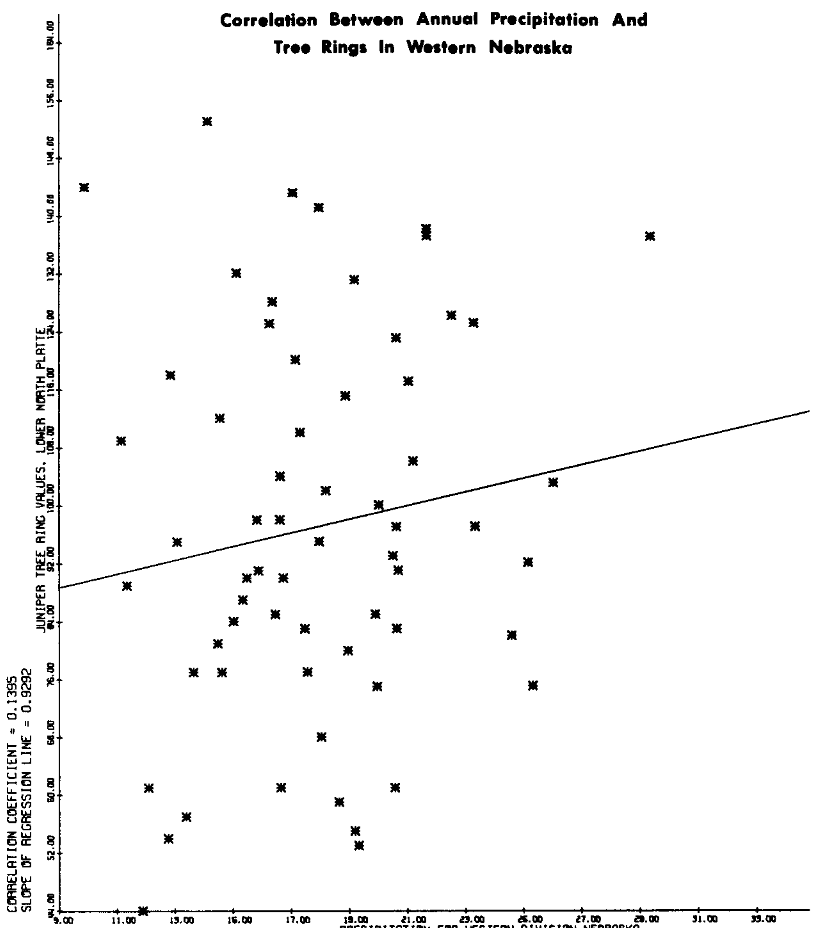


Figure 2

Central Mississippi Basin

Hawley, studying oak and pine tree rings in the central Mississippi drainage basin, noted a similar, but slight, increase in correlation with the use of water-year calculations (November through October) as opposed to calendar years.[28] Over a sixty-five-year period from 1871 to 1936, unsmoothed pine tree-ring width correlation with annual precipitation was .52 as compared with a correlation of .53 for the water year. Correlations of oak and annual precipitation were .33 versus .34 for the water year. Al-

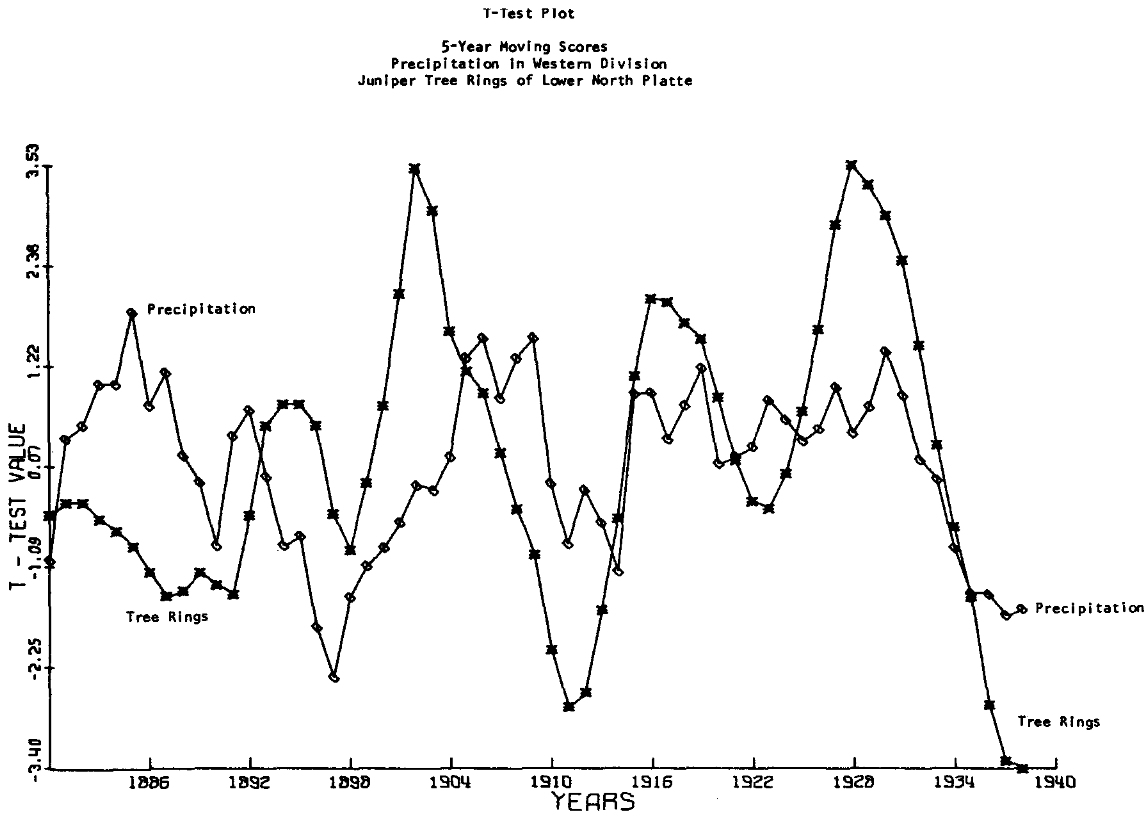

T-Test Plot
5-Year Moving Scores
Precipitation in Western Division
Juniper Tree Rings of Lower North Platte
Precipitation
Tree Rings
Precipitation
Tree Rings
T - TEST VALUE
3.53
2.38
1.22
0.07
-1.09
-2.25
-3.40
1886
1892
1898
1904
1910
1916
1922
1928
1934
1940
YEARS

Figure 8

though not sought, it would be reasonable to expect correlation values to increase similarly to those obtained by Harper in Oklahoma when high rainfall amounts are neglected during computations.[29] Studies by Fritts using stepwise multiple regression analysis demonstrates that white oak in Illinois relates best to the climatic conditions of spring and summer, the period during which explorations and pioneer crossings of the trans-Mississippi West were most frequent.[30]

Despite the low positive values of correlation for tree-ring widths with precipitation, Hawley was satisfied that legitimate chronological interpretations were possible within the massive area of the central Mississippi drainage basin.[31] Were this region dissected into finer segments using weather data gathered in closer proximity to tree samples, correlations would be expected to increase. This can be explained by the fact that the twenty-three pines were collected from an area of many hundreds of square miles while correlations were calculated for precipitation at Cairo, Illinois.

Southeastern Wyoming

Not all researchers have been successful in demonstrating a significant correlation between growth and rainfall. In southeastern Wyoming, Hansen found no correlation between spruce and fir annual growth rings and precipitation at Laramie only thirty-five miles from the tree sites.[32] He seeks to explain this conclusion by suggesting that most precipitation occurs in the form of snow, which creates a sizable amount of runoff and evaporation moisture loss which is consequently unavailable for tree growth. The significance of Hansen's findings must be in doubt as it appears that no standardization of rings was attempted even though the tree ages varied from 70 to 157 years. Also, no attempt was made to smooth the data, which may or may not be a valid decision, nor did Hansen state in statistical form the degree of correlation.

Summary of Climatic Influences on Tree Growth in the Trans-Mississippi West

Investigations to determine significance of various climatic parameters on the growth of certain tree species have continued for many decades. However, the refinement of statistical techniques and introduction of computerized programs have only recently provided appropriate methods for advanced studies on this subject.

The current knowledge about the relationship between tree growth and precipitation is synthesized in table 3. Monthly serial regression coefficients have not been calculated for the tree-ring charts of Nebraska or Oklahoma. For this reason, the influence of any climatic variable cannot be deduced for periods of less than a year. However, one can conclude that tree rings in the trans-Mississippi West probably reflect mostly moisture in the spring and early summer, with secondary dependence on precipitation during late autumn and winter. Complications can upset this simple construct: an example is extreme temperatures. Growth can be inhibited by a very cold winter as well as by a hot (dry) summer.

TABLE 3

SUMMARY OF GROWTH-PRECIPITATION RELATIONS FOR TREES IN THE TRANS-MISSISSIPPI WEST

Species	Location[a]	Period of Best Correlation between Growth & Precipitation
Pseudotsuga menziesii (Douglas fir)	Montana, Wyoming	October through June
Pseudotsuga menziesii (Douglas fir)	Colorado	October through June[b]
Pseudotsuga menziesii (Douglas fir)	New Mexico, Texas	October through June
Juniperus scopulorum (Red cedar)	Western Nebraska	October through Sept.[c]
Pinus ponderosa (Pine)	Western Nebraska	October through Sept.[c]
Quercus stellata (Post oak)	Oklahoma	October through Sept.[c]
Quercus alba (White oak)	Illinois	Sept., May, June, July
Pine	Central Mississippi Basin	Nov. through October

[a] See related figure 12, p. 29.

[b] Narrow rings associated with high temperatures and low precipitation during March through May. Best correlation with Palmer drought index for July.

[c] Monthly correlations not attempted.

Generally, the studies cited in the above review demonstrate that a distinct relationship exists between annual tree growth and some particular temporal parameter of precipitation, whether on a monthly basis, the water-budget year, or even a twenty-four-month total. It does appear certain that interpretations of *annual* precipitation from master charts should be questioned when applied over a vast regional extent.[33] With the use of smoothing procedures, such as the moving average, there is reason to believe that extreme conditions, that is, severe drought, are reflected over a larger area, thus facilitating generalizations of a regional nature.

Statistical Considerations for Evaluating Fluctuations of Climate

The uncertainties of using a single tree ring for a specific year as an indicator of environmental conditions restrict the utilization of tree rings by historical geographers for interpreting the probable condition of the landscape during exploration or later migration. As reviewed above, the species of the tree being analyzed determines the period of best climatic correlation. Interpretations of conditions during a particular exploration would be complicated when the date of traverse across a region did not coincide with the period of highest climatic dependency. For example, a Douglas fir tree ring for a particular year, 1820, would not explain the precipitation regime in the upper Arkansas basin experienced by Captain Long crossing the region in August.

A second complication affecting the validity of climatic analysis of a terrain during a particular year or season is the vegetational response to possible drought. The drought of a single year may have little effect on the visual appearance of the landscape other than on loss of color in vegetation. However, a prolonged drought of six or seven years in the Great Plains has historically resulted in severe vegetational denudation. Studies following the drought of the 1950s demonstrate a 90 percent loss of grass cover in central Kansas.[34] An explorer unaccustomed to viewing such obvious drought conditions could perhaps be justified in misinterpreting the settlement potential of the Midwest.

Yet another disconcerting fact confronting the historical geographer is the lack of availability of tree-ring charts in areal proximity to the routes followed by explorers of the West or the Oregon and Santa Fe trails of a later period. Unfortunately, the grasslands, whether natural or plagioclimax in origin, do not provide an adequate laboratory for tree-ring collection.

Despite the seemingly formidable problems encountered in an attempt to interpret the regional conditions experienced by the first Americans in the cis–Rocky Mountain West, valid generalizations can be derived from the careful application of certain statistical techniques, allowing the comparison of climatic conditions of subperiods of varying duration over the last 350 years.

To accomplish this statistical examination of tree growth, indices for eight regions in the Western Interior of the United States were selected for study. Growth indices for the upper Missouri, upper North Platte, upper Arkansas, upper South Platte, upper Rio Grande, and Big Bend regions were obtained from investigations of Douglas fir by Edmund Schulman.[35] Data for the central Mississippi Valley were derived from Hawley's research on pine growth rings.[36] The master chart derived by Weakly working with juniper was used for the lower North Platte.[37] For each location except Big Bend, Texas, and the central Mississippi region, records are available prior to 1600 A.D. For purposes of this study, data were used from circa 1600 to the mid-twentieth century because (1) the number of specimens declined with the pre-1600 years, (2) teleconnection was often necessary to obtain those pre-1600 dates, and (3) the original site of the trees was often unknown. Also tree ring data collected at sites in North Dakota, Montana, and central Oklahoma were rejected because there existed insufficient specimens for the construction of a master chart.[38]

The problem is to determine the stability of a long-term record as compared with shorter segments of that overall record. Conditions during a subperiod (say, ten or fifty years) would seem an appropriate indicator of the situation encountered relative to the long-term run. Cramer's *t*-test was applied to determine if short-term variations in the data significantly exceeded a value compatible with random deviation.[39] The *t*-test values were computed for moving ten- and fifty-year periods from circa 1600 to 1950.

Computer plots of moving ten-year *t*-scores for each basin are shown in figures 4 through 11. Each value on the upper graph represents the *t*-test calculation for the preceding ten years inclusive. For example, in figure 4 the *t*-score at location zero on the X axis (time in years) represents the subperiod 1600–1609 as compared to tree-ring growth in the upper Mississippi basin for the period 1600–1950. Horizontal lines depict the value at which the *t*-test

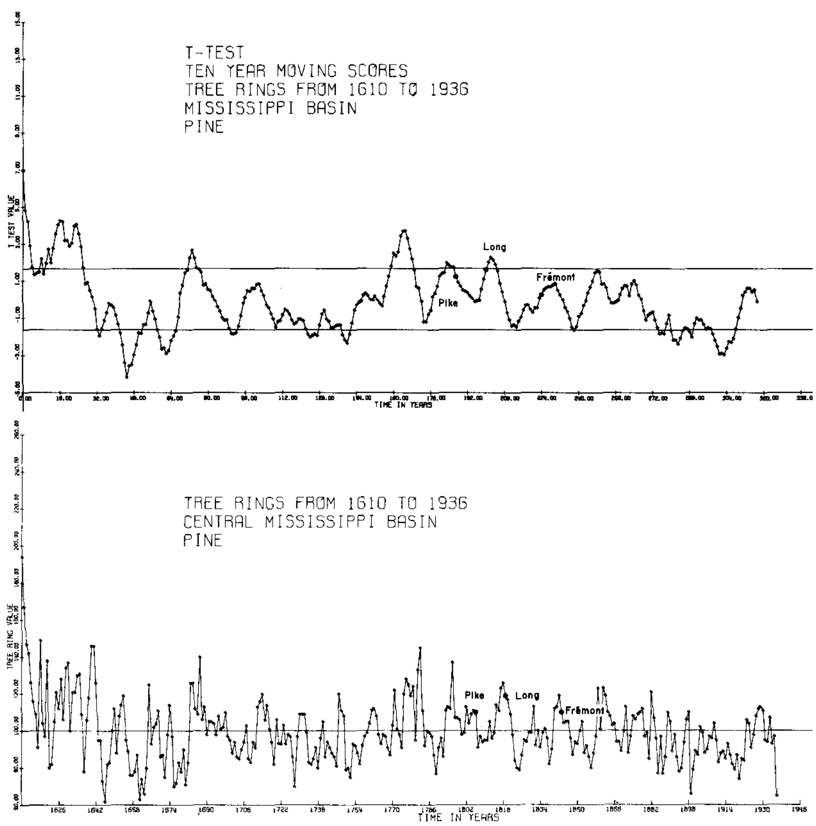


Figure 4

value becomes significantly wet or dry at the .05 level (single tailed). The lower graph is a plot of the recorded yearly tree-ring index.

In applying Cramer's test, $\bar{x}$ and s were calculated for each of the regional indices, where $\bar{x}$ is the mean and s is the standard deviation for the period 1600–1950 (N).

Therefore,

$$\bar{\bar{x}} = \frac{\sum_{i=1}^{N} Xi}{N} \qquad s = \left[\frac{\sum_{i=1}^{N} Xi^2}{N} - (\bar{\bar{x}})^2 \right]^{1/2}$$

If $\bar{\bar{x}}_K$ is defined as the mean of the subperiod with n observations, to be compared with $\bar{x}$,

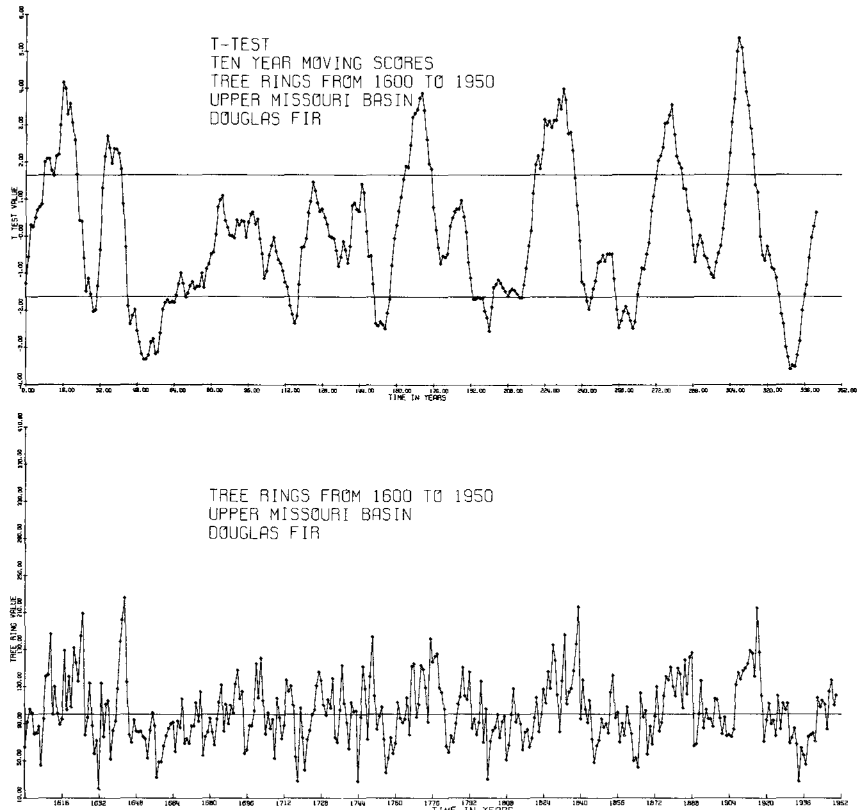


Figure 5

$$x = \frac{\sum_{i=K+1}^{k+n} Xi}{n}$$

then $$T_K = \frac{(\overline{x}_K - x)}{s}$$

and $$t_K = \left[\frac{n\,(N\text{–}2)}{N\text{–}n\,(1 + T_K^2)}\right]^{1/2} T_K$$

The resulting statistic *t* distributed with *(N-2)* degrees of freedom, can be interpreted as to levels of confidence with any "student's *t*" table. An arbitrarily chosen significance level of .05 is representative of significantly wet or dry conditions. The validity of this choice becomes apparent when *t*-test values drop below –1.64 during known historical periods of drought in the Western Interior, that is, the drought of the 1930s.

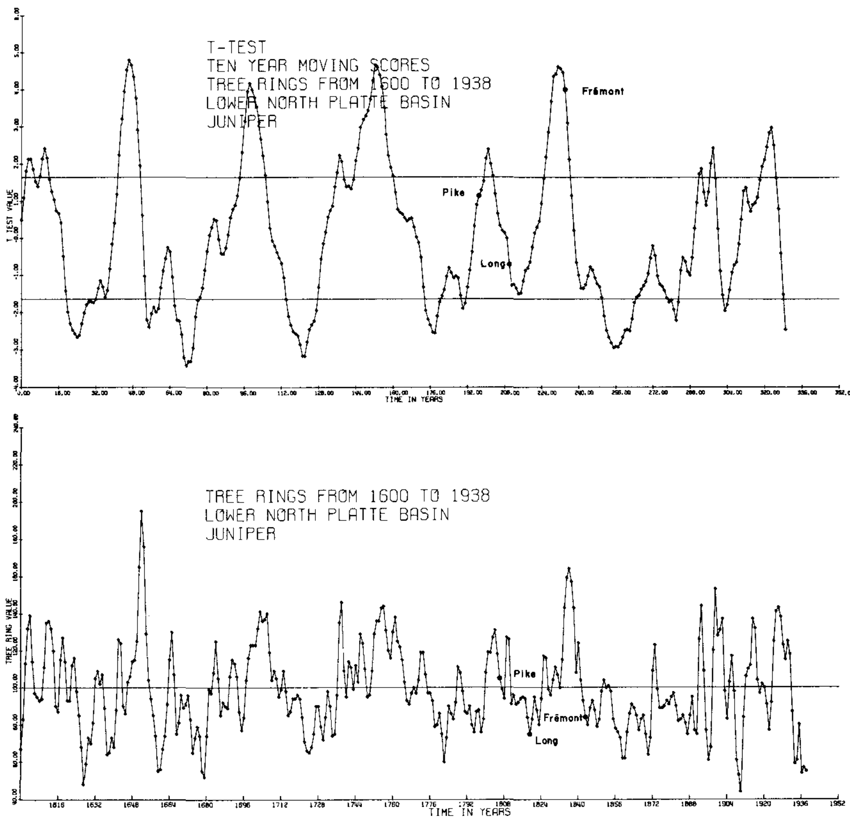


Figure 6

Reconstructing Anomalies in Past Climate

In an absolute sense, it is not possible to identify *long-term* changes in climate using tree-ring data because of the manner in which master charts are constructed. Tree growth averages are computed for the trees of record during a certain period. Therefore as trees die and are replaced by other trees, one derives a valid measure of annual growth only relative to other contemporary trees but not necessarily to trees no longer living. A climatic change occurring slowly over a period of 350 years would not be discernible. In fact, this would be the case even if the same trees constituted the master chart throughout the period of record, because the regression line for standardizing growth characteristics would similarly reflect the possible long-term changes. Fluctuations of shorter

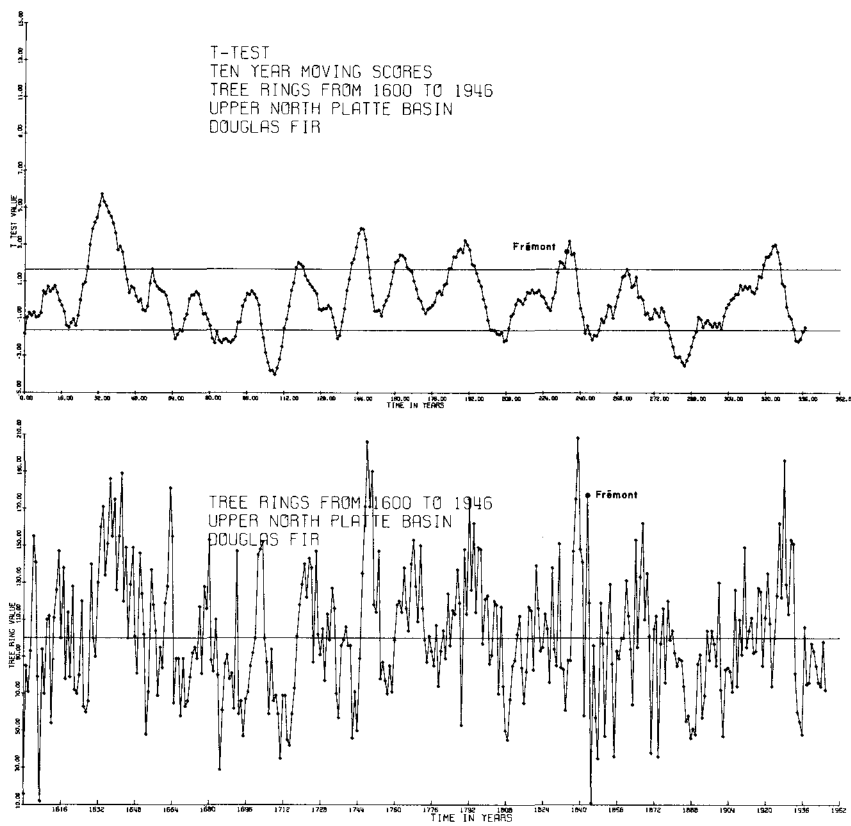


Figure 7

subperiods can be identified within the limits of statistical validity, however.

Thus, inspection of the regional plots of ten-year moving *t*-test scores allows some generalizations to be made concerning fluctuations in tree growth characteristics throughout the period of record. For the most part, the plots of these scores for each individual site generally exhibit numerically similar periods of significantly wet and dry periods in terms of both individual years and the duration of those extremes. The upper Missouri and lower North Platte basins experienced the greatest number of extreme wet and/or dry *t*-values with a distinguishable decrease becoming apparent for site locations of a lower latitudinal position. It appears that wet periods are usually more persistent in duration than dry

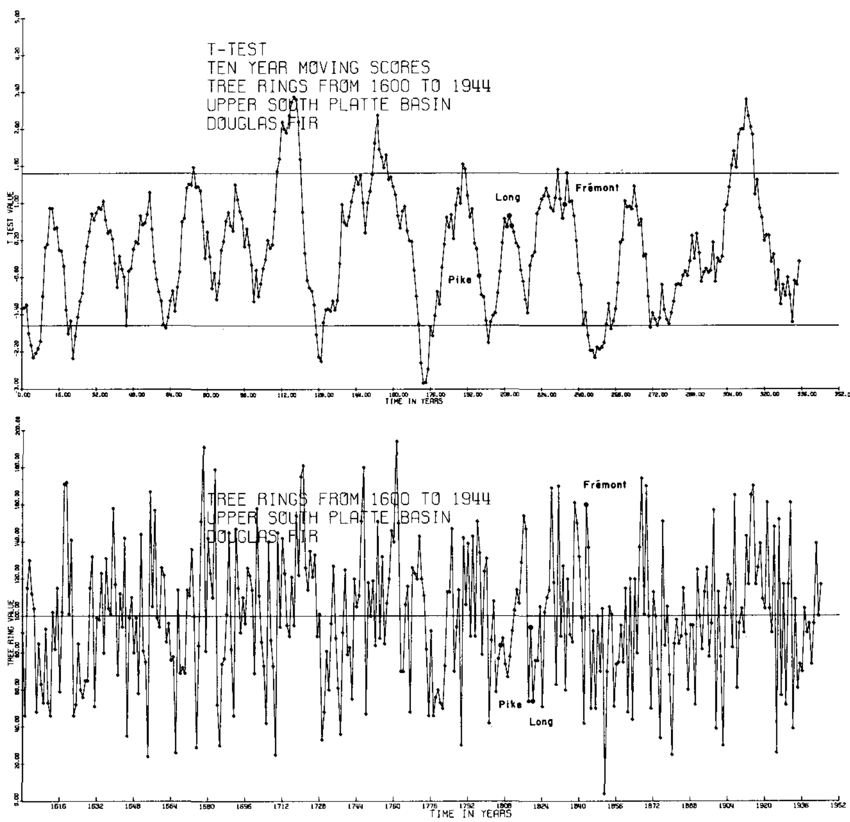


Figure 8

spells. One notable example is the plot for the Big Bend, Texas (fig. 11), which experienced the same number of extreme wet and dry *t*-values but the wet years were in two continuous groupings while the droughts were shorter, numbering as many as eight.

Looking more specifically at the only plot for the plains per se, the lower North Platte basin, one notices that ten droughts affected the region from 1600 to 1938. Although the average duration of these droughts was seven years, their length varies from two to fourteen years. The most intense drought became statistically apparent by 1675 and reached its maximum intensity by 1680. This can be interpreted as meaning that the ten years of tree growth prior to and including 1680 were the least of record.[40] The drought of greatest longevity was first statistically recorded in 1860 and

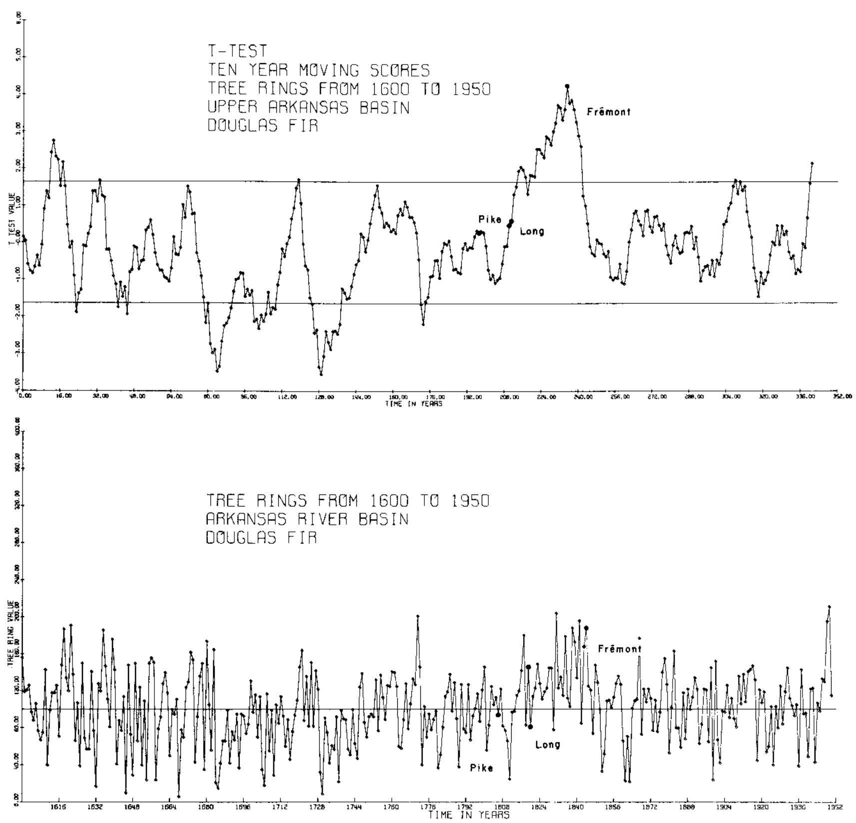


Figure 9

peaked in 1866, but did not become statistically insignificant until 1874. One can speculate upon the impact that this prolonged dryness had on nurturing the concept that "rain follows the plow," for as the plains were gradually being settled after the Civil War, this region was recovering from its longest recorded drought since 1600. After 1845, however, no continual wet phase was apparent until just preceding the drought of the 1930s. In fact, the first 250 years of record reveal four periods of extremely wet conditions, which produced *t*-test scores exceeding 4.0.

Thus, the temporal distribution of prolonged wet or dry periods on an interregional basis is complex enough to resist meaningful generalizations. Superposition of the plots as well as supplementary graphs which display various drought periods of five years or

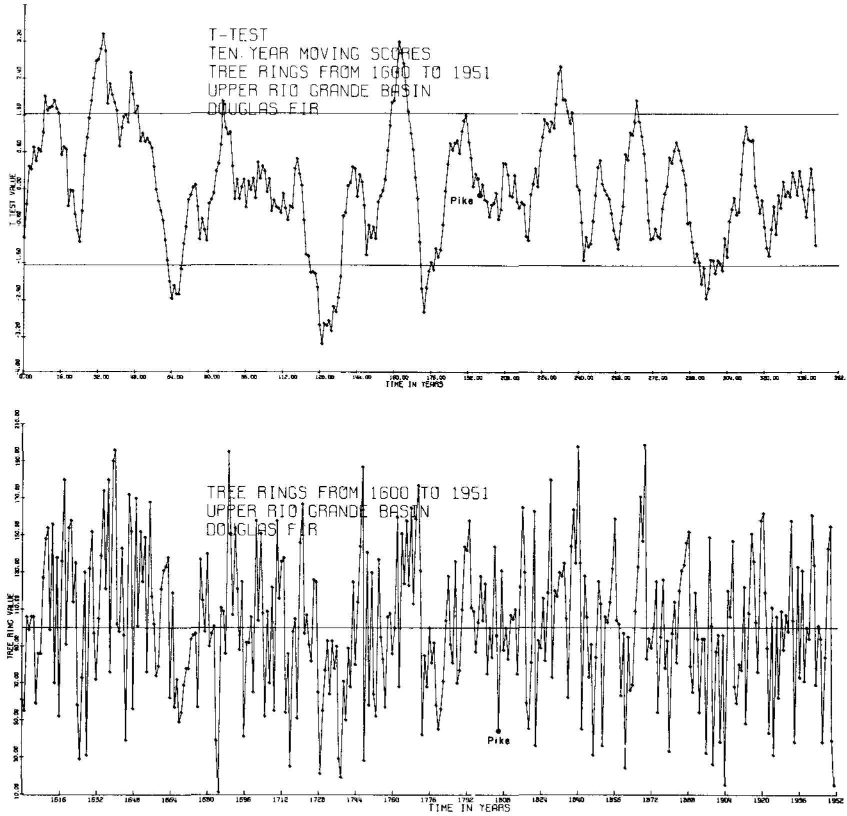


Figure 10

longer reveals little temporal relationship from region to region. A single exception to this conclusion occurred during the last decade of the sixteenth century (data not available in *t*-test scores), when there appear to have been widespread drought conditions along the western margin of the plains. Analysis of graphs representing yearly drought conditions from 1750 to 1850 does not reveal any temporal groupings, either. However, working with tree-ring data for the entire western United States, Schove believes he can identify several types of oscillation with differences in the phase of occurrence.[41] Accordingly, long dry periods might begin in southwestern Canada and slowly migrate southward, reaching the Rio Grande or southern California maybe as much as a decade later. The oscillation wave lengths accounting for climatic patterns

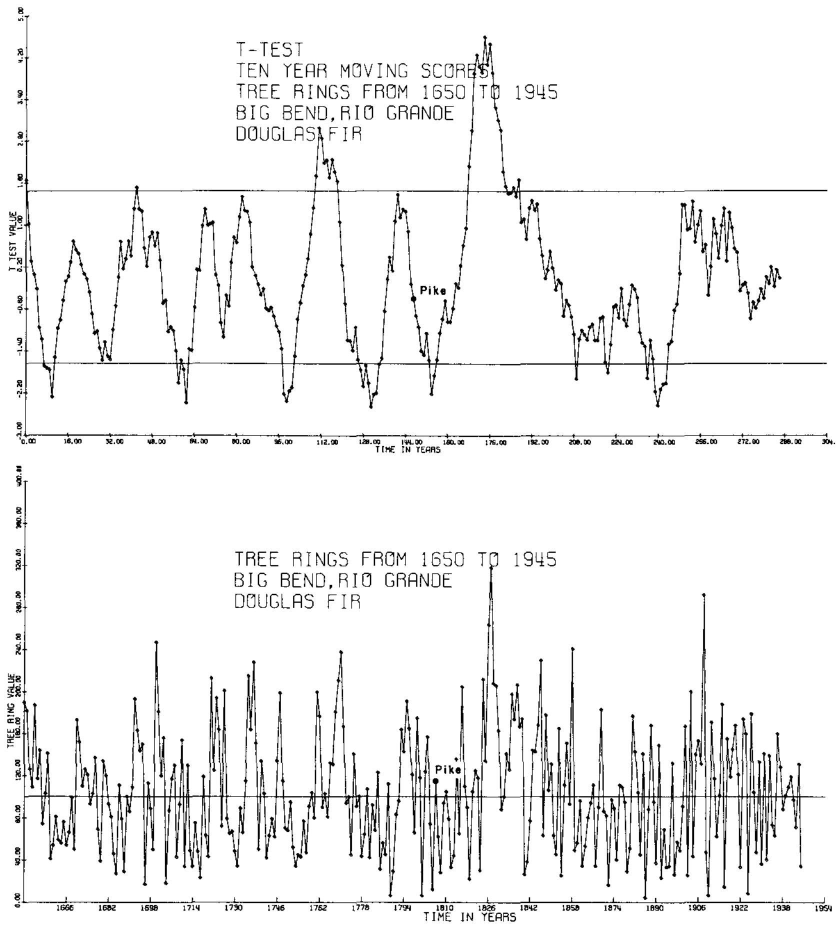


Figure 11

in North America have been estimated by Schove to be of seven different periodicities and range from two or three years (southern oscillation) to two-hundred-year cycles. The statistical reliability of his conclusions must be seriously questioned. Inspection of either the raw tree-ring data or plotted ten-year moving *t*-test scores does not reveal any meaningful temporal relationships.

In attempting to assess the time-series characteristics of the plots presented above, caution must be exercised. The widespread practice of smoothing meteorological series data using moving statistical parameters, (in this case *t*-test values rather than the more common mean) can lead to erroneous conclusions as to the periodicity of the data, if an incautious attitude is taken. Statisticians for many years recognized that the formation of a moving average curve normally displays an irregular periodicity even when generated from random data.[42] This is known as the Slutzky-Yule effect. As a demonstration of this principle, I chose to generate tree-ring data randomly for the central Mississippi basin. These data possess the same variance and standard deviation exhibited by the real tree-ring index. The computer-generated random tree growth data were then transformed to ten-year moving *t*-test values in the same manner as the real data had been. The procedure was repeated on numerous occasions. Plots of the random time series consistently produced curves displaying an irregular periodicity, but understandably, no similarity in phase could be ascertained from one plot to another. Further implications of this concept will be discussed in Chapter V.

Yet, if the entire period of record were to be considered, it must be concluded that in general, the period 1800–1850 was considerably wetter than the 1600–1950 climatic record for the interior West. Also, it appears that the beginning of the twentieth century was much drier than the first half of the preceding century, a point which contemporary historians might consider (table 4). Further inspection reveals that between 1825 and 1850, the period of incipient westward expansion, moisture conditions prevailed, thus influencing all those crossing the continent during this time.

TABLE 4

FIFTY-YEAR *T*-TEST VALUES FOR TREE RINGS

Basins in Proximity to Exploration	1800–1849	1887–1936
Central Mississippi	.50	–3.51
Lower North Platte	2.15	.52
Upper Missouri	.15	.82
Upper North Platte	–.28	–.89
Upper South Platte	–.16	.67
Upper Arkansas	4.01	–.07
Upper Rio Grande	.74	–1.4

TREE RING COLLECTION SITES RELATIVE TO EXPLORATION ROUTES

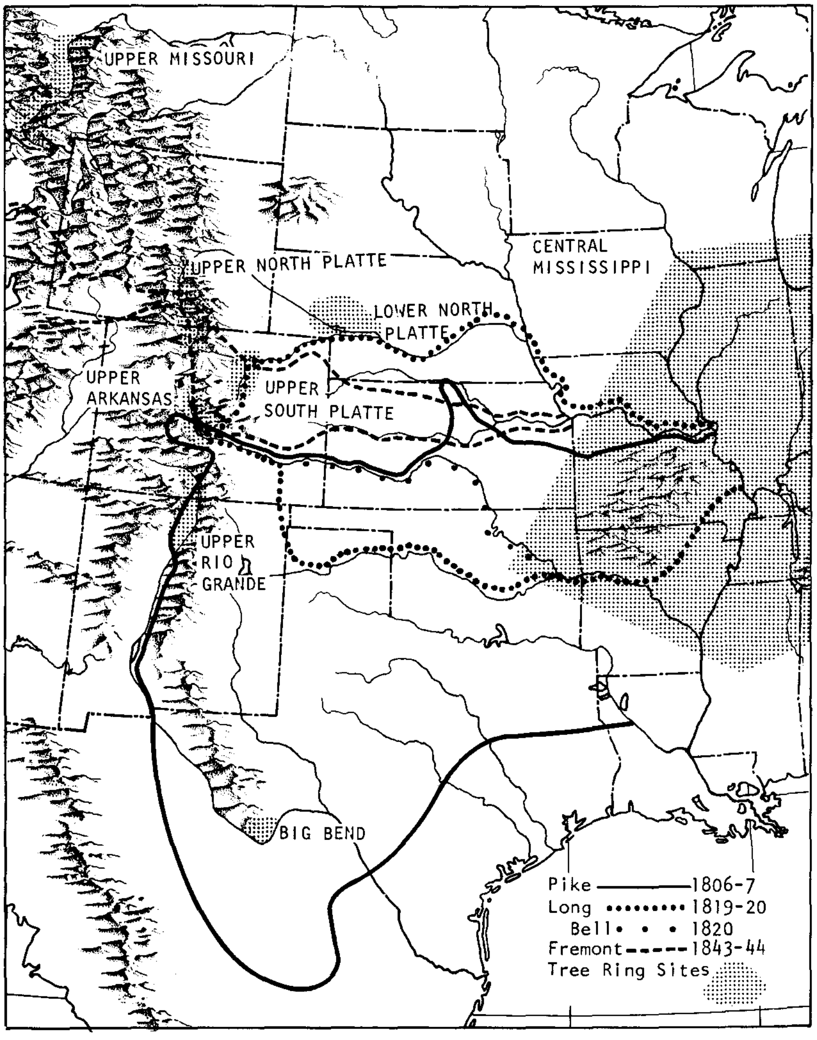


Figure 12

More specifically, climatological analysis of the interior West during initial explorations is facilitated by the above resultant graphs for each drainage basin (see also figure 12). The *t*-test values for tree rings during the decade prior to the explorations of Pike, Long, and Fremont are also presented in table 5. The *t*-test values indicate that the decade prior to Pike's explorations of 1806–1807 was within the limits of the long-term climate. Therefore, with the use of this statistical technique, it does not appear likely that Pike's journey was preceded by substantially low growth (dry conditions). Although not significantly wet, the basins of the central Mississippi, lower North Platte, and the upper Rio Grande were quite moist (medium growth) during this subperiod.

TABLE 5

T-Test Values for Tree Rings during Decades Prior to Exploration

Explorer						Basin in Proximity to Exploration
Pike		Long		Fremont		
Date	*T*-Test Value[a]	Date	*T*-Test Value	Date	*T*-Test Value	
1806	1.20	1819	1.56	1843	0.23	Central Mississippi
1806	1.14	1820	–1.29	1843	4.01	Lower North Platte
1806	–0.58	1820	0.51	1843	0.97	Upper South Platte
1807	0.31	1820	0.59	1844	4.23	Upper Arkansas
1807	1.29	—	—	—	—	Upper Rio Grande
1807	1.74	—	—	—	—	Big Bend
1807	0.89	1820	1.97	1844	0.48	Central Mississippi

[a] Values below –1.64 are significantly dry at the .05 level.

Long's expedition of 1820 was preceded by close to but not significantly dry conditions in the lower North Platte basin. The other three basins of exploratory contact were above average in moisture, with the central Mississippi basin becoming significantly wet by Long's return in 1820.

Precipitation during the subperiod circa 1825–45 led to *significantly* wet conditions in six of the eight basins, with all areas receiving above average effective moisture. Thus, a wet period of major proportions was coincidental with the initial pioneer contact in the Western Interior. During this time, the upper Arkansas, Big Bend, and Rio Grande basins endured their regime of most effective moisture of the past 350 years. Fremont traversed the cismontane and Rocky Mountains at the height of this prolonged "monsoon."

Interpretation of climatic conditions in the vicinity of the Oregon and Santa Fe trails for the decade prior to the Gold Rush of 1849 is facilitated by inspection of the plots for the Mississippi, lower North Platte, and upper Rio Grande basins. Although tree growth in 1849 was slightly below average for the Mississippi basin, the decennial *t*-test value was almost 1.0, yet not significant at the .05 level. Along the Oregon trail near the fork of the Platte, tree growth was only 80 percent of normal in 1849. The ten-year subperiod prior to the Great Migration also appears to have experienced lower tree growth. Calculation of a five-year *t*-test value ending with 1849 is similarly negative at –1.20. Thus, the length of the subperiod is not a negating factor to a valid interpretation. For those traveling the trail in the Santa Fe region that year, tree growth was slightly above average. The longer ten-year subperiod was almost exactly average when compared to the total 352-year record. It has been previously established that serious problems affect the validity of assessing annual tree growth. But even if one were to anticipate a lag of one or two years in response of tree growth to precpitation, similar conclusions would be reached, that is, climate (weather) as interpreted from master charts of tree rings was not abnormally wet (high growth) or dry (low growth) prior to the Great Migration.

Finally, the subperiod 1851–1860, which brought thousands of pioneers across the plains, appears to have been *very* dry in the North and moderately dry in the South. Working much farther to the west, Keen concluded that between 1839 and 1859 eastern Oregon was experiencing severe drought conditions.[43] Lakes in the region must have been dry by the late 1840s, allowing wagons to pass over their beds and thereby creating deep ruts that were later exposed in 1925. Limited tree-ring growth during the 1840s and early 1850s was observed by Keen to be almost as severe as the lack of growth during the drouth of the 1930s. However, from Oregon's discovery by the Lewis and Clark expedition in 1805, through incipient settlement until the vast immigration of the 1840s, the tree-ring record indicates a relatively wet climatic regime.

In summary, dendroclimatological evidence substantiates the notion that fluctuations in conditions affecting tree growth have taken place in the Western Interior for hundreds of years. In this time, droughts have occurred which have exceeded twenty years in duration. They most probably created a landscape denuded of most nonarboreal species except for xerophytic types. Had the western plains region been explored during such a period, one could not challenge the veracity or judgment of those who might have rendered negative evaluations of the West's potential upon their return. For this reason, it has been necessary to catalog our present capability for investigating the *reality* of climate prior to major expeditions of the United States into the Louisiana Territory. There does not appear to be any evidence, however, that a drought preceded either the Pike, or Long, or Fremont exploration into the Western Interior. Conversely, in the first years of migration to Oregon, it appears that abnormally wet conditions existed in the Far West, but by the year following the discovery of gold in California these conditions persisted only in the Mississippi basin. With increasing migration across the Sante Fe and Oregon trails, the government extended its network of military posts westward. With these the historical climatologist is provided another data source for assessing the climate of the "Great American Desert."

3. The Military-Recorded Plains Meteorology: Reconstructing the Summer of the Forty-Niners

There is extant a very large body of information on the geographical exploration of our West that has been so infrequently tapped by historians, geographers, and others who are interested in successive changes in the landscapes, from initial observation, through settlement, to intensive land use. I refer here to the treasure trove of reports, journals, accounts, and the like that were prepared by civilians and especially by military personnel in response to an official request and as part of a prescribed obligation to the federal government.[1]

With this passage, Herman Friis issued a challenge and suggested the means for interpreting the physical and cultural modifications to the landscape of the interior West. Accounts prepared by keen observers, trained in "response to specified needs for information," are lamentably overlooked by historians and historical geographers unwilling to search for the primary data collected by these scientists and engineers. Much of the physical and biological material collected during exploration was lost en route, either intentionally by disgruntled subordinates or through accidental misfortunes such as the sinking of supply rafts. Many of the original botanical and faunal specimens which survived the treacherous journeys were ultimately lost to either indiscriminate governmental house cleaning or the ravages of fire. Fortunately for the historical climatologist, meteorological observations have not shared these unfortunate ends, probably because they were entered as part of the daily recorded events of the official journal kept by the commanding officer.

Every expedition sent into the Western Interior was charged with keeping a journal of distances, global coordinates, and other geographical data. These journals frequently include a separate section for recording daily weather characteristics. For the historical geographer interested in the behavioral approach to environmental assessment, a veritable laboratory exists in which the meteorological events encountered by explorers can be analyzed and compared with the explorer's "personal encounters with the landscape"[2] as expressed in the color and emotion of their descriptions. Strangely, no such comparisons have been attempted, but much has been made of the generalizations and day-to-day impressions of the explorer and his chronicler. Why, for instance, has no historical researcher sought to interpret Zebulon Pike's encounter with and assessment of nature (topophilia) in relation to his recorded physical (e.g., meteorological) experiences during the expedition?[3]

Following these initial exploratory incursions into the Western Interior, semipermanent military installations were erected to protect the advancing edges of America's frontier. When it became apparent that vast numbers of easterners would cross the continent in search of gold or, as in the case of the Mormons, to escape religious persecution, posts were strategically placed along the overland trails to provide protective security for the emigrants. At the direction of the Office of the Surgeon General of the United States, the resident surgeon at each post made systematic meteorological observations with the purpose of documenting the impact of climate upon the health of the military personnel.[4]

Climatic Interpretations Utilizing the Meterological Records of Military Installations

To establish whether climate was affected by population growth or cultivation, a system of meteorological observations was instituted to record the impact of weather and climate upon health disorders.[5] Beginning in 1819 data was collected at eighteen forts; one of these stations was Fort Atkinson, located at the Council Bluff.

Information available for this earlier period includes temperature, which was read at 7:00 a.m., 2:00 p.m., and 9:00 p.m., and wind, expressed in terms of daily directional prevalence from one of eight possible coordinates. The daily temperatures were consolidated and summarized to yield mean daily, mean monthly, and yearly mean temperatures and temperature extremes for each station. Weather at each station is presented as days of fairness, cloudiness, rain, and snow.

By 1842, meteorological records were being kept at sixty-two posts, of which the farthest west was Fort Gibson, Cherokee Nation, Arkansas.[6] The number of posts collecting climatic data had increased to 159 by 1855.[7] Meteorological observations made at these stations were presented in tables containing monthly, seasonal, and yearly means of temperature in a report concerned with sickness and mortality within the army. In addition, the report contained descriptive information on rainfall, wind, and weather.

Thus during the presettlement period in the Western Interior, a modest meteorological network had been established on the periphery of the region. This provides an instrumental record which permits the historical geographer to conduct a quantitative study of weather situations. A datum plane thus exists for the assessment of meteorological exposure experienced by those crossing the Great American Plain.

The purpose of this chapter, then, is to analyze meteorological observations recorded by army personnel at forts on the frontier during the summer six months of 1849, to reconstruct the plains climate of 1849, and to establish a methodology that will permit comparison of the climatic conditions of 1849 with those of the last 120 years.

By 1849, twelve military facilities were collecting and systematically reporting meteorological data within the trans-Mississippi West (fig. 13). Military installations in closest proximity to or along the emigrants' trails include Saint Louis Arsenal, Jefferson Barracks, Fort Leavenworth, Fort Kearny, and Fort Laramie along the Oregon Trail; with Fort Scott and Fort Marcy close to the Santa Fe Trail, and Forts Smith, Gibson, Washita, and Towson in close proximity to the Marcy-Simpson route to Santa Fe (Fig. 16, p. 42). The distribution of these forts unfortunately emphasizes the perimeter of military control along the 95th meridian west. Even more limiting, observations at Fort Laramie and Fort Marcy commenced in September of that year. Thus no significant contributions are made by these stations during the spring and summer of the first great emigration across the plains. Also, observations at Fort Atkinson, which was abandoned in February after the Winnebagos had been removed, were suspended after January, 1849.

All but two military posts collecting weather data in 1849 did so for the Office of the Surgeon General (table 6). Voluntary observations for the Smithsonian Institution under the immediate direction of James P. Espy[8] were conducted by 150 daily observers

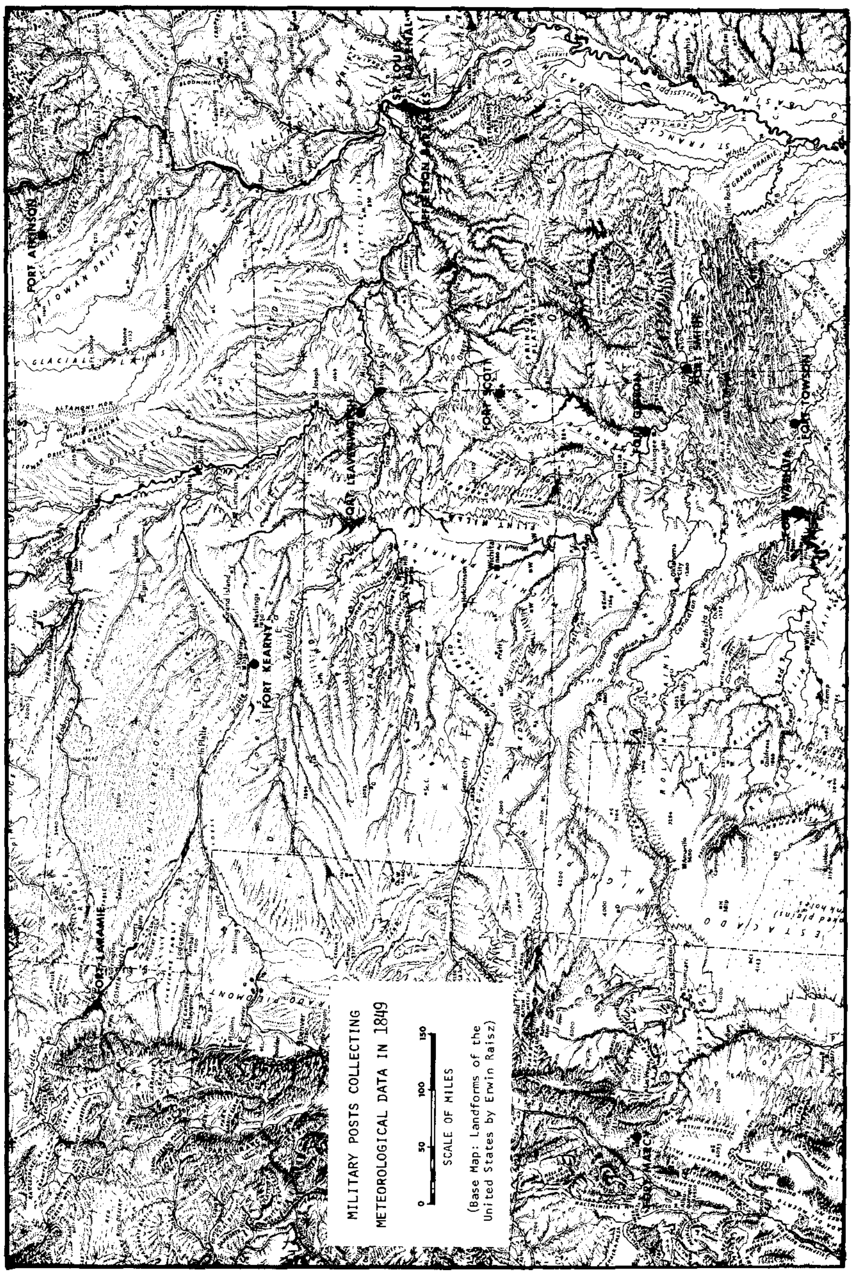

MILITARY POSTS COLLECTING
METEOROLOGICAL DATA IN 1849
0 50 100 150
SCALE OF MILES
(Base Map: Landforms of the
United States by Erwin Raisz)
FORT ATKINSON
FORT LEAVENWORTH
FORT SCOTT
FORT SMITH
FORT TOWSON
FORT KEARNY
FORT LARAMIE

Figure 13

at the close of 1849.[9] Two posts, Fort Kearny and Laramie, maintained voluntary observations for a portion of 1849. Fort Kearny was the only station to report both forms simultaneously.[10]

TABLE 6

MILITARY POSTS COLLECTING METEOROLOGICAL DATA IN 1849[a]

Post	Agency and Duration
Jefferson Barracks (10 miles below Saint Louis)	SG-1: June 1827–March 1831, July 1831–Dec. 1835, Oct. 1836–Sept. 1837, Apr. 1838–Dec. 1859 (gaps)
Saint Louis Arsenal (3 miles south of Saint Louis)	SG-1: Oct. 1835–Mar. 1840 Oct. 1840–Nov. 1856
Fort Atkinson	SG-1: Oct. 1840–Mar. 1841, May 1841–Dec. 1843, Jan. –May 1846, Oct., Nov. 1848, Jan. 1849
Fort Leavenworth	SG-1: July 1827–Dec. 1859 (gaps)
Fort Scott	SG-1: June 1842–Mar. 1853
Fort Gibson	SG-1: July 1824–June 1826, June 1827–June 1839, Oct. 1839–June 1857
Fort Smith	SG-1: March 1821–March 1824, July 1838–June 1850, April 1852–March 1861
Fort Towson	SG-1: July 1824–March 1829, July 1831–April 1846, June 1849–April 1854
Fort Washita	SG-1: July 1842–Dec. 1859
Fort Kearny	S1: March–Dec. 1849
	SG-1: Jan. 1849–Dec. 1859
Fort Laramie	S1: Sept.–Dec. 1849
	SG-1: Jan. 1851–Dec. 1858
Fort Marcy	SG-1: Jan. 1849–July 1851, Sept. 1852–Oct. 1856

SOURCE: United States, National Archives, *List of Climatological Records* (Washington, D.C., 1942).

[a] This tabulation is given for military posts collecting data in 1849. However, the entire period S1 and SG-1 observations is presented.

Post surgeons recorded their observations on two forms issued after 1843: Form 3, entitled "Meteorological Register," and Form 4, entitled "Hourly Meteorological Reports." Daily records were kept on Form 3 (fig. 14):

Barometer: Sunrise, 9:00 a.m., 3:00 p.m., 9:00 p.m.
Thermometer: attached to the barometer and detached, same hours
Sky: Clearness, same hours
Wind: direction and force, same hours
Wet bulb: sunrise and 3:00 p.m.
Rain: duration and quantity
Remarks: descriptive accounts of late or early frost, hail and ice accumulation, vegetation blooms, floods, etc.
Monthly means: all data

Hourly observations recorded during solstices and equinoxes were made on Form 4 for only a short time.

First-class observers for the Smithsonian Institution were similarly equipped as those for the army, with gear including barometers, psychrometers, wind vanes, thermometers, and rain gauges. Readings were taken at sunrise, 9:00 a.m., 3:00 p.m., and 9:00 p.m., which corresponded with SG-1 observations (fig. 15). The following information was collected:

Barometer: at four hours noted above with attached thermometer
Thermometer: detached
Psychrometer: wet and dry bulb
Precipitation: quantity, duration (no snowfall depth until 1856)
Sky: cloud direction and velocity, 0 indicating calm, to 6 indicating violent storm
Remarks: similar to SG-1 reports—frost dates, bird migrations, crop conditions[11]

Space provided in the journals did not permit extensive descriptions of weather events.[12] Commonly, notations of rain would amount to little more than "thunder and lightning a.m." Many statements had interesting implications, however, especially for researchers interested in the controversy of grassland origins. Prairie fires were commonly repotred by post surgeons, particularly during the months of February and March when winter-killed grasses made tinder by drought were kindled during spring thunderstorms. At Fort Leavenworth, for example, the entry for March 13, 1849, reads, "Heavy rain with thunder and lightning at 6 p.m."

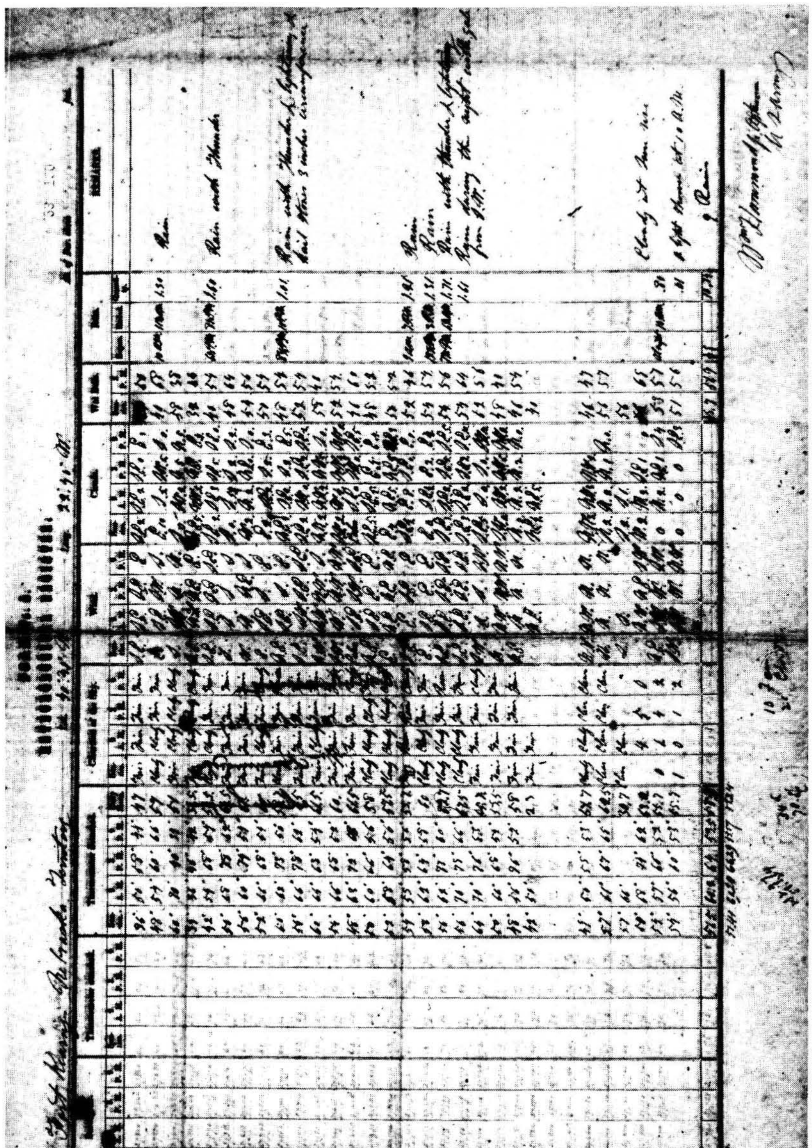


Figure 14

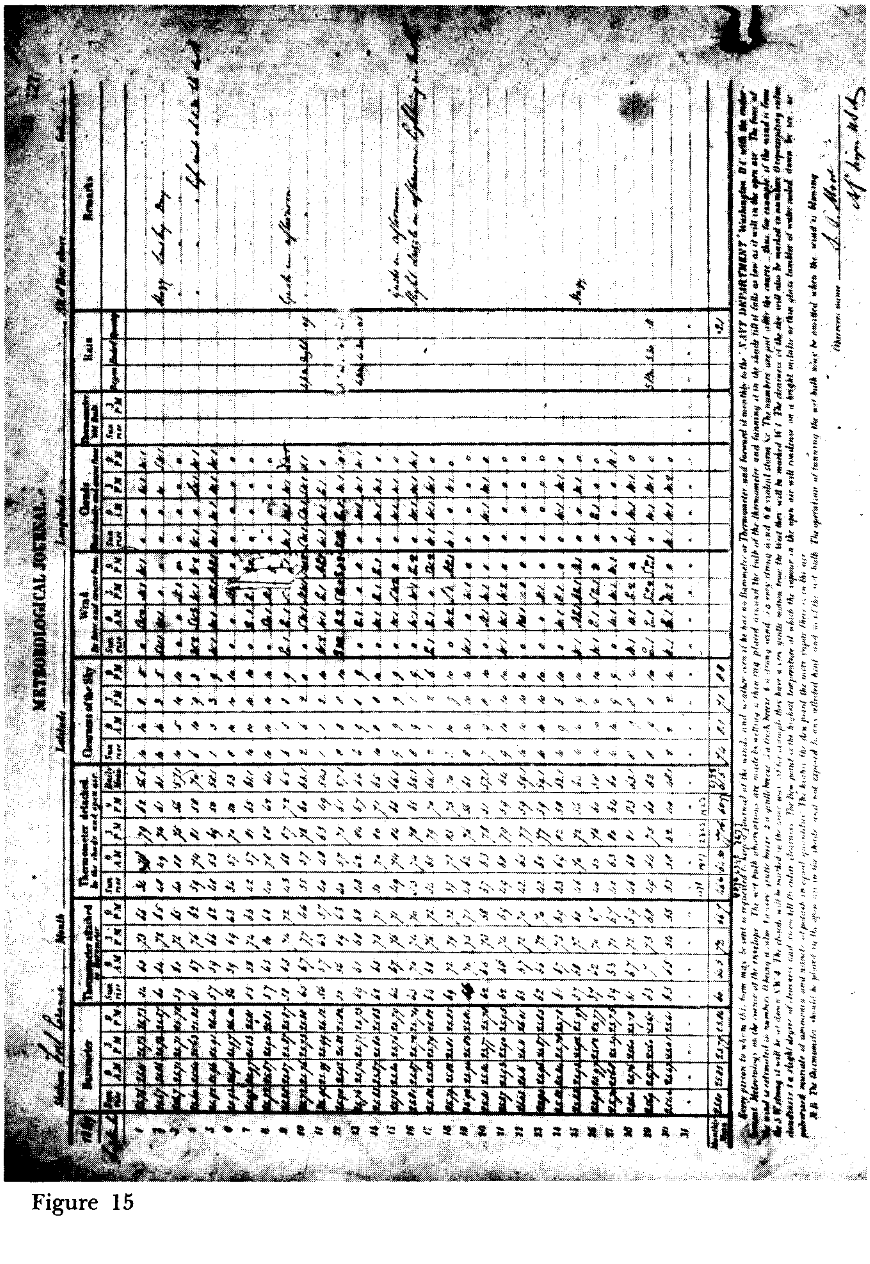


Figure 15

On the following day, it states, without speculation as to its origin, "Frost-Prairies on fire." These insights into the environmental vicissitudes of the prairies are quite incidental, however, to their potential for assessing the meteorological record of the period, a time in which over thirty-thousand migrating Forty-Niners crossed the Oregon Trail.[13]

THE FORTY-NINERS' SUMMER ON THE PLAINS: THE MILITARY RECORD

To most of those crossing the plains, Saint Louis represented the "Gateway to the West." With the exception of those joining the Marcy and Simpson army detail which traveled to Santa Fe up the Canadian River from Fort Smith, the majority of the prairie travelers made their way by riverboat or overland to Saint Louis during the winter of '49 before disembarking for Saint Joseph, Weston,[14] Kansas City, or Council Bluffs. Only a few came overland, as the bulk of the travelers arrived on precarious steamboats from Saint Louis. Perhaps it is appropriate that Saint Louis was to become the gateway, for as early as May 15, 1813, the *Missouri Gazette* of this city had stated, "It appears that a journey across the continent of N. America, might be performed with a wagon, there being no obstruction in the whole route that any person would dare to call a mountain."[15]

Over three decades passed, however, before the beginning of the Great Migration. As parties formed, not all were optimistic that the anticipated paradise would be worth the risk. In June, 1844, the *Missouri Republican* admonished, "No man of information or in his right mind, would think of leaving such a country as this, to wander over a thousand miles of desert and five hundred of mountains to reach such as that."[16] Desert or not, by 1849, with news of the gold discoveries in California and with word of the official cession of California following the Mexican War, masses of pioneers were ready to trek across the continent. "In a single year the numbers so increased that for one person who traveled the trail to California in '48, fifty traveled it in '49."[17]

Was their journey across a "thousand miles of desert"? The decade of the 1930s has demonstrated the possibility of this environmental condition west of the Missouri.

Weather on the Plains, 1849

As the pioneers began to assemble at their points of departure,[18] winter was all but past. In Saint Louis, January had been excep-

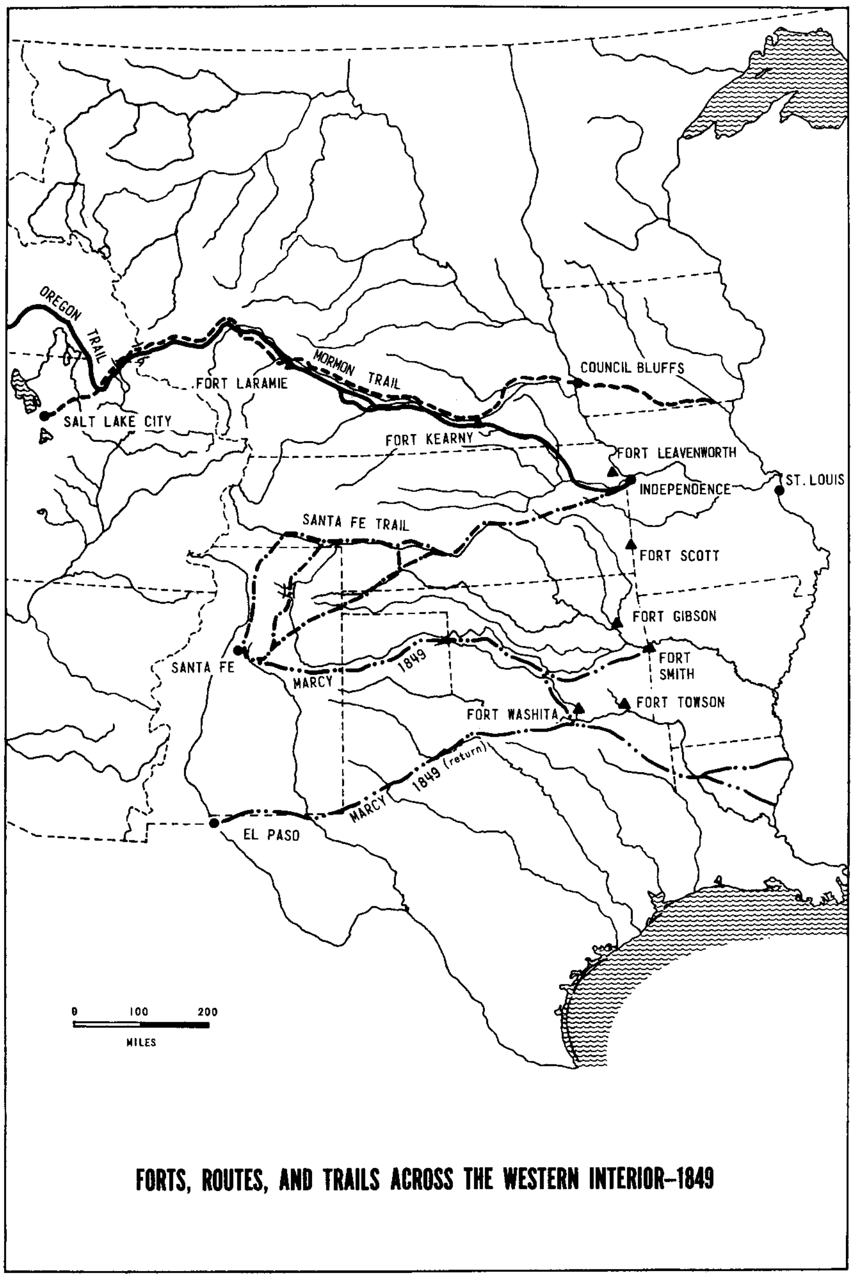

OREGON TRAIL
MORMON TRAIL
FORT LARAMIE
SALT LAKE CITY
COUNCIL BLUFFS
FORT KEARNY
FORT LEAVENWORTH
INDEPENDENCE
ST. LOUIS
SANTA FE TRAIL
FORT SCOTT
FORT GIBSON
SANTA FE
MARCY
1849
FORT SMITH
FORT TOWSON
FORT WASHITA
EL PASO
MARCY
1849 (return)
0 100 200
MILES
FORTS, ROUTES, AND TRAILS ACROSS THE WESTERN INTERIOR–1849

Figure 16

tionally wet (7.6 inches), exceeding the secular[19] long-term average by 300 percent.

By contrast, however, February was extremely dry, with a little over one-half inch of precipitation. It appears that these dry conditions were quite extensive, as Fort Leavenworth experienced barely six-tenths of an inch. By the end of the month, the surgeon at the fort notes, "River still passable on the ice." Spring was not far off as "wild geese flying north" and "flocks of Black Birds" were also recorded at that time.

At Fort Scott, the February drought was even more intense, with .18 inch of precipitation recorded. Following a cloudy but warm January, precipitation fell on only two days that month, one with snow and one with rain. The surgeon observed "hazy sky much of month" with "prairies burning" and "heavy windstorms," conditions certainly not conducive to growth of luxuriant grass.

Troops at Fort Gibson fared similarly. January had been normal. Cloudy skies prevailed twenty-three days, but rain was light on seven occasions, while snow occurred only once. Fair skies returned in February with temperatures reaching a maximum of 80° F. The four rain showers and a single snowfall produced less than one inch of precipitation.

On the middle Platte, winter was much more severe at young Fort Kearny. Writing in January, the fort surgeon laments, "Snow from two to three feet in depth has lain on the ground from the middle of Nov. 'til the present."

No rain fell in January at the fort, but eight days with snow were noted. February remained cold, averaging 15.7° F. "No rain during the month though snow of same depth as in preceding month has continued to cover the ground." Snow cover for this length of time is uncommon in Nebraska. High temperatures in March could create serious flood conditions lower in the Missouri Valley.

By March, precipitation had returned to "normal." At Saint Louis Arsenal, records show that 3.6 inches of rain fell during the month. Nearby Jefferson Barracks experienced eleven rainy days, but slightly less than three inches of precipitation. On the Missouri, at Fort Leavenworth precipitation totaled close to three and one-half inches, as was the case with Fort Scott to the south. Both locations, however, were dry enough to permit numerous "prairie fires late in the month." Prairie flowers were blooming by March 18 at Fort Scott, the same day as martins arrived at Fort Gibson, where temperatures were as high as 80° F. Precipitation at the fort was notably above average.

March at Fort Kearny was a month of contrasts. With a deep residual snow cover, temperatures soared as high as 70°, with many exceptionally warm days recorded. A total of 6.12 inches of precipitation fell in only three storms. This must have added to the melt-water runoff. Kearney, Nebraska, presently averages 1.25 inches of rain for March. Unfortunately, river levels of the Platte were not mentioned in the journal, but it is obvious that soil moisture conditions must have approached saturation. By April 1, 1849, twenty-thousand eager emigrants had gathered along the banks of the Missouri, ready to begin the trip over the trail just as soon as the spring grass would make its appearance to sustain the oxen and mules.

Those wagons crossing the Oregon Trail that year favored Saint Jo as a point of departure, followed by Kansas City, and then Council Bluffs.[20] The proximity of the starting point of the original Santa Fe Trail, whose track led southwest out of Independence, only compounded the numbers of emigrants busily assembling wagons, gear, and provisions as they waited for the grass to green on the prairie.

Those who had not yet arrived at the jumping-off places and were still making their way upriver from Saint Louis, experienced fairly pleasant temperatures. Jefferson Barracks recorded a monthly low of 30° F. and a high of 83° F. Nine lightning storms dropped slightly above normal precipitation.

Night temperatures were cooler at Fort Leavenworth in April, with even one day having snow. The month was generally fair.

In the vicinity of Forts Scott and Gibson, April was quite cloudy and overcast, with a high daily frequency of rain. But the accumulation was not excessive. Farther south, temperatures at Fort Smith averaged a warm 64° F., accompanied remarkably by a very soggy 8.5 inches of rain. On the Red River south of the Marcy-Simpson route, similar wet conditions were recorded at Fort Washita. Twelve days with rain and one with snow produced seven inches of precipitation.

The first half of April at Fort Kearny proved extremely wet, with eight inches recorded, followed by a period with no rain until May 2. (This break allowed work to resume on the construction of one-story sod [mud] buildings.) The first emigrant was not to arrive at the infant post until May 6.

When the crest of migration began to sweep across the eastern plains in late April and early May, the rains seemed to follow, as did the dreaded cholera disease.[21]

The heavy roads filled with mud only added to the emigrants' problems. A total of seven days were reported as "fair" at Fort Scott in May, a month that saw over twelve inches of rain soak the area. Fort Gibson's precipitation totaled much less, but its distribution was such that it occurred on fourteen days. For the second month in a row, the rain gauge measured over eight inches at Fort Smith.

But these figures cannot compare with the relative monsoons recorded at Fort Washita and Fort Kearny. The month in which the migration peaked in their vicinity, storm waters practically inundated these forts. Fort Washita meteorological records show thirteen rain days with 14.61 inches in that month. Seven of the storms each produced over one inch of rain. At Fort Kearny, the May rains totaled close to eleven inches. A particularly violent thunderstorm on May 9 recorded three-inch-diameter hailstones.

Joseph Hackney, described the waterlogged post and its setting on May 24, 1849:

> This has been one of the worst days that we have experienced since we left St. Joseph it commenced raining soon after we left camp and rained all day we passed fort childs[22] at noon it is situated opposite the head of grand island Thear is nothing hear now but a few mud huts but theay are going to build a regular fort thear is two company of regulars stationed hear we took the wrong road at the fort and had to go through a number of swamps.[23]

The decline in emigration was quite evident by June even as far west as Fort Kearny. At the end of the month, only the odd straggler was making his way west behind the forward wave of pioneers. River waters for the middle Platte were now indicating the abnormal precipitation amounts in the upper basin. Writing in the meteorological journal at Fort Leavenworth on June 24, the surgeon notes, "The Missouri has continued high since the opening of navigation in March."

The general cyclonic rains with associated frontal thundershowers of spring now had been replaced by intense convective shower activity with the warm weather. Fortunately, most wagon trains had moved west of this activity. Although descriptions of these violent thunderstorms were common in the diaries of emigrants, the post surgeons generally recorded the events quite perfunctorily. An exception, however, was the description of a storm at Fort Kearny early in June: "A severe *hailstorm* with hail stones as large as Nutmegs—breaking the window panes on north and w.—the fall of *hail* lasting altogether about 20 minutes and nearly covering the ground with hail."[24]

Among those pioneers certain to have been traveling along the first leg of the Oregon Trail in June were those escorted by Captain Howard Stansbury of the Topographical Engineers. He and his party of fifteen soldiers did not leave Fort Leavenworth until May 10, arriving at Fort Kearny during the third week in June. Although traveling behind perhaps sixty-thousand animals that had cut a swath across the plains, Stansbury and his group had somehow successfully eluded the earlier devastating hailstorms. At Fort Kearny, he first learned of their magnitude from Colonel Bonneville, the commanding officer: "I was told that the hailstones had been very frequent this season and quite destructive, cutting down the weeds and stripping the trees of their foliage."[25]

Rainfall amounts were now becoming incredible along the eastern portions of the trails. Saint Louis Arsenal totaled 29.37 inches in June and July; most of the precipitation came in the form of nocturnal thundershowers. Nearby Jefferson Barracks also received record precipitation for the summer of '49 (1840–59),[26] as did Fort Gibson (1836–54), Fort Smith (1837–54), Fort Washita (1844–54), and Fort Kearny (1849–55). Records at Fort Towson for 1849 were incomplete until June. Lightning and thunder were observed with or without rain on twenty-three days that month and seventeen days the following month. The intense July showers exceeded all other Julys of comparable record from 1836 to 1854.

Air Temperature in the Plains, 1849

Temperatures for the summer months were excessively cool. Comparability of fort temperatures with modern secular data is not possible because of divergence in the method of calculation of daily averages. Journal entries, following the directions of the Surgeon General, computed mean daily temperatures by averaging the readings obtained at sunrise, 9:00 a.m., 3:00 p.m., and 9:00 p.m.[27]

Unfortunately, the observers at the forts made few qualitative remarks about the temperatures, probably because most had little prolonged experience in the region to provide a basis for comparison. A physician traveling with the Wisner company, Dr. Israel

Lord, on arriving at Fort Kearny in early June made these relevant observations concerning the intemperate weather:

> Vegetation is backward. The gardens have been planted three or four times, and the seed has mostly rotted. Potatoes were two inches high, and peas in full bloom, five inches . . . . The weather has been so cold till the last three days as to require overcoats in the middle of the day.[28]

Comparability of temperature readings is tenuous even when fort records are compared with daily diary entries of emigrants. On June 17, camped outside Fort Kearny, J. Goldsborough Bruff made the following observations, "Cloudy, with strong breeze from S.E. Temp. 52° occasional showers. I visited the fort after breakfast."[29] The June 17 entry at the fort reports a sunrise temperature of 67°, with winds from the south at a force of one.[30] Cloud direction at this time, however, was from the southeast. Rain began falling at 9:00 a.m., lasting one hour with an accumulation of one-tenth inch.

One rather simplistic but descriptively revealing technique for developing at least some insight into the contrasting temperatures experienced by the argonauts would be interpretation of monthly maximum and minimum temperatures. Figures 17 and 18 relate the monthly temperature extremes and mean for each fort with available records. It becomes evident that by April temperatures were quite warm, reaching into the eighties at all forts except Fort Scott. Most forts recorded subfreezing temperatures, the coldest being observed at Fort Kearny.

In general, May temperatures averaged ten degrees warmer, but maximum readings at the forts were insignificantly higher and in two instances lower than the lowest maxima of the preceding month. No forts registered frost conditions, although a twenty-degree minimum temperature gradient (monthly average) existed between Fort Kearny (34°) and Fort Washita (54°).

June appears to have been unseasonably cool at most of the weather stations. Maximum temperatures exhibited very little latitudinal gradient. Afternoon temperatures rarely reached the nineties. The contrast between minimum and maximum readings was diminishing noticeably. It would appear that the majority of the emigrants did not suffer extreme afternoon temperatures. This situation continued into July, with even the forts to the south still not recording extreme temperatures. Along the Oregon Trail, minimum temperatures fell below those of June. The monthly average was no more than two or three degrees warmer.

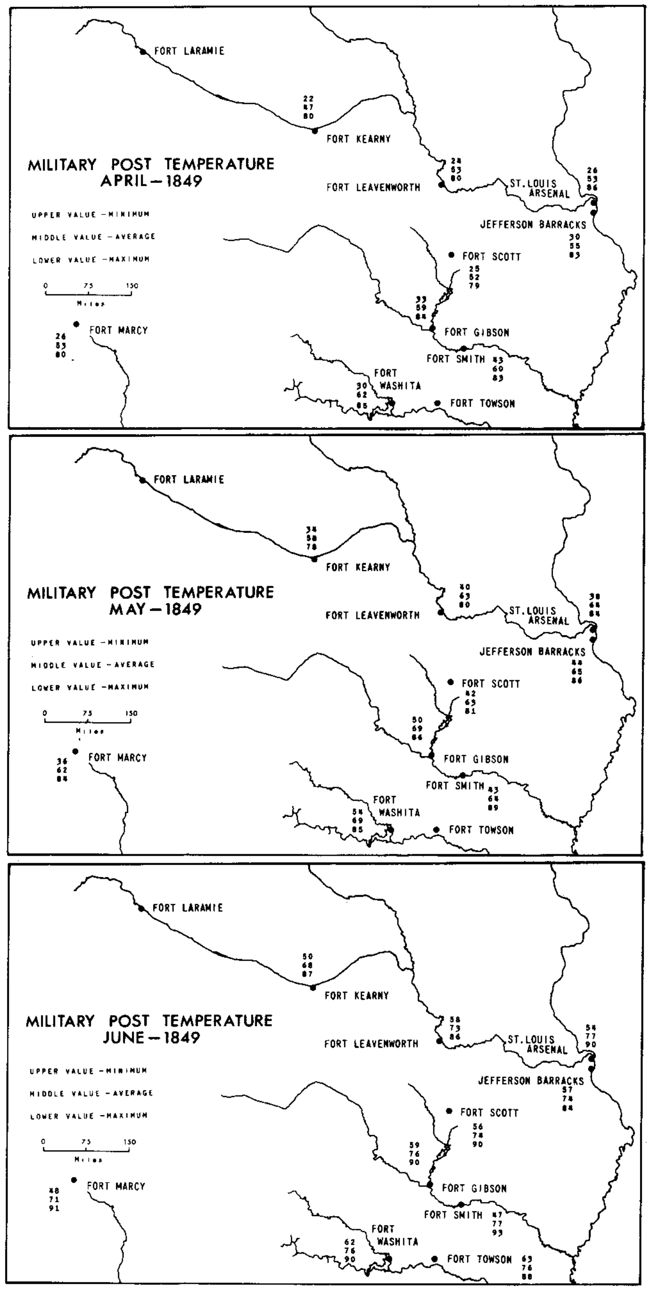

MILITARY POST TEMPERATURE
APRIL – 1849
UPPER VALUE – MINIMUM
MIDDLE VALUE – AVERAGE
LOWER VALUE – MAXIMUM
0 75 150
Miles
FORT LARAMIE
FORT KEARNY 22 47 80
FORT LEAVENWORTH 24 53 80
ST. LOUIS ARSENAL 26 53 86
JEFFERSON BARRACKS 30 55 83
FORT SCOTT 25 52 79
FORT GIBSON 33 59 84
FORT MARCY 26 53 80
FORT SMITH 43 60 83
FORT WASHITA 30 62 85
FORT TOWSON
MILITARY POST TEMPERATURE
MAY – 1849
UPPER VALUE – MINIMUM
MIDDLE VALUE – AVERAGE
LOWER VALUE – MAXIMUM
0 75 150
Miles
FORT LARAMIE
FORT KEARNY 34 58 78
FORT LEAVENWORTH 40 63 80
ST. LOUIS ARSENAL 38 64 84
JEFFERSON BARRACKS 44 65 86
FORT SCOTT 42 63 81
FORT GIBSON 50 69 86
FORT MARCY 36 62 84
FORT SMITH 43 64 89
FORT WASHITA 54 69 85
FORT TOWSON
MILITARY POST TEMPERATURE
JUNE – 1849
UPPER VALUE – MINIMUM
MIDDLE VALUE – AVERAGE
LOWER VALUE – MAXIMUM
0 75 150
Miles
FORT LARAMIE
FORT KEARNY 50 68 87
FORT LEAVENWORTH 58 73 86
ST. LOUIS ARSENAL 54 77 90
JEFFERSON BARRACKS 57 74 84
FORT SCOTT 56 74 90
FORT GIBSON 59 76 90
FORT MARCY 48 71 91
FORT SMITH 47 77 93
FORT WASHITA 62 76 90
FORT TOWSON 63 76 88

Figure 17

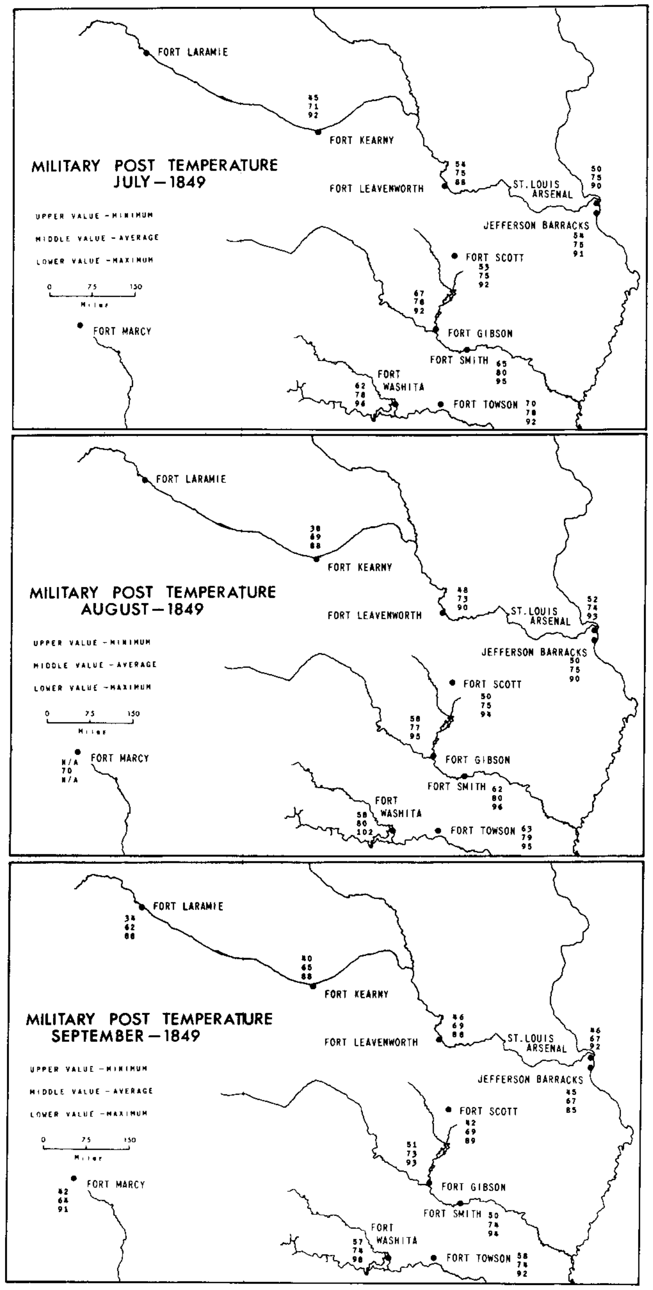

MILITARY POST TEMPERATURE
JULY – 1849
UPPER VALUE – MINIMUM
MIDDLE VALUE – AVERAGE
LOWER VALUE – MAXIMUM
0 75 150
Miles
FORT LARAMIE
45 71 92
FORT KEARNY
FORT LEAVENWORTH
54 75 88
ST. LOUIS ARSENAL
50 75 90
JEFFERSON BARRACKS
54 75 91
FORT SCOTT
53 75 92
67 78 92
FORT GIBSON
FORT SMITH
65 80 95
FORT WASHITA
62 78 94
FORT TOWSON
70 78 92
FORT MARCY
MILITARY POST TEMPERATURE
AUGUST – 1849
UPPER VALUE – MINIMUM
MIDDLE VALUE – AVERAGE
LOWER VALUE – MAXIMUM
0 75 150
Miles
FORT LARAMIE
38 69 88
FORT KEARNY
FORT LEAVENWORTH
48 73 90
ST. LOUIS ARSENAL
52 74 93
JEFFERSON BARRACKS
50 75 90
FORT SCOTT
50 75 94
58 77 95
FORT GIBSON
FORT SMITH
62 80 96
FORT WASHITA
58 80 102
FORT TOWSON
63 79 95
FORT MARCY
N/A 70 N/A
MILITARY POST TEMPERATURE
SEPTEMBER – 1849
UPPER VALUE – MINIMUM
MIDDLE VALUE – AVERAGE
LOWER VALUE – MAXIMUM
0 75 150
Miles
FORT LARAMIE
34 62 88
FORT KEARNY
40 65 88
FORT LEAVENWORTH
46 69 88
ST. LOUIS ARSENAL
46 67 92
JEFFERSON BARRACKS
45 67 85
FORT SCOTT
42 69 89
51 73 93
FORT GIBSON
FORT SMITH
50 74 94
FORT WASHITA
57 74 98
FORT TOWSON
58 74 92
FORT MARCY
42 64 91

Figure 18

August understandably proved to be the warmest month in terms of maximum temperatures recorded. All reporting stations with the exception of Fort Kearny exceeded ninety degrees. Very surprising is the fact that Fort Washita was the only post with temperatures surpassing 100°. Temperature ranges for this month became more pronounced than they had been in July.

The dry conditions in September were associated with fairly warm readings. Temperatures generally appear to have been quite pleasant, with no frost hindering the rain-delayed gardens.

In total, temperatures on the plains were favorable to travel, considering the laborious tasks required of the Forty-Niners. Moderate or even unseasonably cool June temperatures would depress the drought-producing capability of the normally high potential evapotranspiration. Temperatures had been warm in April, thereby facilitating early greening of the grass, and cool in May and June, and thus protecting the high soil moisture levels.

A significant limitation of descriptive analysis, such as this, is the apparent lack of any comparability with a climatic "norm" or extended average for the region. Many of the plains border stations were recording for the first year, and many did not last long. It is difficult to assess degrees of deviation from long-term meteorological parameters. Clearly, the historical climatologist must meet the challenge of providing students of western expansion with climatological interpretations relevant to contemporary knowledge of the area, if this is possible. But he may do so only with a full knowledge of both the problems of potential inhomogeneity of precipitation data and of the attributes of the frequency distributions of precipitation populations.

Problems of Evaluating Homogeneity of Climatological Data

Comparisons of climatological data collected for areas over long periods of time become complicated because of the many possible vicissitudes in instrumentation-observing routine and station location. Were none of these to be altered, the homogeneity of observations would still be unlikely, for there are the inevitable modifications of the local climatic setting brought about by urban growth, industrialization, reservoirs, and other small-scale environmental changes. Historical climatologists must now recognize that comparative interpretations of the climatic record will be increasingly qualified because of man's disruption of natural climatic processes.[31]

Recently, the secretary general to the World Meteorological Organization requested that J. Murray Mitchell, Jr., of the Office of Climatology, National Weather Service, compile an annotated list of long-record climatological stations in the United States.[32] Mitchell recognized three general classes of inhomogeneity characteristics.

(a) Discontinuous inhomogeneity (discontinuity) due to relocation and/or change of elevation of station within local vicinity, usually of order of 1,000 feet horizontally and between half and twice original ground elevation vertically.

(b) Progressive (trend) inhomogeneity due to urban growth around station.

(c) Discontinuous inhomogeneity (discontinuity) due to termination of observations at city station, and relocation of station to an airport usually several miles distant and beyond zone of marked urban influence on climate.

In his report, Mitchell annotatively lists those first-order stations of the U.S. Weather Bureau for which continuous temperature and precipitation data are available. Notations are given which classify each station's instrumental history. The Midwest is represented by a few stations with fairly homogeneous histories prior to 1882. Only three of these (Fort Smith, Arkansas; Saint Louis, Missouri; and Santa Fe, New Mexico)[33] are in proximity to the military units recording observations in the plains area in 1849.

The degree of comparability is reflected in the characteristics of the various meteorological elements to be analyzed. Probably the most reliable of all long-term observations are barometric pressure series, which characteristically display only weak variations regionally and, thus, inhomogeneities can be easily identified. Various corrections must be made, however, before record evaluation can proceed. These include reduction to mean sea level, station changes in elevation, and variations in time of observations. Because pressure observations normally vary only slightly when annually averaged, and because pressure could be considered as much a climatic control as an element, barometric data were not considered in the present study. Future studies of a more synoptic interpretation could utilize this information to greater advantage. Monthly mean sea-level pressure charts for January and July of the type constructed by the British Meteorological Office have allowed reconstruction of Europe's pressure field back to 1750 and that for the north Atlantic Ocean from as early as 1790.[34] Fort meteorological observations from the interior U.S. would enhance the significance of these charts.

Somewhat less reliable for long-term comparability studies, temperature is more critically affected by exposure, instrumentation standards, and mode of aspiration. Temperature was recorded by army personnel using attached and detached thermometers, the former being a part of the barometer. A note at the bottom of each meteorological journal furnished by the Smithsonian Institution cautions the observer concerning correct placement of the detached thermometer: "N.B. The thermometer should be placed in the open air in the shade and not exposed to any reflected heat and so of the wet bulb. The operation of fanning the wet bulb may be omitted when the wind is blowing."

The thermometers adopted by the Surgeon General's Office were standardized after 1843, being manufactured by George Tagliabue, a New York instrument maker. Comparisons of temperature prior to uniform instrumentation should be recognized as tenuous.

The scheduling of thermometer readings can further complicate the derivation of homogeneous temperature data. The arithmetic means of daily maximum or minimum temperatures can be significantly affected by the choice of fixed observation hours.[35]

Rainfall records are even more susceptible to changes in site location. Exposure, gauge design, and height above the ground will drastically affect the opportunity to obtain valid comparative analyses. In very few instances, overlapping data are available and this allows correction factors to be formalized. Occasionally a move even of a few thousand feet will result in no detectable differences in overlapping records.

Early observations on the plains were also influenced by Indian uprisings. Entries on numerous occasions make mention of the fact that a few days had elapsed since the last time the rain gauge had been read because of Indian hostility around the fort.

The Military Record in the Short-Term Perspective

The problem of potential inhomogeneity of climatological fort data can be assumed to be relatively minor if one were to restrict his interpretations to the period of *contemporary record*[36] at each fort. The length of record varies, depending on the longevity of each post. Five of the forts could be considered as maintaining homogeneous observations for approximately twenty years, from circa 1836 to circa 1855.[37] The shortest period of record is that of Fort Kearny, which extends from 1849 to 1855. Tables which list the precipitation maxima at each fort during the length of record are presented in Appendix I.

The annual precipitation totals for 1849, compared with those of other years, generally demonstrate the extreme wetness of the year. At Saint Louis Arsenal, rainfall was thirty inches above the contemporary norm (1836–54). To the southwest in the Indian Territory, Fort Washita experienced twenty-three inches of rain above its annual average of almost forty-two inches, while Forts Gibson and Smith similarly reported precipitation far in excess of their norm for the period. At each of these locations, the record maximum rainfall was established in 1849.

Two anomalies appear to complicate the overall pattern. Only a few miles from Saint Louis Arsenal, the post observer at Jefferson Barracks reported thirty-three fewer inches of rain; indeed, it exceeded its average by less than one inch. If the records are reliable, they demonstrate the extreme spatial variability of intense convective showers occurring in eastern Missouri, primarily during July and August.

Also antithetical to the general weather pattern for the year are the observations at Fort Scott. At this location slightly less than 80 percent of the normal precipitation was recorded; yet, interestingly, one-third of this total fell in May.

The monthly and seasonal generalizations to be derived from the tables in Appendix I reenforce our earlier conclusions. In the east, Saint Louis Arsenal did not receive record-breaking rains until July and August (although June was also very wet). Over half of the annual total was observed during June, July, and August. A similar situation existed at Jefferson Barracks.

Both spring and summer rainfall maxima were established to the west and southwest, where monthly records were set in April, May, and June at many forts. Forts Smith, Kearny, Washita, Gibson, and Towson experienced record rainfall during one or more of these months in 1849. The only forts not establishing monthly records for the six-month warm season were Forts Leavenworth and Scott.

Of primary significance to those traveling the Oregon Trail, the post surgeon at Fort Kearny reported April and May to be the wettest in seven years of known homogeneous record. One might well challenge the significance of this information, particularly because of the short contemporary record. Thus, a discussion of the implications of these rainfall records from the long-term perspective has been deferred to Appendix II, in which qualifications as to homogeneity of data are relaxed.

In summary, fort records provide a unique form of historical-secular weather identification, limited only by an unfortunate distributional gap along the western trail margins until September of 1849. It is evident, however, that spring came late to the plains as the pioneers assembled at their jumping-off places. The upper portion of the Oregon Trail had been blanketed with snow throughout the winter and this resulted in saturated soils for a potentially luxuriant pasturage. Winter had been noticeable drier in the southern plains, for here high winds fanned numerous grass fires throughout much of February and March. As the first of the wagons set out across the prairies, high afternoon temperatures accompanied by excessive moisture must have presented to the eastern travelers a climatic image of the plains that was remarkably monsoonal. The brilliant lightning storms, high winds, and hail of gross proportions amazed and intimidated those unaccustomed to such violence from the heavens. Fort records do not reveal the impact of the weather and climate on those crossing the Great American Desert. They provide the research worker with a reasonable datum for comparison, a comparison of the secular meteorological realities of the time with the physical experiences and mental impressions manifested by the Forty-Niners and ultimately articulated by them to the eagerly awaiting eastern population. The following chapter reviews these notions as recorded by diaries on the trail.

4. The Plains Climate of the Forty-Niners: Historical and Geographical Intrepretations

> From the first of May to the first of June, company after company took its departure from the frontier of civilization, till the emigrant trail from Fort Leavenworth, on the Missouri, to Fort Laramie, at the foot of the Rocky Mountains, was one long line of mule-trains and wagons. The rich meadows of the Nebraska, or Platte, were settled for the time, and a single traveler could have journeyed for the space of a thousand miles, as certain of his lodging and regular meals as if he were riding through the old agricultural districts of the Middle States.[1]

Migration estimates of this wave of civilization across the Great American Desert in 1849 place the number of emigrants at approximately thirty-thousand.[2] The accuracy of these figures appears to be verified by eyewitness accounts of emigrant registers maintained at Fort Kearny and Fort Laramie. Unfortunately, the fate of these records is presently unknown. Many of these Forty-Niners recognized that one day they would take a prominent place in American history. They were caught up in a form of pageantry of a dramatic episode that appealed to the imagination of the country. There are those who insist that the search for gold was but a superficial explanation for a far more complex behavioral process of migration. Many obviously were also intrigued by the adventure of pushing back the personal frontier of their own *terra incognita*. They were bent upon not only seeing the "elephant," but "eating his ears."[3]

The incredible excitement of wagon train organization, the adventure of migrating epic distances in search of a new way of life, the anticipation and anxiety of facing incalculable dangers of the vast continental interior with its diversity of terrain, vegetation, and weather—these were the ingredients of the argonaut's life and the scenes which were to be recorded in the diaries of emigrants or in letters sent east to their friends and families remaining behind.

Overland journals as descriptive narratives of travel in the West have contributed significantly as a source of information for contemporary historical interpretations. Their importance as historical documents is best summarized in an article by Dale L. Morgan.

> The overland journal affords us a very broad cross-section of American life, extending over many decades. First it has something to say, by inference or direct statements concerning the area the emigrant came from and the time of this setting out—the fact that he undertook the journey at all. Second, the narrative is a record of the journey itself, one of the most characteristic experiences afforded by the West, which has left an indelible impress on the American consciousness. Third, it is an exact record of particular places at particular times, local history of the purest distillation. Fourth, it is a record of a particular year's emigration, each of which differed from every other. And, finally, each overland journal is a record of one man's life over a fixed period of time, for whatever we may make of it.[4]

The overland narrative, manifested in either a journal or letter, serves the student of western history as an invaluable informational source. Commonly, the historian has emphasized the social, economic, and political ramifications of emigration, minimizing the environmental aspects except where the latter directly influenced the former. Information as to the structural organization of the overland companies, routes traveled, types of wagons and draught animals used, problems with overloading, and the "skulking" Indian menace has been exhaustively compiled.

Landforms, soil, vegetation, fauna, weather, and climate are known as they affected individuals, yet surprisingly few, if any, attempts have been made to reconstruct the environmental parameters of the folk experience. Too often, perhaps, the historian "envisions the average overland journal as a wasteland of mileage and weather: 'August 25, 30 miles, some cloudy. August 26, 20 miles today, wind from the Northwest.' "[5] But taken together and set in a *spatial context,* the average overland journals can tell us a great deal about the *weather* and *climate* of large sections of earth space in particular seasons, often providing detail that no other sources can give. For instance, three or four diaries of travelers widely separated on the Oregon or Santa Fe trail can give us clues as to the types, intensity, distribution, and frequency of weather situations and climatic systems in, say, the central (and perhaps southern) plains in the months of May and June. They can tell us much about the types of rainfall encountered (frontal or convective), seasonableness of temperatures, whether seasonal rainfall was high or low, etc. When approximately thirty-four diaries for one year (1849) are consulted, as in this chapter, the analysis is more conclusive, particularly when the weather situations can be related to the daily records of weather stations peripheral to the region traversed.

The objective of this chapter, therefore, is to reconstruct the *real* and *experienced* weather and climate of the plains in May and June (and to a lesser extent April and July), 1849, as both an end in itself and as a model for the sort of reconstruction possible for many other years in the 1840s and 1850s from the diaries and letters of overland travelers. Reconstruction of the *real* climate will (of course) make it possible to establish whether the settlers *actually faced* and saw a *real desert* (year) in 1849 and whether they experienced conditions that they might have interpreted as droughty or relatively dry. The reconstructed climate and environment of experiences as relayed by letters and occasionally by (quickly published or excerpted) diaries will tell us much about the information *that must have molded* the environmental imagery of literate Americans.

Overland Journals and Letters

Diaries must be considered the most accurate and informative form of articulation provided by the pioneers. Since most were recorded on a daily basis, events could be identified as to both the exact date and location along the trails. Estimates of the number of diaries still preserved in some form reach as many as 700 covering the period from 1841 to 1866, or approximately one eyewitness account for every 500 travelers across the plains.[6] The greatest proportion of these accounts available today are those for the "year of the greenhorn," 1849. With almost 150 diaries located for this year alone, the diary-traveler ratio is closer to one for every two-hundred people. Each year one or two original manuscripts are discovered in some attic or chest of family memorabilia. Once located, most manuscripts find their way to a county or state historical society. But this resultant wide dispersal militates against a comprehensive analysis of the manuscripts. Fortunately, one-third of them have been edited.

For 1849 there are two standard guides to the readily accessible diaries: David M. Potter's scholarly edition of *Trail to California: The Overland Journal of Vincent Geiger and Wakeman Bryarly* (1945) and Dale L. Morgan's *Overland Diary of James A. Pritchard* (1959). Both make comparisons of the experiences of their diarist(s) with those of other diarists traveling the same route during the summer of 1849. Potter's early and now classic work was derived from the study of only twenty-one published journals and twelve manuscripts of the William Coe Collection at Yale, all pertaining to emigrants who traveled to California, Oregon, or Utah via South

Pass. Morgan was successful in securing some 50-odd diaries in print as well as close to 80 unpublished manuscripts, totaling 134 diary records. Comparison of the two works illustrates the growth of source materials in recent years. The results of Morgan's incredible search are encapsulated in a composite travel chart showing the date of passage and position of these diaries at fifty-one locations. Morgan's work proved to be the fundament and framework for my own methodology. The trail region between the Missouri and the Rocky Mountain front was divided up into subregions centered on fourteen *landmark locations* in the plains recognized by Morgan. The thirty-four diarists were then located for each travel day within these subregions, and every detail remotely relevant to climatological reconstruction was noted. For each subregion it was possible to piece together the succession of daily weather and to reconstruct the climate of the late spring and early summer (late April to early June in the east; mid-may to early July in the west beyond Fort Laramie). It was also possible to see the weather pattern for a given day along a two-hundred- to four-hundred-mile expanse, and sometimes more. Thus we can compare the weather of Courthouse Rock (western Nebraska) with that at the Big Blue River (eastern Nebraska), and at the same time trace the passage, speed of movement, and changing characteristics of frontal systems as they move west to east as well as suggest the extent and general intensity of localized convectional storms. Often there are three or four persons recording the same storm in a given region, and often there is a day without a diary record, but such gaps in the record do not prevent a meaningful reconstruction of general weather patterns.

There were those who never contemplated keeping a diary but who favored instead the generalization and condensation of their experiences into longer narratives composed during infrequent rest breaks, usually in the form of letters home.

The impact of many of these letters was instant and far-reaching, in comparison to that of the diaries. It was the succinct descriptions of landscape, ways of life on the trail, and changing environmental assessments conveyed by these letters that broke on the eastern consciousness, one to two months after the letters were written. Both the limited preexisting popular knowledge and the absence of rival sources of information of the trans-Mississippi West (that might have served as a basis of comparison) ensured that the letters and excerpted diaries would form and/or transform the images held of the West by literate Americans east of the Missouri.

Keeping a journal presented many problems for the diarist and these difficulties limit the comprehensiveness of the record and occasionally produce contradictions. Often those expecting to make daily entries in a journal found it either too difficult to maintain regular notations or became lax as the novelty of the migration was replaced with the toils of reality. Journals often were not kept on a daily basis as the rigors of the journey increased. Usually diary entries were made in the evening following the chores while the events of the day were fresh in the mind, but the onset of darkness and fatigue resulted in morning entries, also. Writing conditions were invariably difficult, and this makes for illegibility and difficulty of transcription in many cases.[7]

Variations in the hour chosen by diarists to record their experiences account for some diversity of their accounts. Weather descriptions by diarists traveling in the same organization normally agree on the general conditions except where a particular storm developed after that day's entry. In this case one diarist writing late in the evening makes special note of the deluge and a second may make no mention of it at all. The next day, however, the entry commonly begins, "Owing to the heavy rain of last night, we did not start so early as usual."

Some problems also arise in establishing the exact location of wagon trains. For instance, halts due to the Sabbath or cholera sickness may go unrecorded; the fording of rivers may have taken a long time because of long queues. Nevertheless, it is possible to approximate the location of the wagon trains from the citations describing ferrying activities, the crossing of small but named streams, and from the sighting of forts such as Fort Kearny and natural landmarks like Chimney Rock. Most diarists augmented this information by registering as their final notation the daily mileage covered.[8] With all these deficiencies noted, the diaries remain an invaluable source for reconstructing the environment and particularly the climate of the plains. As Giffen points out,

> if one were to read all the diaries kept by those who negotiated the hazardous trails to California there would be found a certain similarity. By common accord, and certainly by no predestined plan, *these travelers were primarily concerned with rain, wind, heat, cold, sickness, and all the other physical aspects of their trek across the plains.* Time was another important factor. The hour of breaking camp, the "nooning" and the setting up of a new camp for the night—*these hours were usually meticulously* recorded as well as daily temperatures. [Italics added.][9]

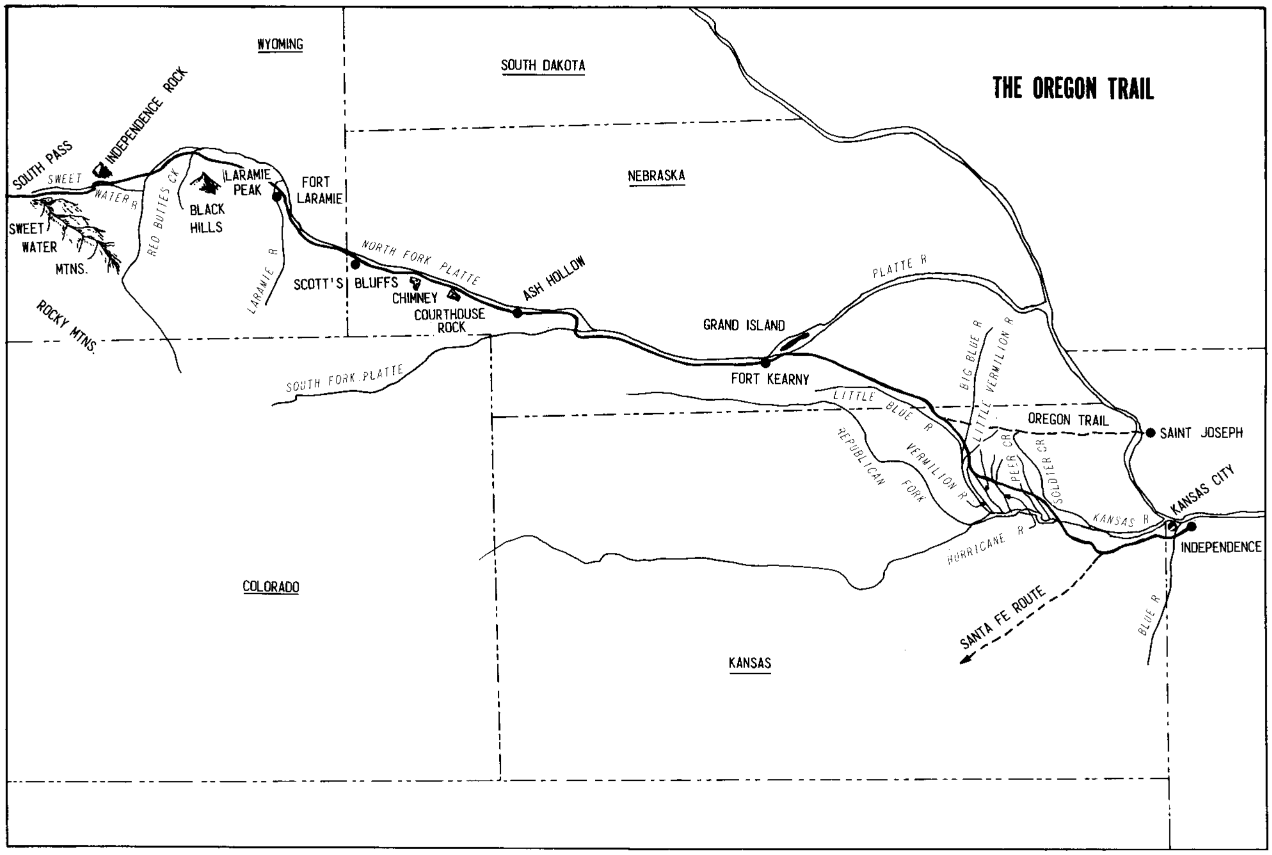

THE OREGON TRAIL
WYOMING
SOUTH DAKOTA
NEBRASKA
COLORADO
KANSAS
SOUTH PASS
INDEPENDENCE ROCK
SWEET WATER R
SWEET WATER MTNS.
RED BUTTES CK
LARAMIE PEAK
BLACK HILLS
FORT LARAMIE
LARAMIE R
ROCKY MTNS.
NORTH FORK PLATTE
SCOTT'S BLUFFS
CHIMNEY
COURTHOUSE ROCK
ASH HOLLOW
SOUTH FORK PLATTE
PLATTE R
GRAND ISLAND
FORT KEARNY
LITTLE BLUE R
REPUBLICAN FORK
VERMILION R
BIG BLUE R
LITTLE VERMILION R
PEER CR
SOLDIER CR
OREGON TRAIL
SAINT JOSEPH
KANSAS R
KANSAS CITY
INDEPENDENCE
HURRICANE R
SANTA FE ROUTE
BLUE R

Figure 19

Climatic Experiences of the Forty-Niners: The Narrative Approach

The organization and preparation for the Great Migration were made final by most wagon train companies each year at various jumping-off places along the Missouri: Westport, Fort Leavenworth, Saint Joseph, Council Bluffs.[10] The primary factor regulating the annual exodus was the condition of the grass on the prairies. By the time the grass was sufficiently green to support the animals, snows would be of small consequence and yet the heat of summer would not dry the intermittent streams of the interior basins.

The spring of 1849 was uncommonly cold and blustery and the grass immature. Those who arrived early at the jumping-off places endured a long, cold, wet sojourn as they unhappily took advantage of the enforced delay by training their team animals on short "shake-down" trips. Experience had shown that April 15 was a good target date for departure. Most emigrants hoped to arrive at the Missouri during the first or second week of that month. By May 15 they would reach Fort Kearny, arrive at Fort Laramie one month later, and enter South Pass by the fourth of July.

William G. Johnston was among those early arrivals at the jumping-off places. Arriving at Independence in mid-March, he was obliged to spend more than forty days sleeping in his wagon awaiting the sufficiency of grass. At first the weather was not unpleasant except for cold nights, which produced "a thick coating of ice . . . on the water bucket."[11] Cold air dominated through mid-April, accompanied by chilling rains almost every day. Then, on the day normally designated as the starting time for crossing the prairies, a snow shower once again delayed departure: "Whilst at dinner, a blinding snowstorm came up, lasting for an hour. The white robe of snow covering the earth has such a wintry aspect, that we feel a fresh blight is thrown over our prospect for rolling out."[12]

Members of the Columbus and California Industrial Association found the weather in Saint Jo to be "cold and dreary" upon their arrival in mid-April. Peter Decker comments on his initial experience sleeping in a wagon: "April 17 weather very cold and high wind got chilled through . . . took off boots and overcoat, laid down and slept for first time on wagon, the night remarkably cold and windy, was cold all night."[13]

Although most of the argonauts had arrived at the jumping-off places at least by the beginning of April, many did not depart from as far away as New England until mid-April. The members of the Boston-Newton Company delayed their departure to enable one of them to complete his medical degree.

In the end this worked to their advantage, since the grass on the prairies was not high enough to provide forage until the second week in May. However, it was unwise to delay departure too long, for if a party did not reach the mountains before snow started it would be in trouble.[14]

Finally, on April 27, W. Johnston succinctly summarizes the long agonizing wait on the weather: "Our march will begin tomorrow. Today ends the sixth week of camp life, attended much of the time with great discomfort, on account of inclement weather, incident to a spring having many of the characteristics of winter."[15]

Once underway, however, the early departees found they had not waited long enough for sufficient growth to sustain the vast numbers of animals associated with the emigration. Major Cross recorded that "the cold weather has considerably impeded its growth, and confirmed me in the opinion that the first of May is too soon to leave Missouri, unless you contemplate a rest after arriving on the borders of the Platte."[16]

Pritchard and his group were persuaded by "old settlers" in the area not to start out till the third of May. "But this advice we found to be extremely detrimental to us—it served only to place us in the reare of a great number of large traines which we were compelled eventually to pass."[17]

The extended delay was very costly to those forced to provide feed for their animals. Those assembling at Council Bluffs (Kanesville) were most hampered by a shortage as the severe winter had necessitated most of their surplus crops' being consumed by the livestock.[18] Winter conditions to the southeast in Missouri were reported by diarists as having been disastrous to horticulture. Nearing Columbia, Pritchard describes the damage to the trees: "Now in the destrict [*sic*] country that suffered so much from the hale and sleet during the last winter—the timber in many places was literally crushed to the earth—the branches were all or nearly so broken off and nothing but the snags and stubs left standing."[19]

The bitterly cold nights persisted throughout most of the time that the pioneers were east of the mountains. Many of the pioneers, including one by the name of Banks, complained bitterly about the cold all the way across the plains. Suffering great facial discomfort, he advised "those coming this route to bring court plaster for lips, nose, and perhaps ears; mine sore."[20] Those remaining in the wagons during the night probably had experiences similar to those of Decker: "Wind blew incessantly last night and today, it rocked my bed (the wagon) like a cradle, and nearly blows one away to-day."[21]

As the days wore on, emigrants, weakened by fatigue, succumbed easily to respiratory illnesses. A typical description of their uncomfortable plight is presented by Hale as he camped near Fort Kearny.

> The cold weather for some days past has given a great number of our emigrants bad colds, attended with coughs. It has had that effect on myself and at night when in the corral, I can hear a dozen persons coughing at a time. Such a scene is not infrequent, with the exception of colds our company is in good health.[22]

The chilling, wind-whipped cold doubtlessly had been expected by the earlier Forty-Niners. But judging from a cursory content analysis of weather notations, they were not prepared for the inordinately heavy or frequent rains that followed them across the plains. For the first half of the trip to California, the pioneer was not plagued with the supposed drought of a Great American Desert, but by cloudbursts of magnificent proportion, swollen rivers, and inundated fords. Accompanied by brilliant electrical displays, "outrageous" downpours driven by winds of "hurricane force" proved devastating to the frail wagon coverings and pitched tents.

The travelers most severely affected by the "copious effusions" were the lead trains of the season. One of the first wagons to leave Independence was that of William Johnston. The first morning out, his train having "reached the frontier line of Missouri, which marks the separation between civilized and uncivilized life," he entered in his journal: "A heavy rainstorm coming up, we were compelled for a time to halt; for it came in such gusts, that neither men nor animals could face it; the former took shelter on the lee side of the wagons, and the mules turned their tails to the severe elements."[23]

It would take Johnston forty-three days to reach South Pass, and rain fell on twenty-four of those. Unknowingly at the commencement of his journey, Johnston and thousands of fellow Forty-Niners were about to wade across the Great American Desert.[24]

Trains departing the vicinity of Saint Joseph at this time were likewise pelted with cold, hard-driving rains. It had not rained at all during the third and fourth weeks of April, but once the trains were underway, torrential nocturnal showers baptized the "greenhorns."

Supplies and equipment as well as travelers were soaked by the torrential rains. Wet flour and sugar were common to most trains even when protected well within the wagons.[25] Searls records shortly after leaving Independence being "awakened at 2 a.m. by a pelting shower of rain. Books, papers, guns, coats, and baggage of every kind were wet or soiled by the tremendous gale."[26] The rain was not unexpected by most of the emigrants, for this was the "usual rainy season." Less than a week out of Saint Louis, Major Osborne Cross of the Mounted Riflemen intimates full knowledge of what to expect from the weather.[27] The "rainy season" having "now commenced," Cross recorded in his journal that the party would

> endure daily rain until into a section of the country where rain seldom falls during the summer, which is generally the case with that section of the country found between the North Platte, the Sweet Water, and Snake River. On the prairie between Forts Leavenworth and Kearny, it commences as early as May, and seldom stops until the latter part of June.

The rains surpassed any that could be remembered by the few who had experienced the climate of the region. "We have had much more rain and cold weather than usual at this season on the Plains, and has been altogether an unusually wet one, with more rain and cold than ever known."[28]

With the rains came the mud as the wagons were slowly and laboriously pulled by teams which had been doubled and tripled to overcome the muck. In places the roads were almost impassable. Day after day entries refer to "heavy roads" because of the previous night's rains. Mud, usually three to six inches deep, resulted in loss of footing for the animals, and tremendous quantities of it stuck to the wheels, binding them tight to the wagon. In the lowland river bottoms wheels commonly went to their hubs in the miry marsh.

Charles Gould and his party, on reaching the lower ferry of the Kansas River, lamented, "We have not gained but five miles in eight days but we trust in making it up in the future."[29] As the wave of emigrants swept westward the roads did indeed become more conducive to travel. In the vicinity of the Big Blue, Gould's trust was proved to be well founded. "Our route continues as usual over the high rolling prairie. The road has been beautiful in many places, being as hard and smooth as a plank floor."[30]

If the storms were now becoming less frequent they were certainly becoming more violent. Encamped ten miles beyond Fort Kearny on May 25, Israel Hale describes a storm which developed, associated, apparently, with an intense cold front, for a light snow had fallen the previous day.

> Last night the thunder roared, the lightning flashed an almost constant flare, the rain fell in torrents and the wind blew so hard that a man could not walk without staggering. This storm commenced before sundown and continued until late in the night. The result was the rain blew into our wagons, the ground was soon over shoe in water and nearly every tent was blown down. Every man of our number wished for a more comfortable lodging place, if they did not wish themselves at home.[31]

There is little doubt that the inclement weather prompted many to turn back. Seven severe storms had beset those of the Kentucky Company the first month on the trail, such that by the time they had reached the Big Blue, people had begun to turn back.[32] Farther along the trail, close to Fort Kearny, two or three emigrants were observed by George Gibbs to have abandoned their journey and settled. "They had pitched their tent for a permanent location, plowed several acres of ground and were about to put in a crop."[33]

Many trains, as they neared Fort Kearny, began to relax the guard at night because of news that the Indians had moved south. As he went to bed one night (May 29) Joseph Hackney noted in his diary, "The weather looks veary stormy i expect we will catch it before morning."[34] Had he only surmised that the violence of the storm would cause the unguarded cattle to seek shelter, he may have prevented the unfortunate episode which followed:

> May 30 Laid by this day last night was one of the stormiest i ever heard tell of the rain fell in torrents and covered the ground a foot deep in water i have seen it rain as hard at home for half an hour but neve seen it pour down by the buckets full f[or] 6 hours incessantly the wind also blew and a perf[ect] gale, driving rain through our tents and wagons covers like as though they had been paper theare was not much chance to sleep without you could fancy wet blankets and a torrent of water running under you when we got up in the mornin our cattel wear scattered to the four ends of the earth we started after them and it was ten o'clock before we found all of them some was ten miles off taking the back track every camp that we saw had lost cattel it commenced raining again at noon and it rained till night.[35]

As the storms became more violent, they frequently included the formation of hailstones. On the average, diarists recorded two such storms during their crossing of the plains (table 7). All of these were located west of Grand Island where the main trail met the Platte River. It appears that near Ash Hollow, the very first emigrants along the trail were unfortunate enough to experience the most devastating hailstorm imaginable. William Johnston, who passed the region of the storm five days after it had wreaked havoc on a wagon train, described what they had encountered.

A number of emigrant trains were passed, among them one called the Platte City Company, commanded by Colonel Ransom; from whom we learned of a hailstorm of considerable violence, encountered on Tuesday last, ten or twelve miles west of Ash Hollow. Their wagon covers and tents had been riddled by hailstones, some of which were of extraordinary size, weighing as much as eight and nine ounces each. The cattle of some emigrant parties were so badly frightened that they ran in various directions for many miles from their owner. When passing the locality where this occurred, we had noticed the ground was torn up, and in places forming large cavities, but were unable to conjecture the cause until learning these facts. We are also able to account for the cold weather which followed the storm we had experienced in the evening referred to had not been accompanied by hail.[36]

TABLE 7

WEATHER SITUATIONS ENCOUNTERED ALONG OREGON TRAIL FOR SELECTED DIARISTS

	Wm. Johnston April 28–June 10	Bennett Clark May 3–June 24	James Pritchard May 3–June 18	Alonzo Delano May 3–June 29	Joseph Hackney May 2–July 2	Niles Searls May 15–July 19	Howard Stansbury May 31–Aug. 6
Days on Trail[a]	43	53	47	57	61	65	68
Days of Rain	24	12	14	12	15	13	8[b]
Severe Storms	8	4	5	8	6	8	5
Hailstorms	3	0	2	0	1	2	0
High Wind	7	4	6	10	4	7	5
Chilling Cold	16	5	6	6	4	7	2
Oppressive Heat	3	0	0	3	1	8	2
Days with Dust	2	0	0	0	2	6	1

[a] From jumping-off place to South Pass.

[b] Stansbury kept meteorological observations separate from his journal, which contains double the number of rainy days.

Another hailstorm along the South Platte proved as vicious. In a letter later published in the *Detroit Daily Advertiser* James Lyon wrote: "All the wagon-covers looked as if they had received a shower of brickbats: and the men one would have thought had received a shower of Indian arrows, to have seen the blood streaming from their heads . . . but none of them had any fracture of the skull."[37]

Mention is made by a few diarists of whirlwinds, but the nature of these is open to conjecture. There can be no doubt, however, that Joseph Berrien, traveling with Colonel Jarrott, unmistakably witnessed a tornado from the summit of a hill near present-day Brule, Nebraska on May 19.

A tornado was whirling across the prairie and though there was but little on which to exert its fury still the commotion of the clouds and the immense masses of vapour whirling around with inconceivable rapidity . . . while the roaring of the wind could be distinctly heard at 2 miles distance, furnishing a sight seldom witnessed. . . . After the tornado had passed clouds of grasshoppers fell from the sky. . . . The cloud presented the appearance of a long funnel the small end downwards as black as ink . . . fortunate for us was it that it did not pass near or over our wagons which had it so occur'd would have been scattered to the four winds of Heaven.[38]

Experiences along the Southern Trails

Those departing from Fort Smith had an earlier start, some even leaving the fort in late March. The wet weather had so saturated the "soft alluvial soil" as to render it almost impassable to wagons for 150 miles. Diary entries such as "cooked our supper in a great hurry in the rain"[39] are common along the Fort Smith trail. Others simply remained in camp, citing in their journal, "The road's a complete bog."[40] Farther south, C. C. Cox, making his way across Texas to El Dorado, noted in his diary, "Our journey . . . was exceedingly toilsome and disagreeable, the recent rains had rendered the road very wet and muddy, and but for the aid of some ox teams that pulled our wagon through the worst places—we possibly would have been there jacking up the wheels till yet."[41]

The streams encountered along the southern routes reflected the extreme wetness of the season. Emigrants found the Pecos River to be "full of bank," and the Rio Grande "overflowed to the edge of the mountains."[42] Along the Santa Fe Trail, delays were frequent because creeks were "too turbulent and deep to be forded."[43] There were instances, similar to that recorded by Charles Pancoast along the Arkansas River near the present Colorado-Kansas state border, when a party would camp for the night in a seemingly dry location only to be indignantly awakened.

That night, after we were all quietly asleep, there came up a thunder storm. About midnight we were suddenly aroused by the water pouring into our tents. We were in a terrible dilemma: our blankets were afloat, and our cattle in the corral up to their knees in water. If the water increased in depth, we feared that it would soon sweep us and our property into the River. The darkness was intense, relieved only by flashes of lightning; the rain came down in torrents; and we paddled about in the dark, seeking to consult each other in regard to the best course to be pursued. Our Captain and Lieutenant seemed to be paralysed, and hesitated about giving orders. The water rose to two feet in our tents, after which the rain began to moderate; and we spent the balance of the night wading around until a late day-break enabled us to relieve ourselves of the terrors of the night by driving up on higher land.[44]

Parker wrote in 1964 that the Forty-Niners "waded to California."[45] The preceding account suggests that they did, certainly during May and perhaps early June in the eastern plains. But this was hardly their condition later in June and July, as can be demonstrated using a geographic approach to analyzing weather notations of diarists along the plains.

Climatic Experiences of the Forty-Niners: The Geographic Approach

To read the individual traveler's letters or accounts in the Missouri country and eastern plains is to agree with Parker's impressionistic conclusion that the argonauts "waded to California." But when the travelers' accounts and their climatic references are set in a spatial context, it becomes clear that their wading was largely restricted to portions of the prairie-plains and that they were fortunate if they had "heavy dews" the remaining months of travel. Parker reveals no knowledge of climatic systems and shows no awareness of the probable pattern and extent of the storm-producing systems about which he quotes and paraphrases apparently at random. What follows is an attempt to reconstruct the daily weather and climatic systems that affected the plains between mid-April and mid-July. Only in this way can we establish with any exactitude whether the monthly and seasonal rainfall was above average, or below it, and whether travelers *waded across the Plains or burnt their soles on the sands of the desert.*

The daily weather situations duly noted by diarists on the trail can serve collectively to facilitate and provide a unique opportunity for identifying the meteorological systems that were affecting their travel. As the earlier departees headed west, with the main wave following two to three weeks later, a meteorological network of sorts began to spread out, ultimately extending the entire width

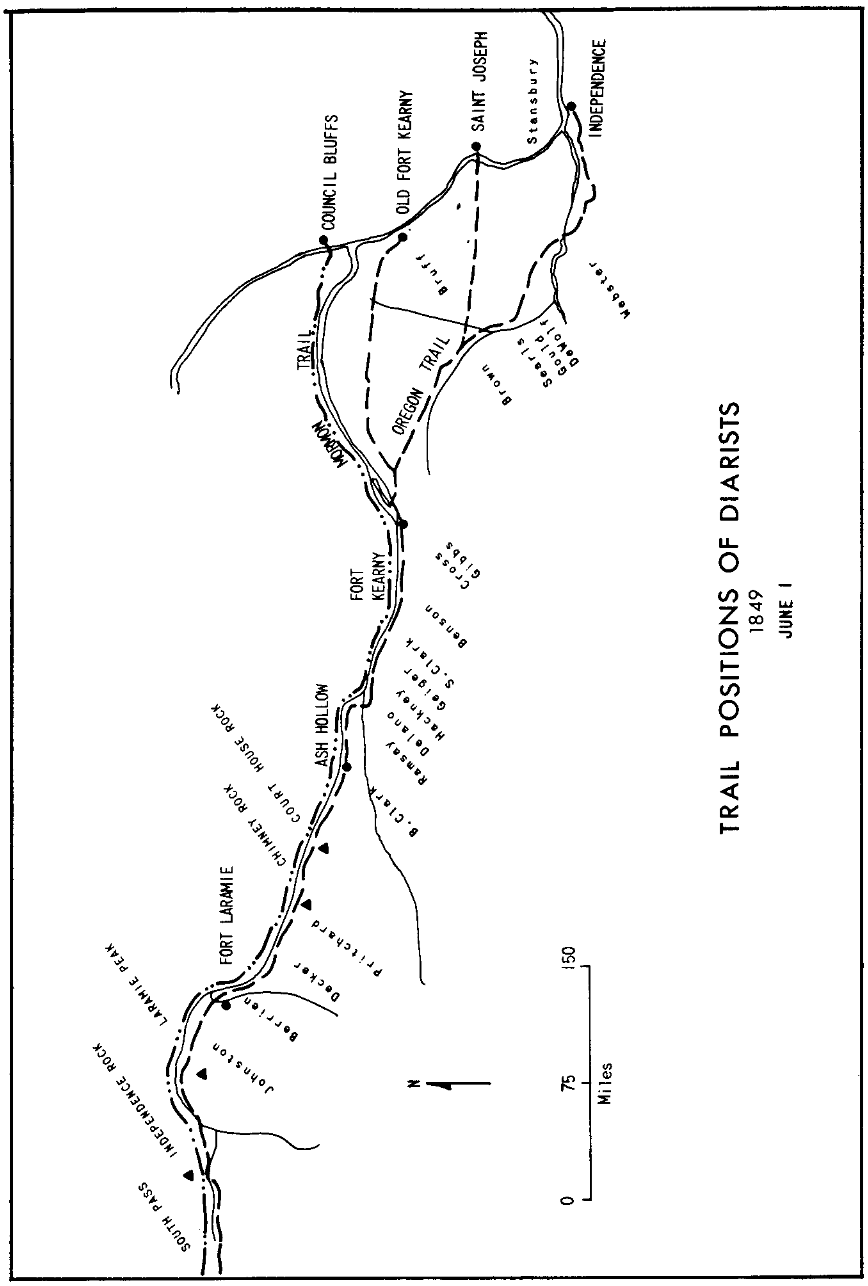
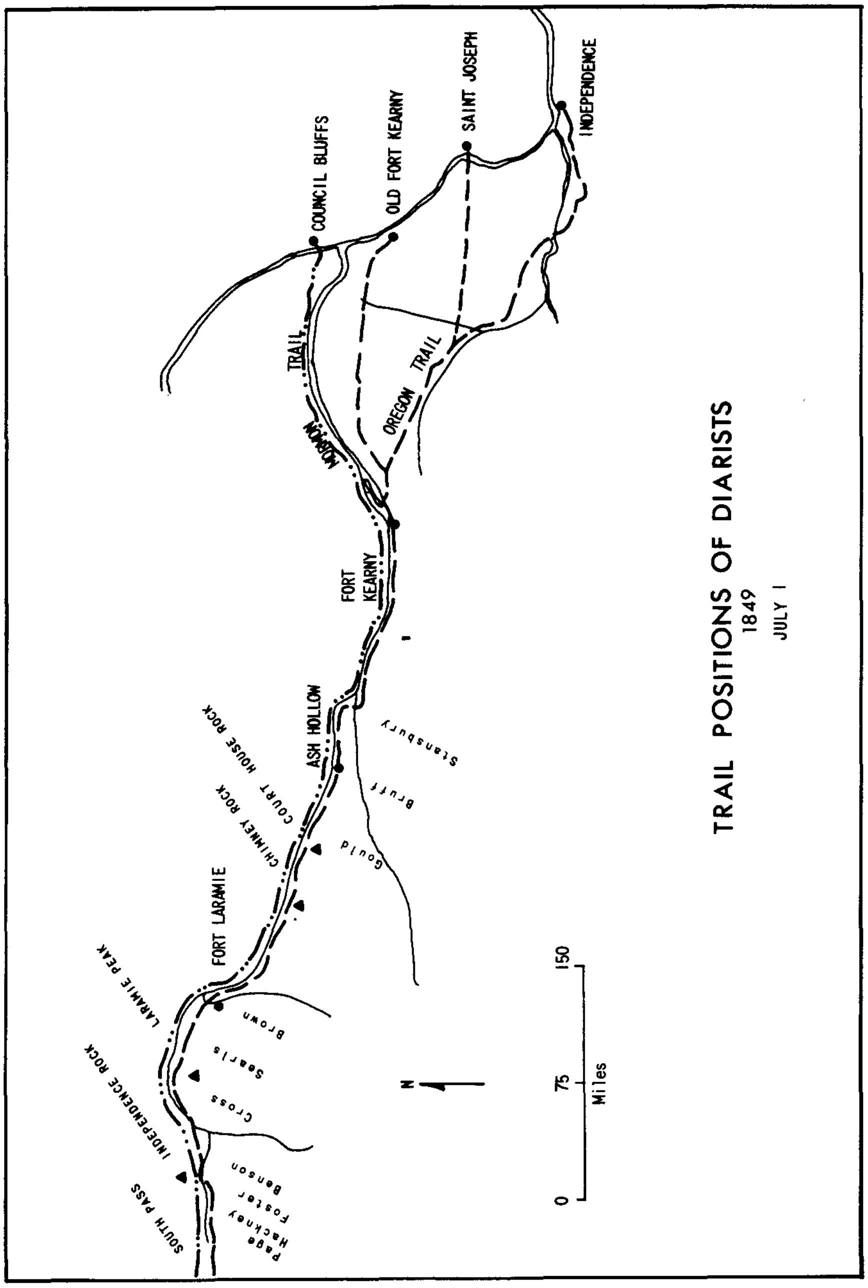

TRAIL POSITIONS OF DIARISTS
1849
JUNE 1
COUNCIL BLUFFS
OLD FORT KEARNY
SAINT JOSEPH
Stansbury
INDEPENDENCE
MORMON TRAIL
OREGON TRAIL
Bruff
Webster
Brown
Searls
Gould
Dewolf
FORT KEARNY
Cross
Gibbs
Benson
S. Clark
Geiger
Hackney
Delano
Ramsay
B. Clark
ASH HOLLOW
COURT HOUSE ROCK
CHIMNEY ROCK
Pritchard
Decker
FORT LARAMIE
LARAMIE PEAK
Berrien
Johnston
INDEPENDENCE ROCK
SOUTH PASS
N
0
75
150
Miles

Figure 20


TRAIL POSITIONS OF DIARISTS
1849
JULY 1
COUNCIL BLUFFS
OLD FORT KEARNY
SAINT JOSEPH
INDEPENDENCE
MORMON TRAIL
OREGON TRAIL
FORT KEARNY
ASH HOLLOW
COURT HOUSE ROCK
CHIMNEY ROCK
FORT LARAMIE
LARAMIE PEAK
INDEPENDENCE ROCK
SOUTH PASS
Stansbury
Bruff
Gould
Brown
Searls
Cross
Benson
Foster
Hackney
Page
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0
75
150
Miles

Figure 21

of the plains. The nature of the comments—generally referring to wind velocity with occasional direction, relative daily temperature comparisons, and sky conditions such as degree of cloudiness, rain, or even dustiness—provide the historical climatologist with an acceptable data source which is quite adequate for deducing generalized synoptic patterns prevailing during the peak of migration. Information of this type is particularly appropriate if one is to evaluate the areal extent of the weather situations cited by the travelers. Also, this technique can be applied by researchers for as early as 1841, and certainly by 1845, considerably before the establishment of meteorological observations at military posts in this region.

Tabulations of daily weather conditions were constructed by this author from thirty-four diaries of Forty-Niners as they crossed the Western Interior to the South Pass.[46] The spacing of these records was reasonably well distributed within the overall wave of emigrant passage, facilitating analysis of weather types throughout the critical months of May, June, and into July.[47]

In general these tabulations indicate that the month of May was associated with an inordinately large number of cold wave incursions from the northwest, whose intensification was particularly noticeable as they progressed from west to east, bringing cold, chilling rains lasting anywhere from one to three days. The rate of frontal movement seems in most cases to have decelerated toward the east, becoming almost stationary on one occasion. Particularly impressive is the fact that surface wind speeds were extremely high, especially considering the previous lack of exposure to such "hurricanes" by most of the pioneers who were bearing their brunt.

Accompanying these cold winds were relatively short, violent thunderstorms frequently associated with hail development closer to the western margin of the plains. As the frontal system progressed eastward, the chilling rains became more prolonged, occasionally initiating squall lines. As these closely spaced, fast-moving perturbations swept across the plains, the polar front gradually weakened, shifting the track northward as it extended to the east. Thus, fewer frontal storms influenced the region as far south as Independence.

The first of these May storms swept rapidly eastward behind a well-developed fair weather system that had dominated the region since mid-April. Following the snowfall which dampened the hopes of the first arrivals for getting an early start, cold, dreary winds gave way to warm, pleasant breezes by the twenty-second of that month. Gradually the warm sector moved to the east, as winds intensified. By the last day of April, with strong drying winds having prevailed for more than a week, the winter-killed grasses caught fire, the blaze being fanned across the prairies in the vicinity of Saint Joseph. At this time, those traveling to the northwest of Independence recorded what appear to be isolated convectively induced thunderstorms which may or may not have set the prairies on fire. What is certain is that Independence received heavy rain on April 30, but that Saint Joseph (fifty miles away) had a pleasant day. By May 2 a weak but rapidly moving cold front had displaced the warm winds (which presumably had been out of the southwest).[48] A second, more contrasting cold front followed only two days later, bringing torrential, cold rains throughout the night of May 3 and leaving "horses shivering in the cold wind" the following morning. Within two days yet another incursion of polar air triggered widespread rains of considerable amounts. The roads had now become a general quagmire, making travel cumbersome and slow. By the second week of May, the air over the interior was moderating in temperature. Warm, cloudless days but with rapidly dropping temperatures at night caused by radiational cooling became commonplace. Occasionally this cooling led to showers, which the comprehensive records of that date indicate to have been isolated, yet concentrated in the center of present-day Kansas and Nebraska. One particular example of the type of relevant information given so frequently by journalists is an entry describing the sunset on the evening of one of the nocturnal showers.

> May 9th Sun set on the prairie is more beautiful than other places and this evening was the most sublime sunset I ever beheld, a large cloud seemed to partially hide it and in places openings blazed like streamers of liquid gold. The cloud was bordered around its whole mountain like edge with a spangled light as if silvered. Over all ran a highly arched flood of rays.[49]

The rain that fell that night was recorded only by Peter Decker and William Johnston, who were in the vicinity of the Independence and Saint Joseph trail junctions.

Generally widespread rains had not fallen for more than a week. The roads were now dry and hard. But the new grass lacked water to sustain a growth sufficient for the "scourge" of thousands of grazing animals. By the twelfth, "great clouds of blinding, stifling dust filled the air, covering with a thick coat wagons, mules and men."[50] The vanguards of the migration, who had gambled on enough pasturage, were now benefiting from excellent dry road conditions but seriously concerned about the availability of grass to the west.

Then, the much needed water came in the form of a well-developed, rapidly moving cold front. The nocturnal "heavens hung with black clouds," illuminated by "serpentine streaks" of lightning lasting several hours during the night. To the east, these conditions began later and extended into the following day. Winds were once again "cold," "chilly," and "piercing."

The diarists were well spread out along the trail by this time, with those in the lead pushing two or three days beyond Fort Kearny. The region was now about to come under the influence of a frontal system which appears to have extended along a west-east axis, stagnating for four to five days, presumably as a stationary front. In the third week in May, cold, rainy weather prevailed along most of the Oregon Trail east of the fork of the Platte. Winds blew incessantly; interspersed with "gloomy," "drizzling" rains which became hard-driving storm cells at times. The prolonged impact of this system brought extreme hardship to the travelers, fatiguing the animals with heavy road conditions, and weakening further the health of the weary travelers. Unable to secure warmth and shelter, many cholera victims died during this period of inclement weather.

As the stationary system gradually dissipated, hot, sultry air moved into the vicinity of Ash Hollow and Courthouse Rock. That night (May 19) another cold front moved in a wavelike manner from the northwest into the plains region. The accompanying rain was torrential; hail fell at Ash Hollow; a "deluge" occurred at the South Platte ford; and a tornado was sighted near present-day Brule, Nebraska. By early the next morning the fast-moving squall line of showers had passed Kansas Ferry. Two days later a second line of showers swept east, penetrating well to the south. Winds changed to the northeast, bringing cool air and severe showers. Just east of Fort Kearny, S.B.F. Clark experienced violent thunder and lightning with a storm that left six inches of water in his tent. Temperatures behind the front were frigid, dipping as low as 36° according to Hale's record in the vicinity of Fort Kearny.[51] Yet before the month was out, the entire pattern was once again repeated, bringing the total number of frontal passages to eight since the first argonauts had embarked on their trek to California.

Comparison of records at Fort Kearny verifies the suspected sequence of weather situations. The inordinately large rainfall recorded at the fort resulted from a great number of cyclonic depressions pulsating across the plains, manifested by extreme temperature contrasts, constant winds, and incredible precipitation as both rain and hail.

By the beginning of June, the last of the stragglers had just passed Kansas Ferry. With every passing mile the opportunity for meteorological reconstruction was increasingly truncated along the eastern margin of this migration. The evidence clearly indicates that June was not abnormally wet. Following the intense frontal passage at the end of May, recognition of any but the convective type of storms proves elusive. The polar front appears to have finally retreated northward. Winds became highly variant, with the formation of daily convective buildup. There now becomes a distinct randomness in the spatial distribution of storms. Diarists begin to notice lightning on the horizon, often with the storm passing around their location. The frequency of storms cannot be generalized as increasing to the east except that the locations from Fort Laramie to South Pass experienced no rain from mid-June to mid-July. Diarists in the Courthouse Rock vicinity mention no rain after June 20.

Examples of isolated rainstorms can be found at Ash Hollow on June 5, Independence Rock on the sixth, Fort Laramie on the twelfth, and South Platte Ford on June 14 and 27. In each case no rain is recorded in contiguous locales. To one traveler, compelled to stop on account of a storm near Courthouse Rock, the violent storms of the locale were less than random: "Mr. Bryant observed today that he had camped within 5 miles of this rock some 4 times and that a violent storm blue [*sic*] up on each occasion. There is most probably some local cause for this fact."[52] The record does not support his theory, however.

The days had now become "hot and sultry." The warmest temperature recorded while crossing the plains was by Dewolf, who, one day's travel east of Fort Laramie, cited a stifling 110° combined with choking dust. In the same location, Cross encountered his "warmest day yet" much later in the month.

The only period of relief from the warm June days appears to have been fostered by the only cold frontal passage of the month. A severe storm track can be plotted commencing in the evening of June 19. Acompanied by hail, a "fearful tempest" can be traced from Courthouse Rock and Ash Hollow to the South Platte ford and Fort Kearny. The following day cool temperatures were reported at these locations, but by June 21, "oppressive heat" had returned. Captain Stansbury, to the east of Fort Kearny, noted both a windshift and drop in temperature following the rain.[53]

Throughout June and the short record for July, only rains accompanied by thunder and lightning are described by the pioneers. It is perhaps of synoptic interest that the diurnal occurrence of these convective cells appears to vary. At western localities, scattered showers were almost always in the afternoon, often curtailing the day's travel. Farther to the east, at Fort Laramie and Courthouse Rock, all storms were nocturnal, whereas in the area of the Little Blue River the shortened tabulation for June indicates a higher number of morning showers.

One cannot assess the overall frequency of rain during June as anything more than average. The fort record at Kearny tends to reenforce this conclusion. The weather situations east of the available diary notations appear to have been monsoonal, as concluded in the previous chapter. It might be surmised that the meridional position of the jet stream in May, 1849, was more over the central plains, then shifted eastward over the prairies by June, allowing more stable continental tropical air to dominate the Western Interior.

The record for July is primarily restricted to the region west of Fort Laramie. Gould passed the fort on July 6, with Stansbury following one week later. Now only the occasional shower broke the monotony of the heat and dust. Wind continued almost daily but was rarely the harbinger of the much needed rain. Instead it brought unbearable dust storms. Stansbury relates these conditions as they pulled through deep, heavy white sand beyond La Bonta Creek:

> morning bright and pleasant—but at 9 a.m. the wind rose from the southwest, and blew almost a hurricane the whole day, tearing up the sand and gravel, and dashing it into our faces, as we rode, with such violence as to cause sensible pain. It was impossible to look up for a moment, as the eyes became immediately filled with sand, so that the teamsters were obliged to fasten their handkerchiefs over their faces to enable them to see where they were going.[54]

In the vicinity of the North Platte Ferry, rain clouds were now replaced by clouds of dust and sand. No rain fell at this location throughout the entire period of record (June 3–July 17), making the region destitute of grass. At Independence Rock, July was similarly without moisture until the afternoon of the twenty-second, when an afternoon thundershower "settled the dust."

One must conclude from this climatic systems analysis of weather conditions along the Oregon Trail east of the Rockies that the region cannot be pictured as having experienced ubiquitous heavy rains throughout the entire season of emigration. There is excellent evidence from the spatial tabulation of diaries that above average precipitation resulted in May from a series of strongly developed cold fronts sweeping west to east across the eastern portion of the trail. With a weakening and northward displacement of the polar front by June, the frequency of storms decreased as their distribution similarly diminished. Primarily convective in origin, these storm cells generated as much intensity as the previous storms, but their extent was now restricted both temporally and areally. As the argonaut continued west, the roads that had been "heavy" because of rain now became clogged with sand. The grass that had been so luxuriant was now burning under the heat of the sun or trampled by the hooves of thousands of pasturing stock animals. So, having established the *real* meteorological experiences of the Forty-Niners, one is now in a better position to assess the impact of that *reality* on the attitudes of those experiencing it, and consequently the possible reevaluation of the eastern imagery of the plains.

5. A Search for a Climatic Model of the Plains before 1850

Historical geography, as usually and fairly narrowly defined as a specialist field, has tended to drift slowly from the mainstream of geography into the backwaters, admittedly comfortable ones. There, it is too much content to rest on its oars and laurels while the rest of the geographical fleet rows by at a very high rating.[1]

Of late, statements of this nature, critical of the lack of methodological and theoretical innovations within the field of historical geography, have been common. Hopefully they will stimulate enough concern among historical geographers to foster a revolution within the discipline. The scholastic cry is not for imitation, but rather, for the selective adoption and adaptation of current methodological techniques presently being employed by geographers with less interest in the temporal dimension of geographical explanation. Using a book review as a vehicle for expressing similar concern, William Koelsch writes:

If historical geography is to retain an authentic place within geography, historical geographers need to equip themselves with those conceptual frameworks, models, and techniques which have distinguished geography in the 1960s. Historical geography is not a refuge for geographers unwilling to cope with theoretical and methodological developments in the field of geography; nor is it the latter-day substitute for the holistic regional geography of the thirties; nor is it history on the cheap for those geographers who, having remained aloof from the newer modes of geographic thought, believe they can do more under those conditions than merely add a few special-purpose footnotes to the writing of history.[2]

The ultimate product of historical-geographic scholarship hopefully will be scientific generalization expressed with reference to a prevailing paradigm or model against which the accumulation of newly acquired facts can then be judged or evaluated. Eventually this should and will result in the modification of the conceptual framework or in its general acceptance. This chapter will review various formulations of temporal and spatial climatic models with the ultimate intent of deriving a plausible deductive paradigm for interpreting the climatic history of the trans-Mississippi West. This will be accomplished by first accounting for the conceptual integrity that climatic models must exhibit to represent known facts of climatic change. Then, models will be examined which appear to indicate some promise of representing the spatial and temporal vicissitudes of climate in the interior West. In so doing, this study hopes to obviate the above criticisms succinctly summarized by William Koelsch that "unless new research strategies can be developed which are authentic in terms of the newer paradigms of both disciplines,[3] historical geography will be trapped in a kind of limbo, neither sheep nor goat, merely mule, possessing neither pride of ancestry nor hope of posterity."[4]

Models for a Changing Climate

Most climatic models constructed to describe the worldwide climatic episodes have a temporal magnitude in excess of that applicable for meaningful interpretations of the historical settlement of America. Models accounting for fluctuations of the magnitude associated with glaciation, for example, Milankovitch's radiation curves,[5] do not facilitate postglacial interpretation. Firbas has demonstrated the postglacial discrepancies by comparing the treeline shifts with hypothesized radiation curves. In order to obtain agreement with the Climatic Optimum,[6] the effects of the radiation curve must be delayed by as much as four to five thousand years.[7] The potential for establishing a chronological pattern using this astronomical basis is thus defeated for more recent historical constructs.[8]

Similarly models[9] of the postglacial climatic sequence postulated for North America contribute mostly to an understanding of climatic or ecological mechanisms involved. They do not permit the historical geographer to assess the impact of climatic fluctuations in a shorter time span. Deductions derived from these physical principles and modern analogues can aid in the characterization of the spatial patterning of past climates. Such principles are critical to any further associations one might deduce.

Misconceptions of Climatic Models

Perhaps as a result of man's predilection for symmetry, perhaps because of the European acceptance of Milankovitch's smooth radiation curves, models of climatic change are often postulated as sinuous curves of temperature or precipitation which suggest that changes in climate were slow in transition. Antevs presented a model of postglacial climatic sequence portraying the slow increase in temperature reaching an "altithermal" peak with marked aridity, subsequently reversing toward the cooler, wetter conditions associated with glacial advance.[10] Recently this model has been challenged as being oversimplified.[11] All too often researchers applying these climatic models assume that anomalies of temperature and precipitation are of the same magnitude and sign from region to region.[12] In so doing, they are neglecting the fact that the atmosphere displays nonlinear responses even to cyclical oscillations such as annular solar radiation. As stated by Bryson et al., "Even during the smoothly varying change of solar radiation intensity from winter through summer and into fall, the climatic response to this regular variation of the 'forcing function' is irregular in space and time and quite non-linear."[13] Thus the use of the term *xerothermic* to describe warm postglacial conditions in America is inappropriate for regions not necessarily experiencing the implied increase in aridity at the same time. It is quite plausible that with the winter precipitation maximum of the extreme southwest United States, postglacial warmth would intensify summer aridity. Conversely, in regions with summer rainfall concentration of the monsoonal type, an increase in temperature should theoretically result in more moist conditions. This would lead one to anticipate the occurrence of a "rather moist Hypsithermal in the summer-rain area of southeastern Arizona and a dry Hypsithermal in the summer-drought area of the Mohave Desert."[14]

The fact of the rapidity of climatic change has only recently been established utilizing temporal statistical analyses of radiocarbon dates available for North America.[15] Bryson, Baerreis, and Wendland concluded that the atmospheric transition from one quasi-stable climatic state to another is nonlinear or "step-like" in occurrence, deviating from the widely accepted sinuous assumption of Antevs's model. Those periods indicating ecologic succession are consistent with the European climatic episodes related to the Blytt-Sernander divisions,[16] which would seem to verify the global magnitude of climatic change.

In summary, it is now generally accepted by paleoclimatologists that (1) considering the dynamics of the global circulation of the atmosphere, changes in climate (temperature or rainfall) would most likely display substantial longitudinal variation in climatic anomalies, and thus, latitudinal bands of deviation would not be likely to occur; (2) similarly, a fluctuation in temperature could result in profoundly different moisture characteristics for regions with different climatic controls; (3) the postglacial *temporal* succession of climatic change as related by ecological evidence demonstrates a hemispheric consistency; (4) the rate of transition of one atmospheric state to the next is very rapid and is measurable in terms of years or at the most decades.

Applying these conclusions to the plausibility of a climatic change in the cis–Rocky Mountain West, appropriate models should be investigated which might (1) adequately explain those facts presently known about the climate between 1800 and 1850, and/or (2) serve as a deductive model until replaced by future research.

The Little Ice Age and the Climate of the Plains, 1836–50

At least the following different "recent"[17] climatic phases have been identified on a global scale by paleoclimatologists, geologists, biologists, and archeologists: (1) the Climatic Optimum, warmest of the postglacial period, culminating between about 5000 and 3000 B.C., then reaching its minimum temperatures about 2000–1500 B.C.;[18] (2) the subboreal reversal of temperatures by the early Iron Age, distinguished by a colder and stormier climate culminating between 900 and 450 B.C.; (3) the Little Optimum in the early Middle Ages (known in America as the Neo-Atlantic), culminating between 900 and 1200 A.D., when drier conditions may have existed along the forest-prairie ecotone with a more moist situation in the Great Plains and Southwest;[19] (4) the Little Ice Age, marked by deterioration in temperatures, particularly in the Northern Hemisphere, between 1500 and 1850 (Neoboreal of North America).[20] The first three climatic phases listed above do not pertain directly to the present study except to demonstrate that postglacial climates have left their varying mark in most parts of the world. Since approximately 1500 A.D., however, the period that saw the exploration of the Southwest by Coronado, Spanish and French possession of Louisiana, and the initial exploration by the United States, most parts of the Northern Hemisphere have experienced a sharp decrease in temperatures. This was a period (called the Little Ice Age) of marked forest displacement in the upland regions of central Europe, of distinct expansion of the Arctic pack ice, and of alpine glacial advances in Asia, Africa, Europe, and North America.[21]

Estimates set annual mean temperatures at 1° C. below current century values on a world scale.[22] Post–Little Ice Age temperatures have increased most dramatically in the middle and higher latitudes, suggesting greater depression in temperature in these regions during this colder epoch.[23]

In what ways, then, might the climate of the pre-1850 Western Interior of the United States be expected to have differed from the climate since the Little Ice Age, that is, from 1851 onward? The answer to this question should make it possible to establish whether the plains region was wetter or drier annually and seasonally in the first half of the nineteenth century than it has been subsequently.

Deductive Model of General Circulation

Paleoclimatologists have approached this and similar questions by using circulation patterns derived from present-day modal air-mass frequencies and establishing analog models that most closely approximate the probable circulation of the atmosphere during the Little Ice Age. Evidence indicates that both summer and winter temperatures were depressed when compared to recent norms in maritime Europe, while temperatures farther to the east appear to have become more continental only in winter. Willett's theory of an expanded circumpolar vortex during the Little Ice Age episode posits an equatorward shift in prevailing depression tracks, which would go around more intensified polar anticyclones.[24] The strength of the general circulation was weaker then than now (1900–1939) and this meant that there was an increase in the prevailing number of Rossby waves to five or six, compared with four in secular times. In the United States, the Lamb-Bryson model[25] of the Little Ice Age postulates that a deflected jet stream was associated with a summertime reduction of warm tropical air penetrating northward.[26] The resultant *cool summers* and *cold autumns* were reflected in an expansion of glaciers in the Rockies and by an *increase in frontal-derived precipitation* in the *Great Plains and Southwest.*

Bryson estimates that summer precipitation alone in northern New Mexico (crossed by the Santa Fe Trail) increased two to three inches compared with modern records. The cooler summers would increase the effectiveness of this rainfall because of lowered evaporation potential. Similar conditions would be expected for the central Great Plains, and the vegetational response to the prolonged predominance of these synoptic conditions would be a westward shift in the prairie grassland ecotone at the expense of steppe and a southward expansion of the boreal forest margin at the expense of the prairie grassland ecotone.

With the close of the Little Ice Age,[27] the model posits a reversion to a strengthening of zonal circulation in the northern hemisphere, concomitant with a northward displacement of polar fronts. There would also be a weaker development of continental blocking anticyclones and deflection of storm depressions also to the north. The climatic effect would be periods of pronounced aridity in central Eurasia and North America. At this time, secular annual temperatures would be expected to rise rapidly in the Western Interior of the United States, dramatically increasing the evaporation potential of the region.[28]

In sum, the Lamb-Bryson Little Ice Age model as applied here to the plains region leads us to expect lower annual temperatures, resulting particularly from cooler summers and cold autumns attendant upon a southward displacement of the jet stream aloft. A weaker upper-air circulation reflected in a greater average number of long-standing waves, and the jet stream location, would increase frontal activity, particularly in the early summer, and yield greater precipitation in the summer half year, the effectiveness of which would be great because of lower summer temperatures. With the jet deflected southward, the weaker circulations aloft would also tend to produce more variable surface wind patterns, demonstrated by balanced "wind roses" with few extremes, while the southward deflection of the jet, militating against the strong northward flow of maritime tropical air, would tend to be reflected in a decline in the proportion of winds blowing directly from the south.

The Historic Record

The conclusions drawn from this deductive model cannot be tested directly against wind and precipitation records for stations in the core of the plains region, for there were no such stations. The record of meteorological observations for Saint Louis Arsenal does extend, however, far enough back in time that the closing phase of the Little Ice Age should have been represented. Daily wind direction frequencies have been laboriously tabulated from the historical record at Saint Louis Arsenal for the fourteen-year period 1836–49 (fig. 22). These frequencies were then compared

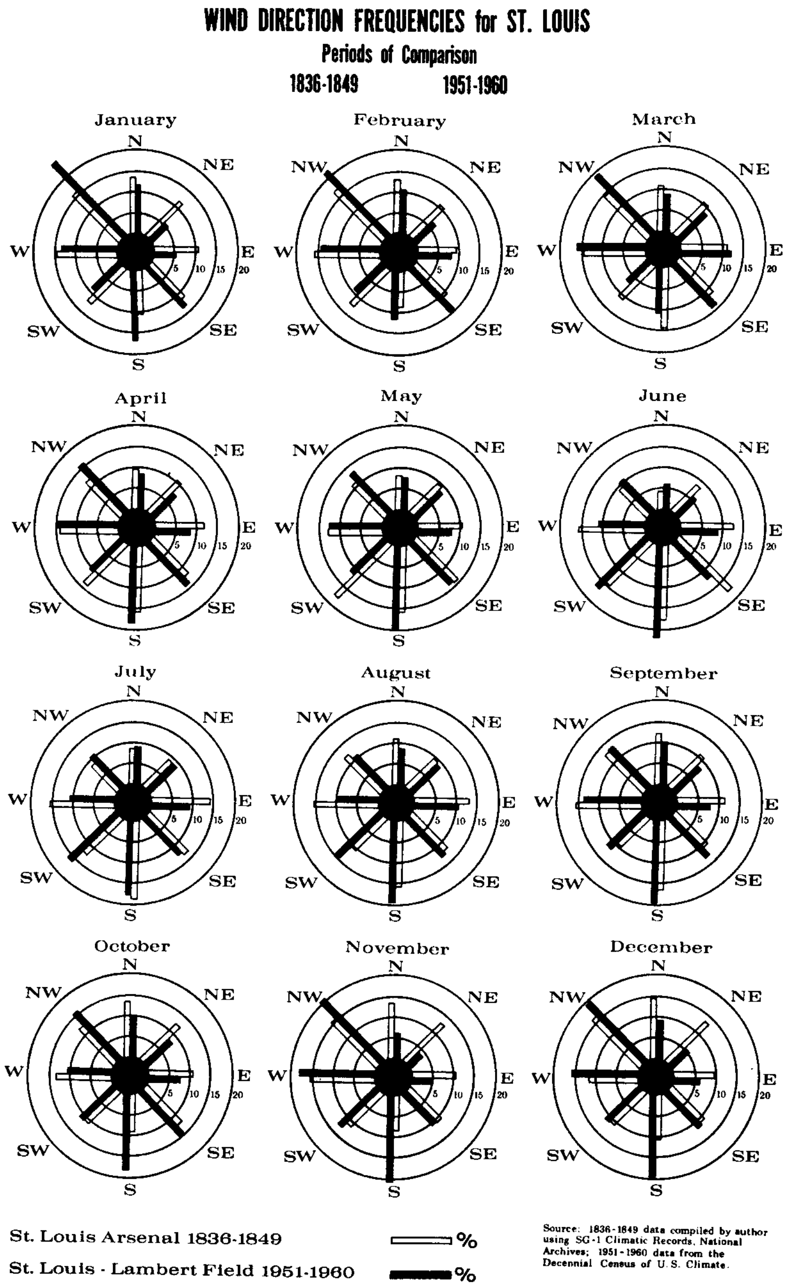

WIND DIRECTION FREQUENCIES for ST. LOUIS
Periods of Comparison
1836-1849
1951-1960
January
February
March
April
May
June
July
August
September
October
November
December
N
NE
E
SE
S
SW
W
NW
5
10
15
20
St. Louis Arsenal 1836-1849
%
St. Louis - Lambert Field 1951-1960
%
Source: 1836-1849 data compiled by author using SG-1 Climatic Records, National Archives; 1951-1960 data from the Decennial Census of U.S. Climate.

Figure 22

with the modern Saint Louis record from 1951 to 1960.[29] Generalizations which can be directly read from the resulting circle graphs appear to support the theorized circulation patterns suggested above. The historical wind rose patterns exhibit more symmetry or balance than the modern record indicates. Winter months for the historical record experienced greater frequency of winds from the east, indicating backing wind systems associated with cyclonic movement farther south than the modern record indicates. The frequency of northeasterlies and easterlies continues to dominate throughout the year with the exception of March. Notably reduced in influence were winds from the northwest. The hypothesized truncation of a southerly air influx during the Little Ice Age, especially during cool summers and cold autumns, is particularly

TABLE 8

SAINT LOUIS ARSENAL PRECIPITATION, 1836–49

Year	Annual Total	April	May	June	July	Aug.	Sept.
1836	—	—	—	—	3.66	6.51	5.90
1837	25.85	1.40	3.00	2.77	4.07	3.10	2.88
1838	24.17	2.00	1.58	3.68	2.00	3.80	1.00
1839	—	3.14	7.40	7.21	5.19	1.50	2.40
1840	—	—	—	—	—	—	—
1841	39.64	3.57	1.20	3.93	3.63	1.95	2.50
1842	31.71	4.05	4.09	4.89	2.21	2.92	1.42
1843	31.06	4.64	4.95	3.53	4.13	.76	2.02
1844	51.11	5.57	11.03	7.54	8.10	1.47	0.03
1845	39.49	3.67	3.05	13.75	.03	7.45	.59
1846	56.17	7.59	5.97	4.94	1.21	.68	6.28
1847	65.09	8.25	5.95	11.47	5.30	.74	2.87
1848	62.86	2.93	9.94	18.96	5.56	3.31	1.18
1849	71.54	4.08	16.39	15.70	13.67	7.95	3.96
Average 1836–49 (gaps)	45.33	4.24	4.54	8.2	4.52	3.22	2.53
1950–61[a]	32.06	3.40	3.30	4.39	3.77	2.22	1.85

[a] Modern wind record.

apparent. These wind direction frequencies reinforce the contention that even to the end of this cool period, synoptic patterns continued to reflect those conditions which prevailed during the Little Ice Age.

The impact of the general circulation of the historical period should be identifiable in terms of precipitation regimes associated with the two periods of comparison, if the integrity of the model is to be maintained. Rainfall for the six summer months was derived from the military record at Saint Louis Arsenal, 1836–49 (table 8). It can be noted that the variability of precipitation during this time was extreme; for example, June, 1845, experienced 13.75 inches of rain, followed by a July recording of .03 inches and then 7.45 inches in August. It would appear that fluctuations in the synoptic situation might result in considerable variation in precipitation, especially when one contemplates the character of humid regions. The monthly and annual precipitation averages for this fourteen-year period support the formulated hypothesis for increased rainfall during atmospheric circulation patterns of the Little Ice Age type.[30]

TABLE 9

Wind Direction Frequencies for Saint Louis

Period of Comparison	1836–49	1849	14-Year Contemporary Summary
January	Northwest	North	Northwest
February	West-northwest	West	Northwest
March	West	West	West-northwest
April	West	West	West-northwest
May	Southwest	West	South
June	South-southeast	South-southeast	South
July	South	East	South
August	Southwest	East	South
September	Southwest	East	South
October	West	West	South
November	West-northwest	West	South
December	North-northwest	North	West-northwest

The Pattern for 1849

In terms of wind and precipitation it would seem, then, that the *period* 1836–49 possessed Little Ice Age characteristics. But was the *year* 1849 representative of the period 1836–49 or more like the present? The high rainfall of 1849 (table 8) established earlier is more akin to that of the preceding period. The comparative wind frequencies are summarized in table 9. In the winter months, the 1836–49 period is quite similar to the modern record. In 1849, the winter months exhibited a more northerly component, shifting to the west by February. The spring frequencies of the historical record correspond to that of 1849 until May, when westerlies predominated at the arsenal. June conditions were more similar to the historical period than to the modern. But in 1849, from July through September, when torrential rains inundated the Saint Louis vicinity, easterly circulation dominated, unlike either of the periods of comparison. By October the similarity returned to that of 1836–49 frequencies.

It is immediately recognizable that the wind pattern of 1849 recorded at Saint Louis Arsenal differs greatly from the modern record. Of particular interest is the summer circulation regime. In 1849, storm tracks beginning in June were deflected south of their normal contemporary cyclonic paths. Rainfall associated with these synoptic situations would be frontal-induced as opposed to convectively triggered in tropical Gulf air. The numerous cold fronts would produce cold, chilling rain in the spring and intense electrical storms in early summer. As reviewed in the preceding chapter, probabilities of exceeding the recorded precipitation at Saint Louis Arsenal for June and July, 1849, approach zero.

A deductive model of long-period climatic change and some supportive evidence suggest that the years 1836–50 in the plains were generally representative of conditions during the Little Ice Age as a whole. Cooler temperatures and increased precipitation, particularly during the summer, characterized the period as against that of circa 1851 to the present. Thus a year randomly selected (say, 1849) during the Little Ice Age is more likely to have had cooler temperatures and increased rainfall during the summer in the plains than a year randomly selected between 1851 and 1972. And as many of the circulation characteristics of the Little Ice Age (except in July, August, and September) were present in 1849, the probability was high that this year had cooler temperatures and higher rainfall annually and in the summer than the average year on the plains since 1850. Evidence in Chapters 2, 3, and 4 supports this deduction from the models of long-term climatic change.

Cycles and Droughts in the Plains before 1851

It is clear, however, that there were substantial fluctuations in rainfall and temperature from year to year during the Little Ice Age,[31] as there were during the subsequent period, which has seen droughts that have displayed an intriguing periodicity. To establish such periodicity, if it exists, is not possible in the plains region, for the time span of available data is too narrow to record accurately more than a few sustained droughts. Prior to 1876, very few stations collected rainfall data. The lack of continuous data collection at sufficient weather stations seriously impedes the statistical analysis of precipitation cycles. This necessitates a search for other indicators of drought which would facilitate cyclical interpretation of moisture deficiency.

Willett's Cyclical Model Relating Annual Precipitation to Solar Activity

Researchers have long been investigating the relationships between the general circulation of the earth and solar activity. The dynamics of the large-scale circulation processes, as complex as they are, have been generalized into types of synoptic patterns linked together with circulation indices. These indices can be thought of as representing the ratios between zonal and meridional components of the circulation. In the former the superficial pattern of cyclones and anticyclones would be from west to east, as opposed to a north-south orientation prevailing with the latter pattern.[32]

Solar climatic relationships were significantly advanced by the classic work of the Duells, who studied the simultaneity of the general circulation in Western Europe with sudden changes in solar emissions.[33] This study, together with the findings of Craig and Hawkins[34] as discussed by Willett, demonstrate the tendency for an increased zonal circulation pattern over mid-latitude oceans to be associated with strong solar flare activity.[35]

Research in the Soviet Union reported by Dzerdzeevskii appears to have established relationships between circulation indices and long-term fluctuations in the solar eleven-year cycle.[36] In detailing the work of Berzrukova, he relates the close agreement between indices of solar activity and circulation types.[37] A direct correlation was observed when solar indices were compared with zonal indices, as opposed to an inverse relationship resulting when meridional circulation was studied. Working with indices of sunspot magnetic fields rather than relative sunspot numbers alone, Willett and Prohaska discovered a greater relationship of atmospheric circulation indices to a twenty-two-year sunspot cycle outside the tropics than to the eleven-year cycle.[38] This double sunspot cycle has been accompanied by reverses in the polarity of the magnetic fields associated with the sunspot groupings on the sun's surface such that alternate sunspot maxima display opposite fields of polarity. Furthermore, during the major sunspot maximum the highest levels of solar-corpuscular emissions are reached, as contrasted with below-average corpuscular radiation at the period of minor maximum.

According to Willett, there appear to be climatological manifestations of the opposite trend during alternate sunspot maxima. He contends that there is a disruption of the general circulation which favors cellular blocking during the major sunspot maximum. At the minor maximum, with its associated below-average solar corpuscular radiation, a prevalence of zonal circulation exists in the lower latitudes with wetter summers in the middle latitudes.

Analysis of general circulation types by Dzerdzeevskii during the twentieth century demonstrates a climatic change over the Northern Hemisphere. During the beginning of this century, circulation was established to be meridional, changing to zonal characteristics by the second quarter and back to meridional since the 1950s.[39] When the relative dominance of circulation types in the Northern Hemisphere (Dzerdzeevskii) are compared with the periods of major droughts in the central United States (Borchert),[40] there seems to be no unique association of drought with the pattern of circulation. Citing research in the Soviet Union, Dzerdzeevskii found a greater persistence of meridional patterns to be dominant during the drought of the 1910s in the circulation of the mid-latitudes, with zonal circulation reaching a peak during the severe drought of the 1930s.[41] Using these findings, Borchert concludes that the significant association between circulation patterns and the occurrence of drought is primarily the persistence of circulation rather than of the circulation type.[42] However, there was no departure of the number of days with zonal or meridional circulation from a sixty-year mean during the drought of the 1950s. At that time, there was no persistence of one circulation frequency over the other. If Dzerdzeevskii's analyses of Northern Hemisphere daily weather maps for circulation types are correct, it would seem that Borchert's conclusions are invalid.

Discrepancies appear to exist, however, between the findings published by Dzerdzeevskii[43] and those of Willett.[44] Whereas Dzerdzeevskii found a meridional circulation prevalent during the first quarter of this century, Willett describes low-latitude zonal as existing between 30° and 50° N. in summer and fall. Between 1920 and 1939 Willett identifies a zonal pattern in the high latitudes between 60° and 80° N. during summer, fall, and winter. Dzerdzeevskii recognizes an increase in zonal circulation with peak years in the 1930s but dominating until 1950. After 1940 to 1959 Willett records the predominance of cellular blocking patterns of the general circulation, whereas Dzerdzeevskii simply refers to the post-1950 period as being meridional.

The significant points to be demonstrated by the above discrepancies can be summarized as follows:

1. Dzerdzeevskii used hemispheric weather maps. Willett primarily analyzed the latitudinal zone between 30° and 60° N.

2. Dzerdzeevskii does not identify the latitudinal zonal position as does Willett, (i.e., low-latitude zonal, high-latitude zonal).

3. Borchert's contention that circulation type is not as important as persistence may be correct but can not be substantiated by Dzerdzeevskii's findings.

More recent findings of Willett, "indicate the falling off of zonal variance and the increase of meridional variance during the current century."[45] Using orthogonal functional analysis[46] of the monthly mean pressure fields over North America for the three winter months, Willett computed the following percentages of the month-to-month variance accounted for during successive periods by the first three functions:

	1900–1960	1900–1919	1920–1939	1940–1959
U_1	40%	30%	45%	25%
U_2	30%	not present	20%	50%
U_3	12%	40%	20%	10%

Where U_1 represents continental monsoonal single cell
U_2 represents E-W contrast, meridional cells
U_3 represents N-S contrast, zonal

Thus it can be demonstrated at least within the meridional zone of North America between 30° and 60° N. that winter circulation patterns have become increasingly meridional. It might be expected, then, that the geographic distribution of drought intensity could vary as the regional dominance of the latitudinal circulation patterns shift. Any paradigm for the prediction of droughts in the Great Plains (and/or the projection of drought occurrence in the past) must recognize that different circulation types can produce regional deficiencies in precipitation that migrate according to some meridional expression.

Willett argues that prolonged secular droughts in the Midwest have occurred at approximately twenty-year intervals, each having a duration of close to six years. He concludes that the phasing of this drought periodicity coincides with the major maximum half of the double sunspot cycle. The intensity of these droughts varies spatially throughout the plains, with succeeding rainfall deficits such that the entire pattern of this twenty (-two) -year climatic cycle shifts latitudinally from farthest south during the first quarter of a long eighty–ninety-year solar-climatic cycle to farthest north during the third phase of the long cycle. The eighty–ninety-year cycle finds most support in the secular temperature data of the Midwest. This is because there is a relatively narrowness of the latitudinal dry and moist zones. In fact, Willett suggests that there is an opposition of phases between southern Canada and the southern United States, with excessive moisture in one region during drought in the other and vice versa. Demonstrating this latitudinal relationship, he shows that the drought of the 1890s was most severe in the southern states from Texas to Arizona. During the early 'teens of the century, the south-central states of Oklahoma, Kansas, and Missouri were most severely affected. The next drought period moved northward, extending even to the Canadian border, while the latest prolonged deficiency in precipitation was manifested once again most severely in the south.

Average annual precipitation for the state of Nebraska has been initially calculated by Bengtson[47] and extended by me for the interval 1850–1970. When solar activity (sunspots) is compared with variations in rainfall (fig. 23) and adjustments are made for latitudinal shifts in drought severity, a reasonable association between the two variables can be derived. Especially consistent is the fact that rainfall deficits of the last eighty–ninety-year cycle never occurred in Nebraska during phases of minor sunspot maxima.

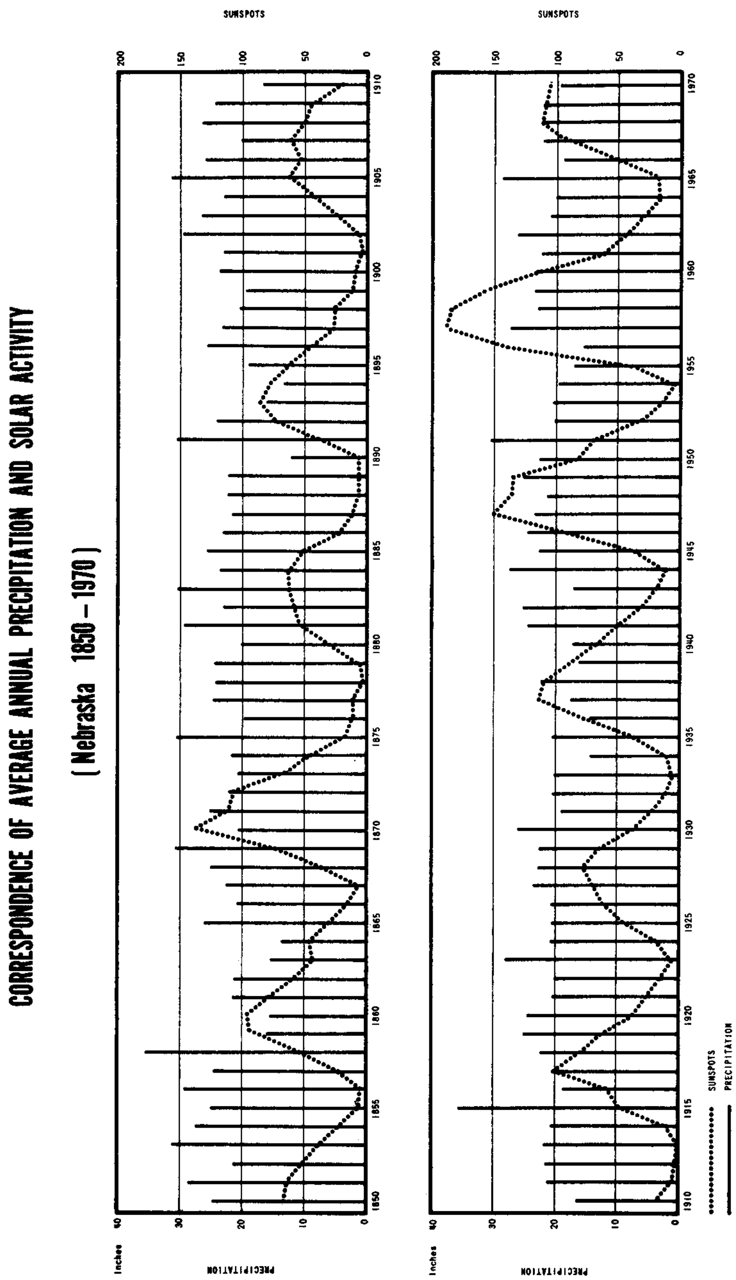

CORRESPONDENCE OF AVERAGE ANNUAL PRECIPITATION AND SOLAR ACTIVITY
(Nebraska 1850 – 1970)
SUNSPOTS
200
150
100
50
0
Inches
40
30
20
10
0
PRECIPITATION
1850
1855
1860
1865
1870
1875
1880
1885
1890
1895
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
SUNSPOTS
PRECIPITATION

Figure 23

Prior to this, the major maximum of 1870 was not coincident with lower rainfall, whereas the minor maximum of 1860 corresponded with intense drought throughout the state.

Retrodicting Droughts in the Plains

Putting these inconsistencies within the model aside for the moment, I have applied the Willett Drought Model to the nineteenth century, something never attempted by him. The intent was to project both temporally and spatially the most probable occurrences of drought on the plains, and then derive possible correspondences with nineteenth-century explorations or incipient settlement.

The retrodiction of droughts by extending Willett's model into the early nineteenth century necessitates the assumption that the behavior of solar magnetic fields then is similar to modern experience of them. It is known, for instance, that the sequence of higher versus lower sunspot numbers relative to major versus minor sunspot maxima reversed during the first part of the century. Although Willett has never attempted to follow the sunspot-drought cycle back to this period, he is of the opinion that the sunspot number is of little significance in the double cycle.[48]

Thus, assuming that the solar-climatic relationship is not based on the number of sunspots but rather on alternate cycles of magnetism, one could expect drought conditions at varying latitudes on the plains just prior to 1804, 1830, 1848, 1871, and 1894. Latitudinal shifting of the narrow zone belts of drought might then be superposed upon the preceding interpretation, thus establishing expected regions of maximum drought severity in the following positions:

1894—Southern plains (Mexican border)
1871—South-central plains (Oklahoma, Kansas, Missouri)
1848—Central to north plains (Kansas, Nebraska to Canadian border)
1830—South-central plains (Oklahoma, Kansas, Missouri)
1804—Southern plains (Arizona, New Mexico, Mexican border)

Verification of this temporal scheme of possible drought can only be fragmental, given the kinds of data currently available. Tree-ring data are the only long-term surrogate currently available for the earlier hypothesized droughts. Perusal of the eight dendroclimatological graphs of master charts[49] reveals that significantly dry conditions existed at three sites for the ten-year periods prior to 1894 and 1871. No locations displayed drought tendencies prior to 1848, and for the decade preceding 1830 three charts registered significantly wet moisture regimes. For the ten-year period before 1804, the upper Missouri[50] was dry, whereas the central Mississippi[51] recorded very wet conditions. Tree-ring data generally support the predictability of droughts after the end of the Little Ice Age. (Of course it is quite possible that our assumption negating the reversal of major versus minor sunspot occurrence is not warranted.)

The predicted drought associated with the double sunspot maximum of 1848 cannot be verified using either tree rings or fort meteorological records. Tree-ring charts show none of the regions to have been significantly deviant in either direction for this period.

One must conclude that although the retrodictive Willett model is intriguing in view of its potential implications for deducing the climatic vicissitudes of the nineteenth century in the Midwest, insufficient supportive evidence is presently available. Droughts were common to the interior West during the Little Ice Age, but it is quite plausible that the inducing mechanism has been altered sufficiently to prevent its identification in a maze of statistical dissonance. When causative factors elude the scientist, he tries to find solace in defining some mathematical expression by which the recurring events can be predicted if not explained.

Cycle Analysis: The Historical Record

The problem of evaluating nonrandomness in meteorological time series has led to the development of power spectrum analysis, a statistical procedure which measures an infinite number of all possible wavelengths possessed by a series of data. The mathematical description of the power spectrum with its limitations and tests of significance is reviewed by Mitchell et al.[52] The absence of a continuous meteorological record of sufficient length does not permit the application of the power spectrum approach toward the search for drought cycles on the Great Plains. However, power spectrum analysis has been conducted using a series of Palmer's Meteorological Drought Index[53] summer values for Saint Louis from 1840 to 1963. Conclusions drawn from this procedure show no justification for assuming the drought-index series to be anything but random except for a small rhythmic component of slightly more than two years.[54] An analysis of total summer-season precipitation at Saint Louis verified these conclusions.

Conclusions: Cycles and Paradigms

Inspection of dendroclimatological data supports the conclusion that drought cycles do not maintain a statistically significant periodicity. Weakly, in a study of drought recurrence using tree-ring master charts collected at North Platte, Nebraska, was unable to identify any particular pattern for the past 750 years.[55] Similarly, Fritts has been unsuccessful in demonstrating periodicities of tree growth for the western United States.[56]

The unsuccessful search for cycles appears at present to restrict the historical climatologist from constructing retrospective interpretations of short-term decennial fluctuations in the climate of the trans-Mississippi West prior to settlement. The most promising model for retrodicting the climate prevailing prior to the explorations of the early nineteenth century is not verified by dendroclimatic data—the most reliable surrogate for climate available to us at present. This may be because the dendroclimatic data are unreliable or, much more likely, because the deductive model is at present inadequate.

The quest for suitable models must continue, or interpretations may become accepted without suitable testing and inquiry. To the historical geographer as well as

> to the historian, at least, it makes little sense to suggest that verification is establishing the agreement of fact with theory. All historically significant theories have agreed with the facts, but only more or less. There is no precise answer to the question whether or how well an individual theory fits the facts. But questions much like that can be asked when theories are taken collectively or even in pairs. It makes a great deal of sense to ask which of two actual and competing theories fits the facts better.[57]

6. Summary

SCHOLARS CONCERNED with the explorations and settlement of the trans-Mississippi West have recently focused much of their effort upon identifying the regional myths and environmental misconceptions that developed during the "exploratory process."[1] The problem with their studies is that the standard against which the cognitive errors are measured is assumed but not known, that is, the "real" past environment is taken to be unchanging. The climatic reconstructions made in this study, using four methodological approaches, demonstrate this working assumption to be erroneous and further demonstrate the possibility of reconstructing the climate of large portions of the plains region in the first half of the nineteenth century.

Although tree-ring evidence cannot be used to indicate long-term climatic *change* (for example, over a 250-year period), one can recognize that the period 1800–1850 was considerably wetter than 1600–1950 period as a whole and especially more moist than 1900–1950. Statistical analyses of tree-ring data for the decade immediately preceding major explorations demonstrate that in the trans-Mississippi West there were no droughts serious enough to justify the characterization of the region as a desert by either Pike or Long.

Conversely, wetter conditions existed in the western margins of the plains during the independent operations of both Fremont[2] and William Gilpin[3] in the early 1840s. By the latter years of that decade drier conditions prevailed along the overland trails, which by then annually carried greater numbers of emigrants bound for Oregon or California. The year of the Great Migration can be *cautiously* considered to have had slightly below average tree growth in the Mississippi and lower North Platte basins and above average tree growth in the Santa Fe region. This could mean that in 1849 depressed tree growth was associated with deficient spring and early summer precipitation, especially in western Nebraska; it could also reflect subnormal moisture levels in the preceding two or three years.

The rather general conclusions about the spring and summer rainfall drawn from the dendrochronological sources can fortunately be supplemented by meteorological observations at twelve forts on the margins of the plains. It appears from the reports that the winter of 1848–49 had been quite severe. Snow remained on the ground in Nebraska (Fort Kearny) until quite late in the season, when high temperatures and considerable rain resulted in rapid melting and runoff. By April anxious pioneers assembled by the thousands along the banks of the Missouri and Arkansas rivers. To the south, where warmer temperatures permitted early maturation of grass, wagon trains were able to embark on the first leg of an incredible trek to California. Most of those taking the southern route left from Fort Smith. Assuming homogeneity of data, there is every indication that April precipitation at the fort was phenomenally high when compared with secular records (Appendix 2). One would expect a similar amount of precipitation only three Aprils in one-hundred years.

For those at jumping-off places along the Missouri, April temperatures had delayed departure more than precipitation did. Late in the month, just as the early arrivals were ready to move out, a snow storm interfered with their scheduled departure. Perhaps this was beneficial in the long run, for the grass was slower to green than in previous years. Finally, by the end of April and first week in May, the caravans headed toward South Pass along the Oregon Trail. Now rains began to turn the hard flat "turnpike" into a trail of mud. Throughout the entire eastern plains, emigrants were inundated with excessive rains. Whether the argonauts had chosen the southern trail, opted for the Santa Fe Trail, or decided to travel the most popular route to the north, they and their draft animals trudged through heavy rains and strong winds. Precipitation probabilities computed for forts in close proximity to these trails consistently reveal May to have been extremely wet.

But with every labored mile the covered wagons drew further from the meteorological observation posts to the east, so that one must eventually turn to diaries as the most accurate data source for reconstructing weather experiences of the Forty-Niners.

Weather notations in thirty-four journals kept by argonauts traveling the Oregon Trail confirmed that the initial portion of their journey was hampered by chilling winds, torrential rains, and bitterly cold nights. The incautious researcher could unintentionally misrepresent the extensiveness of these uncommonly wet conditions unless a geographic form of analysis were used to interpret both the synoptic development of the storms and their areal distribution. For the first month on the trail the emigrants averaged eight miles a day as one cold front after another triggered areally extensive showers accompanied by lightning and thunder, the likes of which few had ever witnessed. The horrors of feared Indian attacks were replaced by the violence of storms that stampeded the cattle. And the dreaded cholera was made more ravaging by the debilitating effects of the weather. As the emigrants approached western Nebraska, intermittent showers only occasionally interfered with travel, most often repairing wagon ruts in the increasingly sandy road or mercifully laying the dust. The ever present winds continued to prevail, but now they were drying the alkaline soil, severely chapping the emigrants' faces, and on occasion causing extreme discomfort with blowing sand. But remarkably, east of the Rockies these hardy souls did not anticipate a Great American Desert. They revealed few misconceptions of the region through which they had passed.

In the final analysis, if one wishes to view the climate of the Great American Desert in a broader temporal perspective, that is, within the context of worldwide patterns of climatic change, it is necessary to develop a deductive conceptual framework for formulating the probable climatic history of the trans-Mississippi West. In this study two such models were considered as potentially suitable for extrapolating the climate of this region during the Little Ice Age. Insufficient evidence necessitates the rejection of a solar-related model for retrodicting droughts on the plains, but a second model produced more promising results. There is abundant evidence for a colder climate circa A.D. 1500–1850 in most parts of the Northern Hemisphere. This is taken to be a result of a weakening of the strength of the zonal circulation, which appears to have deflected summer and winter storm tracks southward by as much as 5°. This deflection most probably resulted in cooler summers and cold autumns, with associated increases in frontal-derived precipitation within the Great American Desert. Furthermore, lowered potential evaporation would tend to augment even a slight increase in the precipitation regime. It seems probable that the period 1800–1850, as part of the Little Ice Age, experienced a higher precipitation effectiveness (and probably a higher precipitation) than the periods 1851–1900 and 1901–50.

Thus, two relatively precise sources suggest 1849 was a wet year, particularly in the spring, and two general sources suggest that it was a rather normal (average) year in a fifty-year wet period. The methods and sources used here must now be extended to the years before 1849 to bring us even closer to a comprehensive climatic reconstruction of the Great American Desert.

Appendix 1

Precipitation Maxima for Military Meteorological Records of the Contemporary Period

TABLE A-1

PRECIPITATION MAXIMA FOR SAINT LOUIS ARSENAL
1836–54 (gaps)

Month	1849	Maximum	Year of Maximum Rainfall[c]
April	4.08	8.25	1847
May	6.39	11.03	1844
June	15.70	18.96	1848
July	13.67	13.67	*1849*
August	7.95	7.95	*1849*
September	3.96	6.28	1846
Spring[a]	14.07	19.82	1844
Summer[b]	37.32	37.32	*1849*
Annual	71.54	71.54	*1849*

Mean annual: 41.95

[a] March, April, May.
[b] June, July, August.
[c] Italics emphasize exceptional wetness of 1849.

TABLE A-2

PRECIPITATION MAXIMA FOR JEFFERSON BARRACKS
1840–54 (gaps)

Month	1849	Maximum	Year of Maximum Rainfall[c]
April	1.53	5.02	1850
May	2.00	8.12	1852
June	5.85	11.85	1852
July	7.70	7.70	*1849*
August	4.72	12.25	1840
September	4.84	5.76	1843
Spring[a]	6.30	17.28	1854
Summer[b]	18.27	18.27	*1849*
Annual	38.58	55.13	1852

Mean annual: 37.83

[a] March, April, May.
[b] June, July, August.
[c] Italics emphasize exceptional wetness of 1849.

TABLE A-3

PRECIPITATION MAXIMA FOR FORT LEAVENWORTH
1836–55

Month	1849	Maximum	Year of Maximum Rainfall
April	2.40	5.53	1843
May	5.10	7.18	1847
June	2.26	15.80	1845
July	6.03	6.78	1851
August	5.80	6.66	1838
September	7.56	7.80	1837
Spring[a]	10.90	15.13	1844
Summer[b]	14.09	24.88	1844
Annual	42.85	48.12	1844

Mean annual: 30.29

[a] March, April, May.
[b] June, July, August.

TABLE A-4

PRECIPITATION MAXIMA FOR FORT SCOTT
1843–52

Month	1849	Maximum	Year of Maximum Rainfall
April	5.38	6.91	1844
May	12.20	14.79	1844
June	3.49	24.56	1845
July	5.77	10.50	1844
August	2.62	7.18	1845
September	.56	5.53	1846
Spring[a]	20.88	25.48	1844
Summer[b]	11.88	36.31	1845
Annual	33.23	62.60	1844

Mean annual: 42.12

[a] March, April, May.
[b] June, July, August.

TABLE A-5

PRECIPITATION MAXIMA FOR FORT GIBSON
1836–54

Month	1849	Maximum	Year of Maximum Rainfall[c]
April	2.17	12.55	1840
May	7.52	10.13	1840
June	9.17	9.17	*1849*
July	8.72	8.72	*1849*
August	3.70	8.18	1843
September	2.05	8.04	1836
Spring[a]	14.59	24.08	1840
Summer[b]	21.59	21.59	*1849*
Annual	52.65	52.65	*1849*

Mean annual: 36.46

[a] March, April, May.
[b] June, July, August.
[c] Italics emphasize exceptional wetness of 1849.

TABLE A-6

PRECIPITATION MAXIMA FOR FORT SMITH
1837–54

Month	1849	Maximum	Year of Maximum Rainfall[c]
April	8.45	14.28	1844
May	8.40	8.40	*1849*
June	6.79	8.91	1837
July	7.90	11.18	1847
August	1.95	9.14	1845
September	1.65	6.90	1837
Spring[a]	21.50	21.50	*1849*
Summer[b]	16.64	16.64	*1849*
Annual	57.54	57.54	*1849*

Mean annual: 42.10

[a] March, April, May.
[b] June, July, August.
[c] Italics emphasize exceptional wetness of 1849.

TABLE A-7

PRECIPITATION MAXIMA FOR FORT WASHITA
1843–54 (gaps)

Month	1849	Maximum	Year of Maximum Rainfall[c]
April	6.96	7.91	1848
May	14.61	14.61	*1849*
June	4.00	10.23	1846
July	13.40	13.40	*1849*
August	4.00	5.85	1847
September	3.74	9.60	1846
Spring[a]	24.66	24.66	*1849*
Summer[b]	21.40	21.40	*1849*
Annual	64.29	64.29	*1849*

Mean annual: 41.66

[a] March, April, May.
[b] June, July, August.
[c] Italics emphasize exceptional wetness of 1849.

TABLE A-8

PRECIPITATION MAXIMA FOR FORT TOWSON
1836–54 (gaps)

Month	1849	Maximum	Year of Maximum Rainfall[c]
April	—	13.6	1840
May	—	9.26	1843
June	6.21	17.5	1839
July	10.76	10.76	*1849*
August	3.57	7.34	1851
September	2.54	6.50	1841
Spring[a]	—	26.5	1842
Summer[b]	20.54	29.9	1839
Annual	—	73.36	1842

Mean annual: 51.08

[a] March, April, May.
[b] June, July, August.
[c] Italics emphasize exceptional wetness of 1849.

TABLE A-9

PRECIPITATION MAXIMA FOR FORT KEARNY
1849–55

Month	1849	Maximum	Year of Maximum Rainfall[c]
April	7.86	7.86	*1849*
May	10.74	10.74	*1849*
June	4.00	9.93	1850
July	7.70	8.28	1853
August	6.05	6.05	*1849*
September	.27	4.60	1854
Spring[a]	24.72	24.72	*1849*
Summer[b]	17.75	17.75	*1849*
Annual	—	29.90[d]	1853

Mean annual: 27.98

[a] March, April, May.
[b] June, July, August.
[c] Italics emphasize exceptional wetness of 1849.
[d] For the period 1850–54.

Appendix 2

The Plains Summer of 1849: The Military Record in the Long-Term Perspective

ALTHOUGH THERE ARE many problems confronting the climatologist who wishes to compare modern secular weather data with that of past periods, it is perhaps valuable to attempt such a comparison as long as one recognizes the qualifications and assumptions that detract from the scientific validity of the study. In this appendix, quantitative techniques of analysis are employed in an attempt to compare the plains military record of 1849 with the long-term situation. For these purposes, it is assumed that the fort meteorological data are homogeneous and that precipitation on the plains is normally distributed.

Climatological analysis necessitates the specification of the frequency distribution of the population from which a climatological sample is to be drawn. This specification can be either derived empirically or inferred with the application of some mathematical function. Interpretations derived from improperly assessed population distributions could mislead the researcher and negate his findings.

Precipitation populations are usually recognized as continuous random variables which commonly exhibit a continuous normal distributive curve. The properties of the normal curve were first illustrated by Abraham De Moivre over two-hundred years ago and later by the independent work of Gauss and Laplace.[1]

Many generalizations concerning the normal curve, also known as the law of errors, have been found to hold true for many continuous random variables. One of these is known as the central limit theorem.[2] It has been discovered that small deviations from a distributional mean occur more often that large deviations. Thus the sums of numerous climatological values as well as their means tend to become Gaussian, or normally distributed. The shorter the period of observation, the more skewed the distribution is likely to be. As applied to precipitation occurrence, stations in regions with average annual rainfall exceeding twenty inches will experience a normal frequency distribution.

Although it could be assumed that precipitation data for the region of study should provide a good fit to the Gaussian distribution, it was decided to evaluate the nature of the frequency curve empirically for the various stations. Cumulative probability curves were produced and plotted on probability paper for historical precipitation records for the month of June at three sites of decreasing rainfall: Saint Louis, Missouri; Kearney; and Laramie. Monthly data were chosen in an attempt to reduce the effect of the central limits theorem. Yearly records would naturally represent a better fit to the normal curve, whereas monthly data might be expected to deviate from this curve because lower values approach zero. Probability graph paper displays the normal curve as a straight line. This technique is preferable to the cumulative plot on ordinary graph paper, as the former enables the normality of the distribution to be tested visually by the straightness of the line. The resulting plots are exemplified by that for Laramie (fig. A-1). June precipitation values for seventy-five years were ranked and their frequency calculated using the formula

$$F = m/(n + 1) \times 100$$

where F is frequency in percent, m represents the rank of the event, and n equals the number of years of record. The various plots reinforce the assumption that monthly precipitation data for the area of study can be treated as Gaussian.

Once it can be assumed that climatological records are both homogeneous and normally distributed, analyses can be performed which allow the researcher to express a portion of the record, for example, a month or year, in terms of the total population. This can best be achieved by recognizing the arbitrary nature of the numerical values for climatological data, that is, precipitation. Yearly, monthly, or seasonal values (scores) can be stated in terms

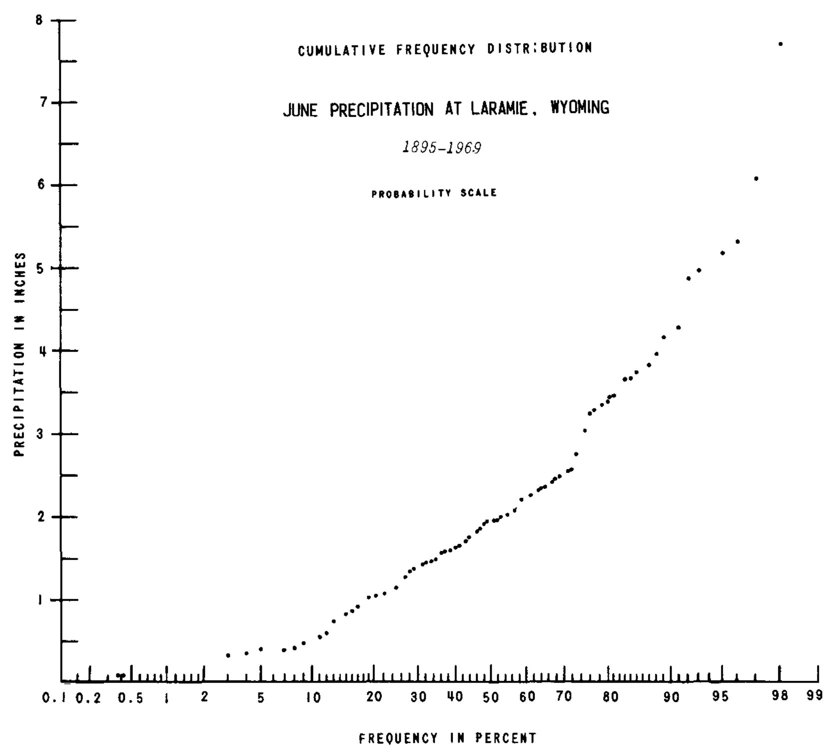


Figure A-1

of standard deviations above and below the mean. The most common linear score standardization or transformation is the standard z-score.[3] In this case, a score transformation is produced with a mean of zero and a standard deviation of one.[4] Mathematically defined, the standard score (z) having a mean of zero and standard deviation of one can be stated as

$$z = \frac{x - M}{S} \quad \text{or} \quad z = \frac{\text{random variable} - \text{expected value}}{\text{standard error}}$$

where z is the standard score, x the value to be standardized, M the mean, and S the standard deviation

The properties of z-score distributions (transformed raw scores, i.e., precipitation) are as follows:

a. *z*-score mean equals zero, standard deviation and variance are one
b. raw scores below the mean are negative *z*-scores, while those above the mean are positive
c. *z*-score units refer to standard deviations

Modern secular monthly precipitation values for each of ten locations assumed to reflect a homogeneous record for each fort were collected, ranging in duration from a minimum of fifty-three years (Tahlequah, Oklahoma–Fort Gibson) to one-hundred-thirty-three years at Saint Louis. Monthly and seasonal *z*-scores were computer generated to provide a statistical comparison of precipitation values in 1849 with those of the long-term norm. Figures A-2 through A-11 present the results of this procedure. The lower portion of the histogram indicates the total monthly and seasonal rainfall observed at each fort and the dark line indicates the monthly average rainfall in the period of long-term record. The top graph expresses as a percentage the probability of a station's receiving more precipitation than the amount that fell in 1849; that is, the smaller the bars, the higher the relative amount of rainfall received, and the less the chance of the station's receiving such a rainfall total again. For Saint Louis Arsenal in the spring and summer, and in June and July, for example (fig. A-2), the chance of receiving the rainfall amounts recorded in 1849 is less than 1 percent!

All stations except Fort Leavenworth had April rains far greater than the long-term average, and in the key station at Fort Kearny the chance of receiving the rainfall experienced in April, 1849, is less than 2 percent. The month of May was even wetter. All seven stations had exceptionally high rainfall in May. In all but Fort Leavenworth the chance of receiving such rains again is less than 2 percent, and in three of the stations the probability is negligible. The June rains varied but were above average in six of the eight stations of record, and far above average in four of them. Thus with the strange and inexplicable exception of Fort Leavenworth, the spring rainfall totals were phenomenally high. At the other six stations for which it was possible to make calculations, the chance of receiving a total similar to that of 1849 ranges from 1 to 10 percent. In relation to the long-term record, the plains margins in the spring of 1849 were saturated and completely drought-free. The rainfall experienced in the region was similar to that occurring on the average in the eastern states of Ohio, Pennsylvania, and Indiana. July continued very wet in all eight stations of record. In Forts Leavenworth and Scott the chance of receiving similar rains in a particular year would be 20–25 percent, but in the other six stations the chance would be less than 1 in 100. Although no calculations were made of the chances of receiving four-month totals similar to those of 1849, it is clear that for all stations but Fort Leavenworth the chance of such a rainfall occurring in any one year would be less than 10 percent and less than 1 percent in all stations except Forts Leavenworth and Scott. For the remainder of the summer, rainfall was about average, with September slightly below the norm and August generally above.

Precipitation Probabilities for St. Louis Arsenal

Summer – 1849

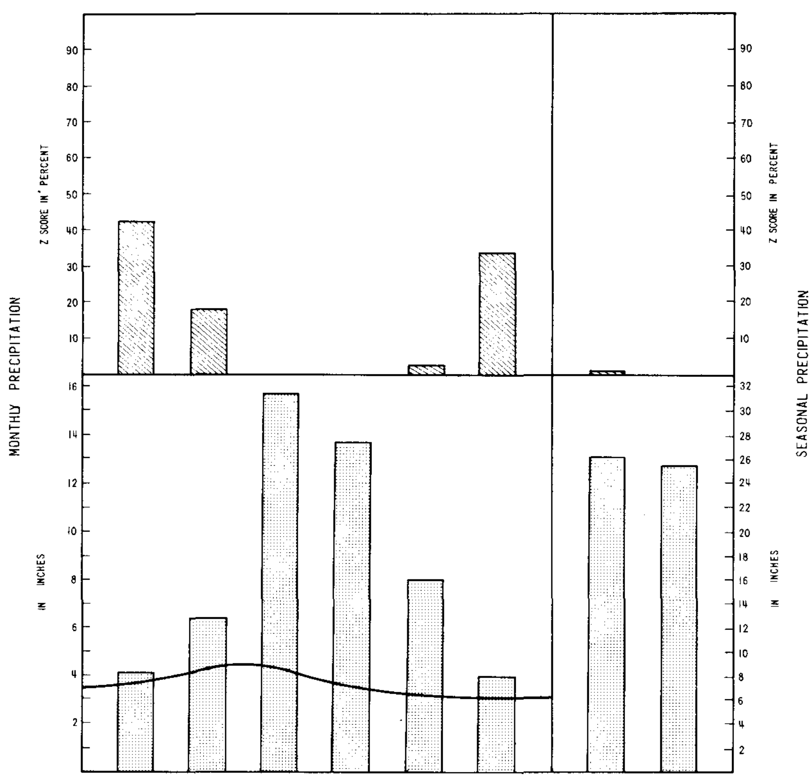


Figure A-2

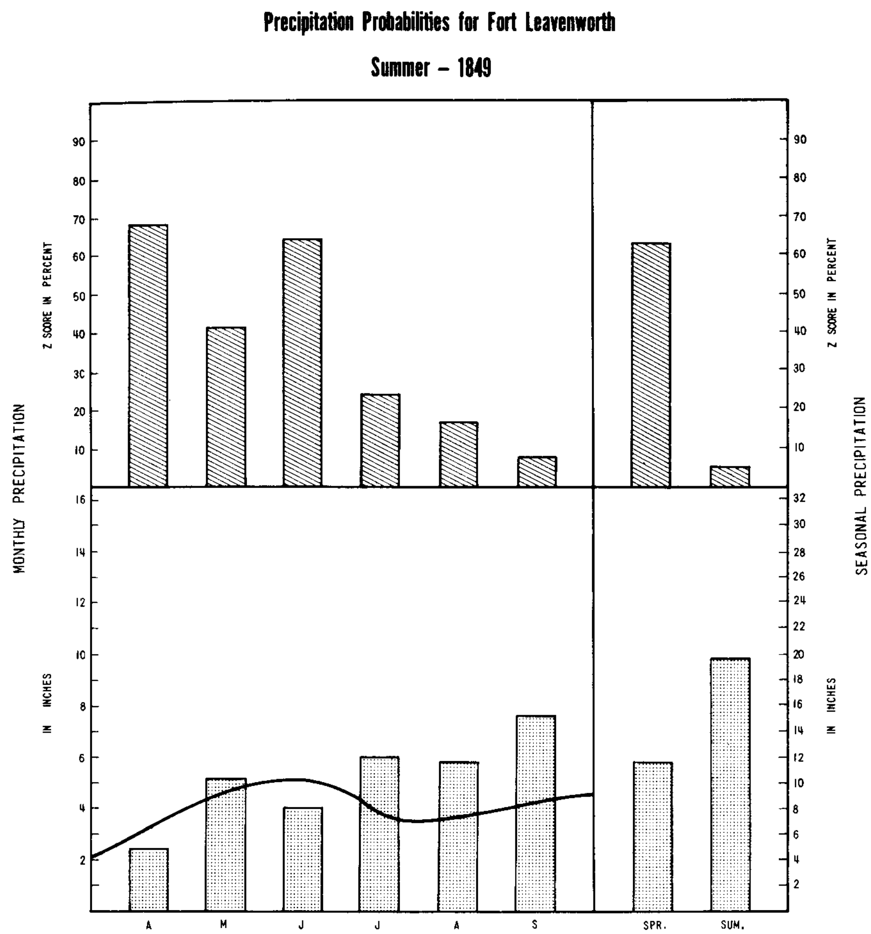

Precipitation Probabilities for Fort Leavenworth
Summer – 1849
MONTHLY PRECIPITATION
SEASONAL PRECIPITATION
Z SCORE IN PERCENT
IN INCHES
A
M
J
J
A
S
SPR.
SUM.

Figure A-3

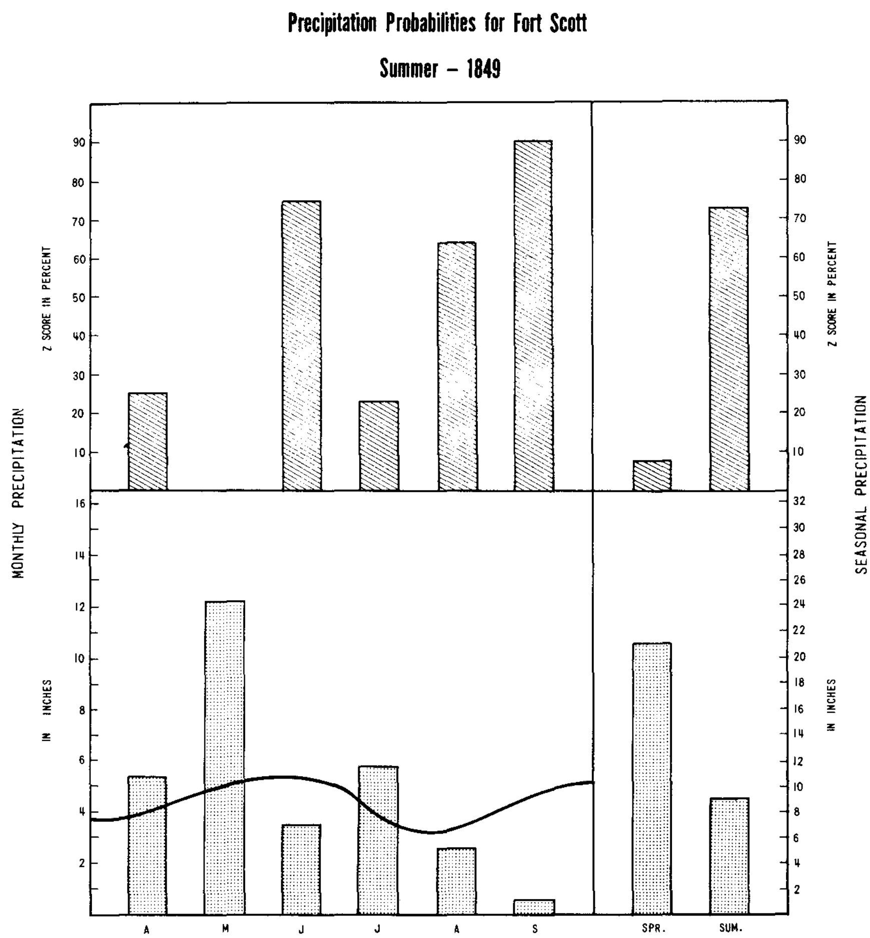

Precipitation Probabilities for Fort Scott
Summer – 1849
MONTHLY PRECIPITATION
Z SCORE IN PERCENT
IN INCHES
SEASONAL PRECIPITATION
A
M
J
J
A
S
SPR.
SUM.

Figure A-4

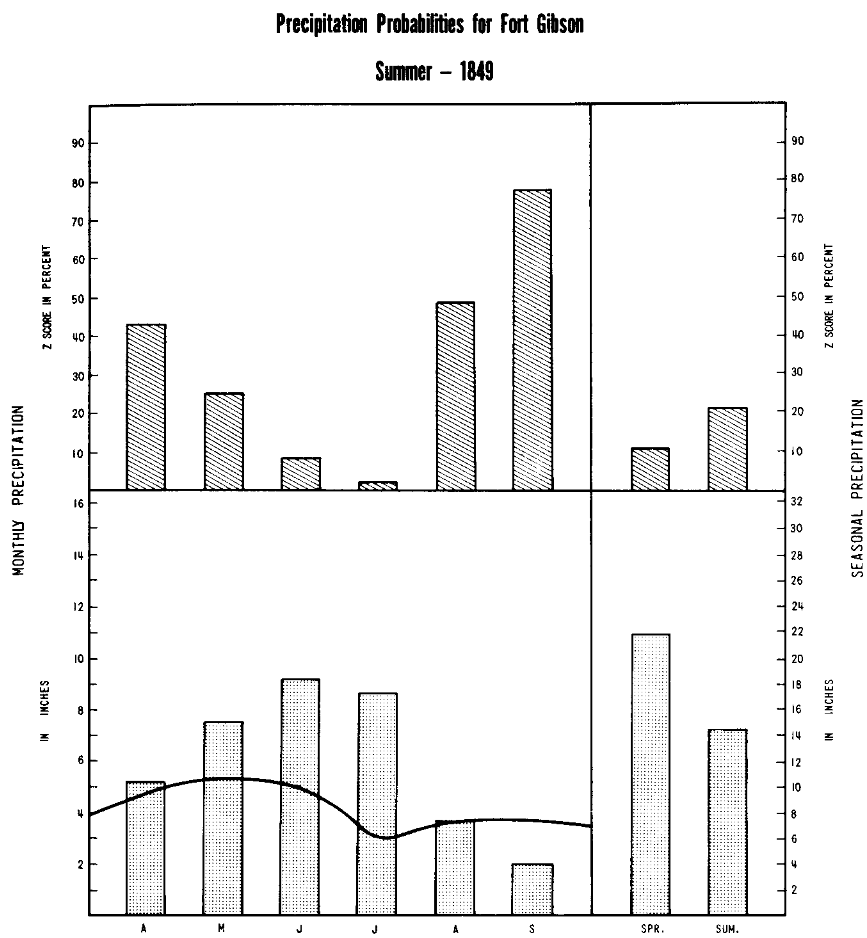
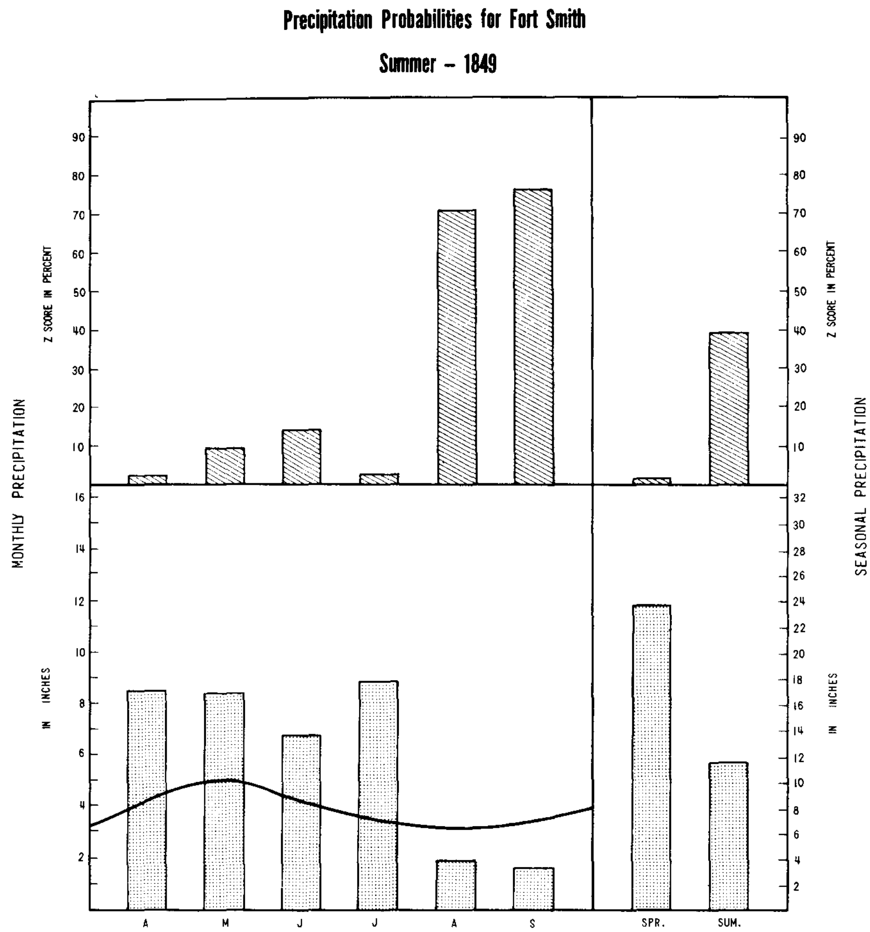

Precipitation Probabilities for Fort Gibson
Summer – 1849
MONTHLY PRECIPITATION
SEASONAL PRECIPITATION
Z SCORE IN PERCENT
IN INCHES
A
M
J
J
A
S
SPR.
SUM.

Figure A-5



Precipitation Probabilities for Fort Smith
Summer – 1849
MONTHLY PRECIPITATION
SEASONAL PRECIPITATION
Z SCORE IN PERCENT
IN INCHES
90
80
70
60
50
40
30
20
10
16
14
12
10
8
6
4
2
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
A
M
J
J
A
S
SPR.
SUM.

Figure A-6

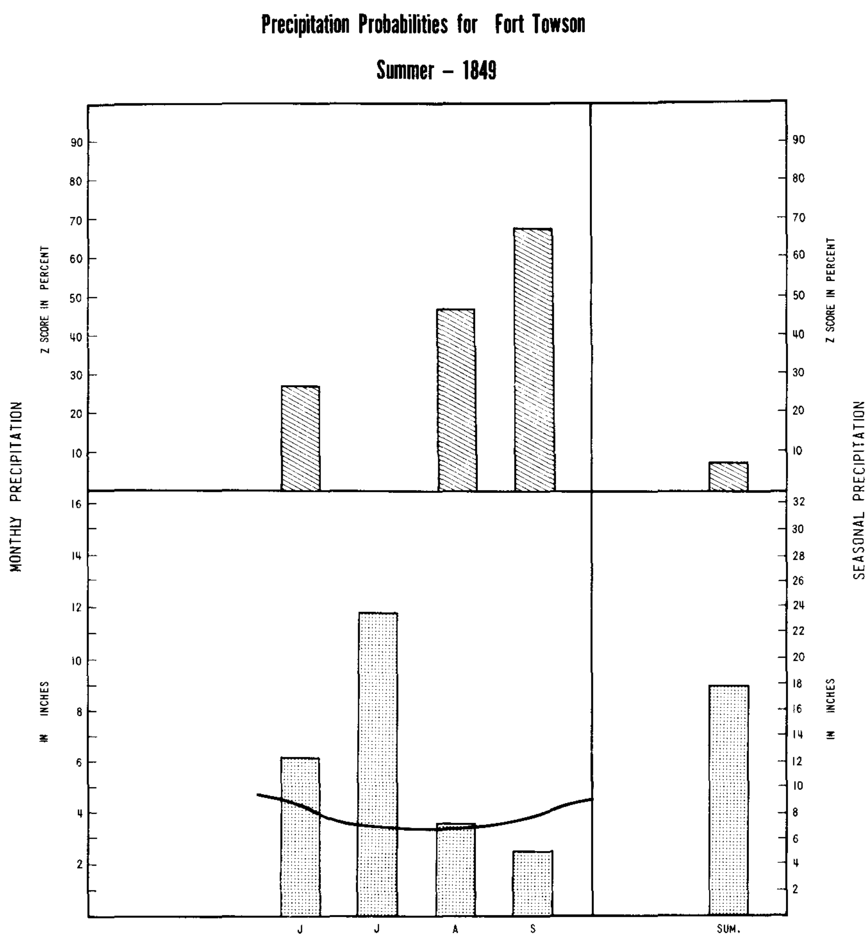

Precipitation Probabilities for Fort Towson
Summer – 1849
MONTHLY PRECIPITATION
SEASONAL PRECIPITATION
Z SCORE IN PERCENT
IN INCHES
90
80
70
60
50
40
30
20
10
16
14
12
10
8
6
4
2
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
J
J
A
S
SUM.

Figure A-7

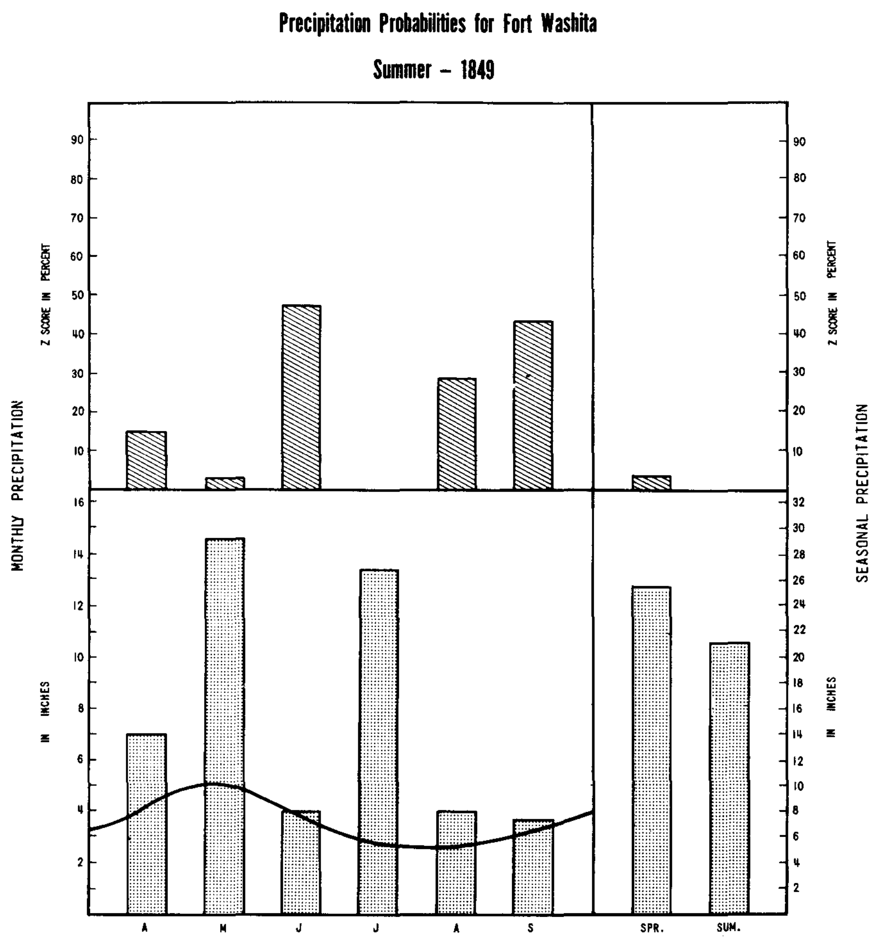

Precipitation Probabilities for Fort Washita
Summer – 1849
MONTHLY PRECIPITATION
SEASONAL PRECIPITATION
Z SCORE IN PERCENT
IN INCHES
A
M
J
J
A
S
SPR.
SUM.

Figure A-8

Precipitation Probabilities for Fort Kearny

Summer – 1849

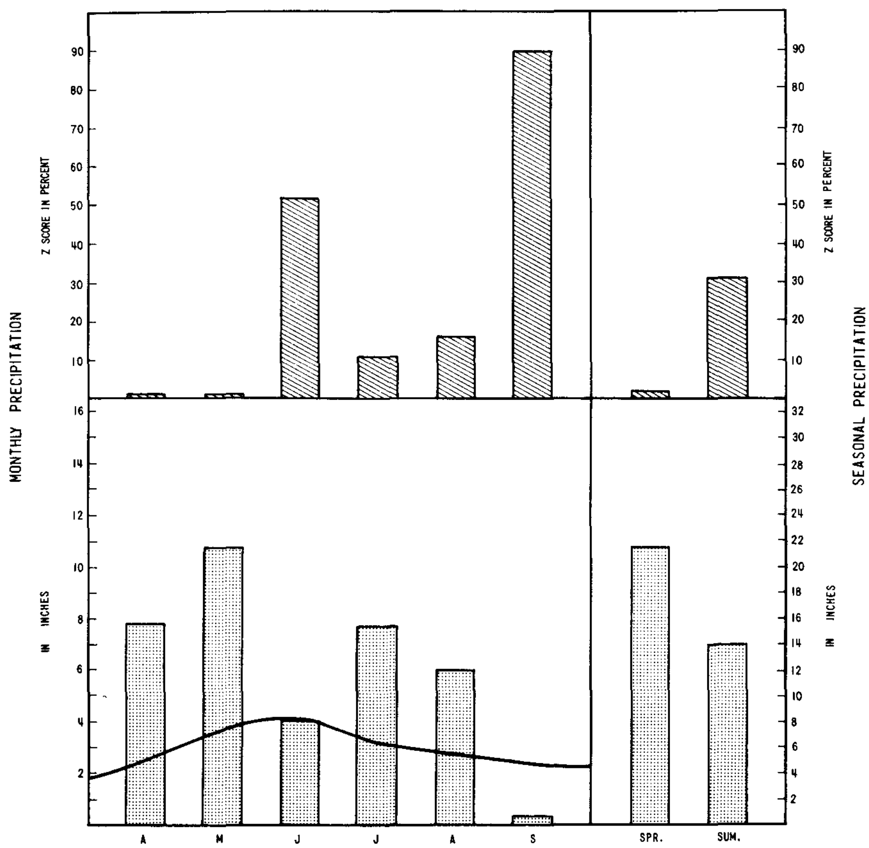


Figure A-9

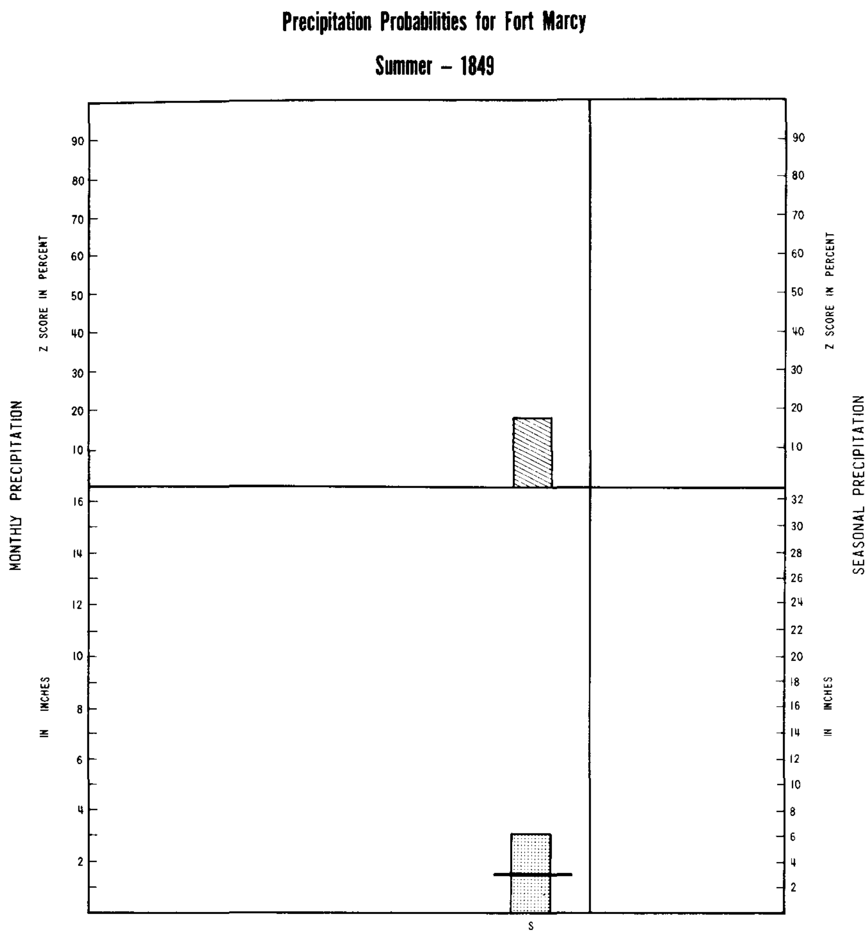

Precipitation Probabilities for Fort Marcy
Summer – 1849
MONTHLY PRECIPITATION
Z SCORE IN PERCENT
IN INCHES
SEASONAL PRECIPITATION
Z SCORE IN PERCENT
IN INCHES
90
80
70
60
50
40
30
20
10
16
14
12
10
8
6
4
2
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
S

Figure A-10

Precipitation Probabilities for Fort Laramie

Summer – 1849

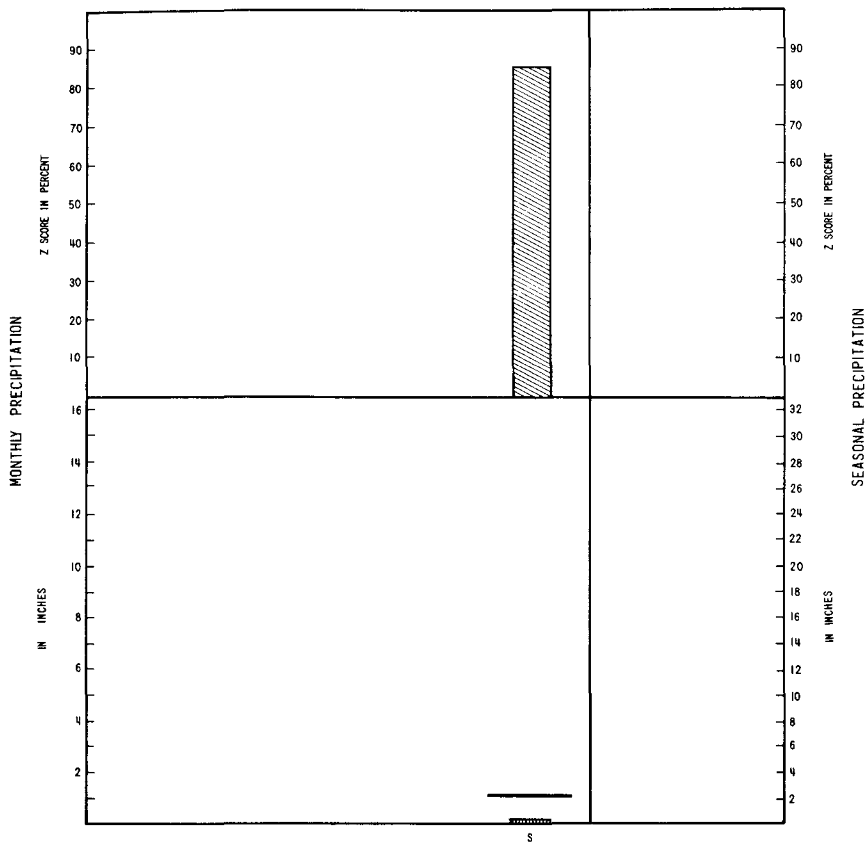


Figure A-11

Notes

CHAPTER 1

1. H. C. Hart, *The Dark Missouri* (Madison, Wis., 1957), p. 31.

2. David Emmons, *Garden in the Grasslands* (Lincoln, Nebr., 1972), p. 197; Henry Nash Smith, *Virgin Land: The American West as Symbol and Myth* (Cambridge, Mass., 1950), pp. 201–13.

3. One of the earliest and most detailed accounts of the idea of the Great American Desert is presented by Ralph C. Morris, "The Notion of a Great American Desert East of the Rockies," *Mississippi Valley Historical Review* 13 (1926): 190–200. Prior to this the subject was introduced by Frank W. Blackmar, "The History of the Desert," *Transactions of the Kansas State Historical Society* 9 (1906): 101–14. In 1935, Guy-Harold Smith presented a paper entitled "The Cartographical History of the Great American Desert" to the annual meeting of the Association of American Geographers at Saint Louis. A shortened copy of the manuscript was kindly furnished me by Professor Smith. Subsequent studies of the desert concept and its impact on western policies and settlement include the following: Walter Prescott Webb, *The Great Plains* (Boston, 1931), pp. 152–60; Smith, *Virgin Land*, pp. 174–83; Francis Prucha, "Indian Removal and the Great American Desert," *Indiana Magazine of History* 59 (1963): 299–322; R. W. Dillon, "Stephen Long's Great American Desert," *Proceedings of the American Philosophical Society* 111 (1967): 93–108; T. L. Alford, "The West as a Desert in American Thought Prior to Long's 1819–1820 Expedition," *Journal of the West* 8 (1969): 515–25; W. Eugene Hollon, *The Great American Desert: Then and Now* (New York, 1966); G. Malcolm Lewis, "Early American Exploration and the Cis-Rocky Mountain Desert, 1803–1823," *Great Plains Journal* 5 (1965): 1–11. Most recently, however, the analysis of nineteenth century books has led Martyn Bowden to conclude that "the myth of the Great American Desert as a popular American image of the Western Interior before the Civil War is itself a myth" (Martyn J. Bowden, "The Perception of the Western Interior of the United States, 1800–1870: A Problem in Historical Geosophy," *Proceedings of the Association of American Geographers* 1 (1969): 21.) Recognizing that he was not the first student of western history to challenge the idea of popular belief in a desert, Bowden cites other scholars who questioned various aspects of the notion's acceptance: F. Paxson, *History of the American Frontier, 1793–1893* (Boston, 1924), p. 332; E. Branch, *Westward: The Romance of the American Frontier* (New York, 1939), p. 309; Bernard DeVoto, *Across the Wide Missouri* (Boston, 1947), pp. 3–5; James C. Malin, *The Grassland of North America . . . with Addenda* (Lawrence, Kans., 1956), pp. 442–43; G. Malcolm Lewis, "Regional Ideas and Reality in the Cis-Rocky Mountain West," *Transactions of the Institute of British Geographers* 38 (1966): pp. 135–50.

4. W. Morton, "The Geographical Circumstances of Confederation," in *Patterns of Canada*, ed. W. Megill (Toronto, 1967), p. 62.

5. Karl F. Kraenzel, *The Great Plains in Transition* (Norman, Okla., 1955), p. 62.

6. F. W. Albertson and G. W. Tomanek, "Vegetation Changes during a 30-Year Period in Grassland Communities near Hays, Kansas," *Ecology* 46 (1965): 714–20.

7. F. W. Albertson, G. W. Tomanek, and A. Riefel, "Ecology of Drought Cycles and Grazing Intensity of Grasslands of the Central Great Plains," *Ecological Monographs* 27 (1957): 27–44.

8. I know of only two studies which make (rudimentary) attempts to assess the actual climatic conditions of the interior West relevant to initial governmental expeditions or settlement: Hart, *The Dark Missouri*, pp. 12–14, 31–36, and G. Malcolm Lewis, "William Gilpin and the Concept of the Great Plains Region," *Annals of the Association of American Geographers* 56 (1966): 42–43.

9. The first of these maps, as drawn by Stephen H. Long's cartographer, Edwin James, is partially reproduced in figure 1. The perceived boundaries of the desert have oscillated, according to Lewis, for various reasons throughout the past three hundred years (G. Malcolm Lewis, "Three Centuries of Desert Concepts of the Cis-Rocky Mountain West," *Journal of the West* 4 [1965]: 457–68). For purposes of this study, the map represents that region of the Western Interior (although lacking boundaries) which is considered the core of the so-called desert. Other terms which are synonymously used by authors to locate the study area include *trans-Mississippi West, cis–Rocky Mountain West, Great American Plain, interior West,* and *cismontane.*

10. Isaiah Bowman, "Our Expanding and Contracting Desert," *Geographical Review* 25 (1935): 56.

11. The term *geosophy* was originally introduced by John K. Wright by compounding *ge,* meaning "earth," and *sophia,* meaning "knowledge." Geosophy, then, "is the study of geographical knowledge from any or all points of view. To geography what historiography is to history, it deals with the nature and expression of geographical knowledge both past and present" (John K. Wright, *Human Nature in Geography* [Cambridge, Mass., 1966], p. 83).

CHAPTER 2

1. Bowman, "Our Expanding and Contracting Desert."

2. In 1931, Ernest Antevs gathered tree-ring records as a part of an investigation of the Great Basin. His results were not published prior to Bowman's article, however.

3. Lewis, "William Gilpin."

4. Bryant Bannister, "Dendrochronology," in ed. Donald Brothwell and Eric Higgs, *Science in Archeology* (New York, 1963), pp. 162–76.

5. Derek J. Schove, "Tree Rings and Climatic Chronology," *Annals of the New York Academy of Sciences* 95 (1961): 605–22.

6. Harold C. Fritts, "Dendrochronology," in ed. H. E. Wright and David G. Frey, *The Quaternary of the United States* (Princeton, N.J., 1965), pp. 871–79.

7. The following sources provide the interested reader with an excellent introduction to the science of dendrochronology: H. C. Fritts, T. Blasing, B. Hayden, and J. Kutzbach, "Multivariate Techniques for Specifying Tree-Growth and Climate Relationships and for Reconstructing Anomalies in Paleoclimate," *Journal of Applied Meteorology* 10 (1971): 845–64; Harold C. Fritts, "Recent Advances in Dendrochronology in America with Reference to the Significance of Climate Change," *Arid Zone Research* 20, UNESCO, Changes of Climate (Paris, 1963), pp. 255–63; Edmund Schulman, *Dendroclimatic Changes in Semiarid America* (Tucson, Ariz., 1956); W. S. Glock, *Principles and Methods of Tree-Ring Analysis,* Carnegie Institution of Washington Publication no. 486 (Washington, D.C., 1937); A. E. Douglass, *Climatic Cycles and Tree Growth,* Carnegie Institution of Washington Publication no. 289 (Washington, D.C., 1919).

8. Harold C. Fritts, "Growth-Rings of Trees: Their Correlation with Climate," *Science* 154 (1966): 973–79.

9. N. C. Matalas, "Statistical Properties of Tree-Ring Data," *International Association of Scientific Hydrology Bulletin* 7 (1962): 39–47.

10. H. C. Fritts, J. Mosimann, and C. Bottorff, "A Revised Computer Program for Standardizing Tree-Ring Series," *Tree-Ring Bulletin* 29 (1969): 15–20.

11. Douglass, *Climatic Cycles and Tree Growth.*

12. R. Friesner, "Some Aspects of Tree Growth," *Proceedings of the Indiana Academy of Sciences* 52 (1943): 36–44.

13. I. Hustich, "Tree Growth and Climatic Fluctuations," *Eripainos Terrasta* 2 (1948): 73–80.

14. W. S. Glock, "Tree Growth. II, Growth Rings and Climate," *Botanical Review* 21 (1955): 73–188.

15. Harold C. Fritts, "Tree-Ring Evidence for Climatic Changes in Western North America," *Monthly Weather Review* 93 (1965): 427.

16. Fritts, "Growth-Rings of Trees," p. 154.

17. Fritts, "Dendrochronology."

18. Schulman, *Dendroclimatic Changes,* p. 39.

19. W. S. Glock, "Tree Growth and Rainfall: A Study of Correlation and Methods," Smithsonian Institution *Miscellaneous Collections* 111 (1950): 1–47.

20. Fritts, "Tree-Ring Evidence," p. 425.

21. Ibid., p. 426.

22. Paul Julian and Harold C. Fritts, "On the Possibility of Quantitatively Extending Climatic Records by Means of Dendroclimatological Analysis," in American Meteorological Society, *Proceedings of the First Statistical Meteorological Conference* (Boston, 1968), pp. 76–82.

23. Wayne Palmer, *Meteorological Drought,* United States Weather Bureau Research Paper no. 45 (Washington, D.C., 1965).

24. Harry Weakly, "A Tree-Ring Record of Precipitation in Western Nebraska," *Journal of Forestry* 41 (1943): 816–19.

25. This statistical procedure is explained below (p. 19).

26. H. Harper, "Drought in Central Oklahoma from 1710 to 1959 Calculated from Annual Rings of Post Oak Trees," *Proceedings of the Oklahoma Academy of Science* 41 (1961): 23–29.

27. Weakly, "Tree-Ring Record."

28. Florence Hawley, *Tree-Ring Analysis and Dating in the Mississippi Drainage,* University of Chicago Publications in Anthropology Occasional Papers no. 2 (1941): 1–110.

29. Harper, "Drought Years in Central Oklahoma," p. 26.

30. Fritts, "Growth-Rings of Trees."

31. Hawley, "Tree-Ring Analysis."

32. H. P. Hansen, "Ring Growth and Dominance in a Spruce-Fir Association in Southern Wyoming," *American Midland Naturalist* 23 (1940): 442–47.

33. In this respect, G. Malcolm Lewis' conclusions (above, p. 7) concerning probable moisture conditions experienced on the plains during the particular years of Gilpin's traversal could be challenged.

34. Albertson, Tomanek, and Riegel, "Ecology of Drought Cycles."

35. Schulman, *Dendroclimatic Changes.*

36. Hawley, "Tree-Ring Analysis."

37. Weakly, "Tree-Ring Record."

38. George Will, *Tree Ring Studies in North Dakota,* North Dakota Agricultural Experiment Station Bulletin No. 338 (Fargo, 1946); Harper, "Drought Years in Central Oklahoma."

39. J. Murray Mitchell, Jr., et al., *Climatic Change,* World Meteorological Organization Technical Note no. 79 (Geneva, 1966).

40. Utilization of this form of moving statistic produces an inherent lag in the plot which can vary according to the length of the subperiod evaluated. For this reason, the calendar year in the upper graph portion of the plots is not identified specifically.

41. Derek J. Schove, "Tree Rings."

42. P. Lewis, "The Use of Moving Averages in the Analysis of Time-Series," *Weather* 15 (1960): 121–26.

43. F. Keen, "Climatic Cycles in Eastern Oregon as Indicated by Tree-Rings," *Monthly Weather Review* 65 (1937): 175–88.

CHAPTER 3

1. Herman Friis, "The Documents and Reports of the United States Con gress: A Primary Source of Information on Travel in the West, 1783–1861," in *Travelers on the Western Frontier,* ed. J. McDermott (Chicago, 1970), pp. 113–14.

2. Yi-Fu Tuan, "Topophilia: Personal Encounters with the Landscape," *Landscape* 2 (1961): 29–32.

3. A preliminary attempt to rectify this methodological gap in the research is Merlin Lawson's "A Behavioristic Interpretation of Pike's Geographical Knowledge of the Interior of Louisiana," *Great Plains–Rocky Mountain Geographical Journal* 1 (1972): 58–64.

4. Sources relating the history of organized meteorological records in the United States include the following early publications: United States Weather Bureau *Bulletin* 11 (Washington, D.C., 1894): p. 207–352; Gustavus A. Weber, *The Weather Bureau: Its History, Activities and Organization* (New York, 1922); Eric R. Miller, "The Evolution of Meteorological Institutions in the United States," *Monthly Weather Review* 59 (1931): 1:6; United States, National Archives, *List of Climatological Records in the National Archives,* Special List no. 1 (Washington, D.C., 1942); Lewis J. Darter, *Weather Service Activities of Federal Agencies Prior to 1891* (Washington, D.C.; United States Weather Bureau, 1943); H. E. Landsberg, "Early Stages of Climatology in the United States," *American Meteorological Society Bulletin* 45 (1964): 268–75.

5. Charles Smart, "The Connection of the Army Medical Department with the Development of Meteorology in the United States," Weather Bureau *Bulletin* 11 (Washington, D.C., 1894): 207–16.

6. Thomas Lawson, *United States Meteorological Register* (Washington, D.C.: Office of the Surgeon General, 1851).

7. R. H. Coolidge, *Statistical Report on the Sickness and Mortality of the Army of the United States* (Washington, D.C.: Office of the Surgeon General, 1856).

8. J. Henry and J. Coffin, *Meteorological Observations,* 2 vols. (Washington, D.C.: Smithsonian Institution, 1861, 1864).

9. S. P. Langley, "The Meteorological Work of the Smithsonian Institution," United States Weather Bureau *Bulletin* 11 (Washington, D.C., 1894): p. 218.

10. Before 1859 two general observational categories of data were available—SG-1, authorized by the Surgeon General's Office, and SI, Reports for the Smithsonian Institution. Both Meteorological Reports (SG-1), 1819–59, and Voluntary Observations of the Smithsonian Institution (SI) have been transferred to the National Archives and rebound alphabetically by state. These are now available on microfilm.

11. United States, National Archives, *List of Climatological Records,* p. xliii.

12. The legibility of these records generally is satisfactory. Microfilms of the documents often have less clarity, especially when the writing from the opposite page shows through. Often the impression of this writing becomes intensified by the photographic process. The surgeon recording observations at

Fort Gibson wrote with exceptional style. Ironically, his signature is so ornate that his name cannot be identified.

13. Merrill J. Mattes, *The Great Platte River Road* (Lincoln, Nebr., 1969).

14. Weston is across the Missouri River from and four miles north of Fort Leavenworth.

15. W. J. Ghent, *The Road to Oregon* (New York, 1929).

16. David Lavender, *Westward Vision* (New York, 1962).

17. George R. Stewart, *The California Trail* (New York, 1962).

18. See figure 16.

19. The term *secular,* used synonymously with *modern,* connotes recent instrumental quantitative meteorological observations.

20. Mattes, *Great Platte River Road,* p. 104.

21. The Asiatic cholera spread primarily by steamboat passengers from Saint Louis so that by May 2, the surgeon at Fort Leavenworth first reports "cholera prevailing."

22. The original name of Fort Kearny.

23. Elizabeth Page, *Wagons West* (New York, 1930), p. 129.

24. Fort Kearny Meteorological Data, Office of the Surgeon General, Record Group 112, United States National Archives.

25. Capt. Howard Stansbury, *Exploration and Survey of the Valley of the Great Salt Lake of Utah* (Philadelphia, 1852), p. 31.

26. Period of record with assumed homogeneous observations.

27. Today the National Weather Service simply calculates the average of the highest and the lowest temperature recorded during the twenty-four-hour period.

28. Mattes, *Great Platte River Road,* p. 185.

29. J. Goldsborough Bruff, *Gold Rush: Journals, Drawings and Other Papers,* ed. G. Read and R. Gaines (New York, 1944), p. 22.

30. Estimate recorded in numbers from zero, indicating calf, to six, indicating a violent storm.

31. H. E. Landsberg, "Trends in Climatology," *Science* 128 (1958) : 755.

32. J. Murray Mitchell, Jr., "Annotated List of Long-Record Climatological Stations in the United States," United States Weather Bureau, mimeograph.

33. Meteorological records did not begin at Fort Marcy until September, 1849.

34. H. H. Lamb and A. Johnson, "Climatic Variation and Observed Changes in the General Circulation," *Geografiska Annaler* 41 (1959): 94–134.

35. J. Murray Mitchell, Jr., "Effect of Changing Observation Time on Mean Temperature," *American Meteorological Society Bulletin* 39 (1958): 83–89.

36. As distinguished from the recent secular record.

37. Although records continued at some forts after 1855, to facilitate comparability of data among all forts, the record was not evaluated beyond that year.

CHAPTER 4

1. Bayard Taylor, *Eldorado; or, Adventures in the Path of Empire* (New York, 1862), p. 282.

2. Variations of notable magnitude exist in estimates of pioneers during this migration period. Higher estimates have been made by Bidlack: "Fifty thousand Americans migrated to California in 1849, nearly one hundred thousand set out in 1850, and even greater numbers went in 1851 and 1852" (Russell E. Bidlack, *Letters Home: The Story of Ann Arbor's Forty-Niners* [Ann Arbor, Mich., 1960], p. 51.

3. James D. Lyon, in a letter to the Detroit *Daily Advertiser,* wrote, as he approached Fort Laramie in 1849, "We are told that the elephant is in waiting, ready to receive us. . . . if he shows fight or attempts to stop us on our

progress to the golden land, we shall attack him with sword and spear." The elephant appears to have been a common mythical symbol denoting danger or adventure during the westward migration. John Walton Caughey, in his *Seeing the Elephant: Letters of R. R. Taylor, Forty-Niner* (Los Angeles, 1951), p. xlii, explains this phrase very convincingly: "In those pre-Republican days this phrase conveyed the meaning of going through a trying and unpleasant experience and getting the best of it, or at least coming out alive. To 'see the elephant' was to graduate completely from the status of greenhorn. The Forty-Niners 'saw elephants' on the plains, at Panama, rounding the Horn, and needless to add, in the diggings."

4. Dale Morgan, "The Significance and Value of the Overland Journal," *El Palacio* 69 (1962): 71.

5. Ibid., p. 71.

6. Mattes, *Great Platte River Road,* p. 24

7. Those attempting to write legible letters to their families in the East would normally include a complaint about the writing conditions which borders on making excuses. D. T. McCallum included this unique explanation for his poor handwriting in a letter mailed from Fort Laramie: "I have written this on the ground—and poorly I have done it,—my hand is not steady. I have just been bringing water, some half mile and my nerves are unsteady" (Bidlack, *Letters Home,* p. 21).

8. In 1849, there were three instruments capable of estimating mileage—the viameter, the odometer, and the roadmeter. The principle of operation was a simple calculation of the number of wagon wheel turns in a day multiplied by the circumference of the wheel. For details see Jesse Gould Hannon, *The Boston-Newton Company Venture* (Lincoln, Nebr., 1969), p. 24.

9. Helen S. Giffen, ed., *The Diaries of Peter Decker* (Georgetown, Calif., 1966), p. 16.

10. See figure 19.

11. William Graham Johnston, *Overland to California* (Oakland, Calif., 1948), p. 12.

12. Ibid., pp. 17–18.

13. Giffen, *Diaries of Decker,* p. 54.

14. Hannon, *Boston-Newton Company,* p. 34.

15. Johnston, *Overland,* p. 26.

16. Raymond W. Settle, ed., *The March of the Mounted Riflemen* (Glendale, Calif., 1940), p. 53.

17. James A. Pritchard, "Diary of a Journey from Kentucky to California in 1849," *Missouri Historical Review* 18 (1924): 541.

18. Walker D. Wyman, "The Outfitting Posts," *Pacific Historical Review* 18 (1949): 14–23.

19. Pritchard, "Diary," p. 538.

20. Howard L. Scamehorn, *The Buckeye Rovers in the Gold Rush* (Athens, Ohio, 1965), p. 16.

21. Giffen, *Diaries of Decker,* p. 78.

22. Israel Foote Hale, "Diary of Trip to California in 1849," *Quarterly of the Society of California Pioneers* 2 (1925): 66.

23. Johnston, *Overland,* p. 29.

24. The concept of "wading to California" was first advanced by Watson Parker, "Wading to California: The Influence of the Forty-Niners on the Notion of a Great American Desert," *Great Plains Journal* 3 (1964): 35–43. In his article, Parker assumes the notion of the desert existed, concluding that the heavy rains of the season must have done much to dispel such beliefs.

25. John E. Brown, "Memoirs of an American Gold Seeker," *Journal of American History* 2 (1908): 129–54.

26. Niles Searls, *The Diary of a Pioneer and Other Papers* (San Francisco: 1940), p. 12. Not everyone was as inconvenienced as Decker. Alonzo Delano took great care in digging trenches around his tent to allow the water to run off when the evening portended rain: "I never saw it rain harder, yet we found our tents a perfect protection, and we slept on our buffalo skin couches with as much composure, as if we had had a tiled roof over our heads" (Alonzo Delano, *Across the Plains and among the Diggings* [New York, 1936], p. 7).

27. Settle, *March of Riflemen,* p. 45.

28. Walker Wyman, *California Emigrant Letters* (New York, 1952), p. 56.

29. Charles Gould, "While Crossing the Plains—1849," copy of MS, Nebraska State Historical Society, Lincoln, Nebr.

30. Ibid., June 6.

31. Hale, "Diary," p. 66.

32. Brown, "Memoirs of an American Gold Seeker," p. 136.

33. Settle, *March of the Mounted Riflemen,* p. 304.

34. Page, *Wagons West,* p. 135.

35. Ibid., pp. 135–36.

36. Johnston, *Overland,* pp. 73–74.

37. James D. Lyon, letter of July 4, 1849, in the *Detroit Daily Advertiser,* September 10, 1849.

38. Joseph Berrien, "Overland from Saint Louis," ed. T. and C. Hinckley *Indiana Magazine of History* 56 (1960): 302.

39. H. Powell, *The Santa Fe Trail to California, 1849–1852* (San Francisco, 1931), p. 23.

40. J. Orin Oliphant, ed., *On the Arkansas Route to California in 1849* (Lewisburg, Pa., 1955), p. 39.

41. Mabelle E. Martin, ed., "From Texas to California in 1849: Diary of C. C. Cox," *Southwestern Historical Quarterly* 29 (1926): 38.

42. Ralph P. Bieber, ed., *Southern Trails to California in 1849* (Glendale, Calif., 1937), p. 266.

43. Powell, *Santa Fe Trail,* p. 23.

44. Potter, ed., *Trail to California: The Overland Journal of Vincent Geiger and Wakeman Bryarly* (New Haven, 1962).

45. Parker, "Wading to California," pp. 41–42.

46. These journals are listed as a separate category in the bibliography.

47. Examples of the trail positions of selected diarists on June 1 and July 1 are provided in figures 20 and 21.

48. This wind direction is neither confirmed nor refuted by any of the available diaries.

49. Giffen, *Diaries of Decker,* p. 67.

50. Johnston, *Overland,* p. 52.

51. Hale, "Diary," p. 66.

52. Ralph P. Bieber, "Diary of a Journey from Missouri to California in 1849," *Missouri Historical Review* 23 (1928): 19.

53. Stansbury, *Exploration and Survey,* p. 425

54. Ibid., p. 63.

CHAPTER 5

1. Peter Perry, "Twenty-five Years of New Zealand Historical Geography," *New Zealand Geographer* 25 (1969): 104.

2. William Koelsch, "Review of *Acadia: The Geography of Early Nova Scotia to 1760,* by Andrew H. Clark, in *Economic Geography* 46 (1970): 202.

3. History and geography.

4. Koelsch, review, p. 202.

5. M. Milankovitch, *Mathematische Klinalehre and Astronomische Theorie der Klimaschwankungen* (Berlin, 1930).

6. The term *Climatic Optimum* refers to a postglacial period of relatively high temperatures which existed about six-hundred years ago.

7. Franz Firbas, "The Late-Glacial Vegetation of Central Europe," *Phytologist* 49 (1950): 166.

8. Another astronomical hypothesis derived using a sun tide–solar energy relationship may evolve eventually into a numerical system of long-range forecasting, but as yet, its historical implications have not been demonstrated adequately. See C. Bollinger, "Sun Tides: An Unexplored Astronomical Approach to Climate Cycles and Trends," *Tellus* 20 (1968): 412–16.

9. Ernest Antevs, "Climatic Changes and Pre-White Man," *University of Utah Bulletin* 38 (1948): 168–91; Ernest Antevs, "Geologic-Climatic Dating in the West," *American Antiquity* 20 (1955): 317–55; J. B. Griffen, "Some Correlations of Climatic and Cultural Change in Eastern North American Pre-history," *Annals of the New York Academy of Sciences* 95 (1961): 710–17; P. Wells, "Postglacial Vegetational History of the Great Plains," *Science* 167 (1970): 1574–82.

10. Antevs, "Geologic-Climatic Dating," pp. 317-335.

11. R. Bryson, D. Baerreis, and W. Wendland, "The Character of Late- and Post-Glacial Climatic Changes," in *Pleistocene and Recent Environments of the Central Great Plains,* edited by W. Dort, Jr., and J. Jones, Jr. (Lawrence, Kans., 1970), pp. 53–74.

12. J. Sawyer, "Possible Variations of the General Circulation of the Atmosphere," in *Proceedings of the International Symposium on World Climate* (London: 1966), pp. 218–29.

13. Bryson, Baerreis, and Wendland, "Character of Climatic Changes," p. 55.

14. Wells, "Postglacial Vegetational History," p. 1578.

15. Bryson, Baerreis, and Wendland, "Character of Climatic Changes," pp. 53–74.

16. Frederick E. Zeuner, *Dating the Past: An Introduction to Geochronology* (London, 1958), p. 57.

17. *Recent* here is interpreted as referring to the geologic Holocene Epoch of the last ten thousand years.

18. H. Lamb, R. Lewis, and A. Woodroffe, "Atmospheric Circulation and the Main Climatic Variables between 8000 and 0 B.C.: Meteorological Evidence," in *Proceedings of the International Symposium on World Climate, 8000 to 0 B.C.* (London, 1960), pp. 174–217.

19. R. Bryson, and W. Wendland, *Tentative Climatic Patterns for Some Late-Glacial Episodes in Central North America,* Technical Report No. 34, Department of Meteorology, University of Wisconsin (Madison, 1967), p. 280.

20. Lamb and Johnson, "Climatic Variation," pp. 94–134.

21. S. Porter and G. Denton, "Chronology of Neoglaciation in the North American Cordillera," *American Journal of Science* 265 (1967): 177–210.

22. H. H. Lamb, *The Changing Climate* (London, 1966).

23. J. Murray Mitchell, Jr., "On the World-Wide Pattern of Secular Temperature Change," in *Proceedings of the World Meteorological Organization,* UNESCO Symposium on Climatic Changes (Rome, 1961), pp. 161–81.

24. Hurd C. Willett, "Solar Variability as a Factor in the Fluctuations of Climate during Geological Time," *Geografiska Annaler* 31 (1949): 295–315.

25. The individual postulates of these men are synthesized here into a single compatible model for the Little Ice Age in the interior West.

26. Bryson and Wendland, *Tentative Climatic Patterns,* p. 296.

27. The end of the Little Ice Age is placed between 1850 and 1880 by various writers, thus indicating a gradual transition rather than abrupt change.

28. M. P. Lawson, D. C. Rundquist, and A. J. Peters, "Secular Temperature Change in the Interior United States," *Great Plains–Rocky Mountain Geographical Journal* 1 (1972): 65–73.
29. These precise dates were dictated by the available record.
30. Caution must be exercised because of the relatively short duration of record and the possibility of inhomogeneous data—the historical climatologist's ever present problems.
31. Tree-ring evidence is unsatisfactory for establishing or identifying long-term changes in climate because of the way in which the measurements are standardized. Thus, attempts to identify the Little Ice Age using dendroclimatological techniques have not been successful. Short-term fluctuations of the type demonstrated in Chapter 2 would indicate that this relatively moist period experienced severe fluctuations in precipitation, if not serious droughts.
32. B. L. Dzerdzeevskii, "The General Circulation of the Atmosphere as a Necessary Link in the Sun-Climatic Variations Chain," *Annals of the New York Academy of Sciences* 95 (1961): 189.
33. B. Duell and G. Duell, "The Behavior of Barometric Pressure during and after Particle Invasions and Solar Ultraviolet Invasions," Smithsonian Institution *Miscellaneous Collections* 110 (1948).
34. R. Craig and D. Hawkins, *Atmospheric Pressure Changes and Solar Activity,* Special Report no. 38, A.M.C. Contract W19-122ac-17 (1951).
35. Hurd C. Willett, "The Pattern of Solar Climatic Relationships." *Annals of the New York Academy of Science* 95 (1961): 93.
36. The term *cycle* is applied here out of deference to common usage. A more accurate term would be *sunspot rhythm,* which recognizes the irregularities in the interval between sunspot maxima and minima.
37. Dzerdzeevskii, "General Circulation of the Atmosphere," p. 190.
38. H. C. Willett and J. T. Prohaska, *Long Term Solar-Climatic Relationships,* Final Scientific Report, NSF Grant 14077 (1963).
39. B. L. Dzerdzeevskii, "Climatic Epochs in the Twentieth Century and Some Comments on the Analysis of Past Climates," in *Quaternary Geology and Climate,* Proceedings of the VII Congress of the International Association for Quaternary Research (1969), p. 51.
40. John Borchert, "The Dust Bowl in the 1970's," *Annals of the Association of American Geographers* 61 (1971): 1–22.
41. Dzerdzeevskii, "Climatic Epochs," p. 51.
42. Borchert, "Dust Bowl in the 1970's," p. 8.
43. Dzerdzeevskii, "General Circulation," pp. 188–99; Dzerdzeevski, "Climatic Epochs," pp. 49–60.
44. Hurd C. Willett, "Solar-Climatic Relationships," in *Encyclopedia of Atmospheric Sciences and Astrogeology,* ed. Rhodes Fairbridge (New York, 1967), pp. 869–78.
45. Hurd C. Willett, personal communication, May 28, 1971.
46. For an explanation of this statistical procedure and its application to the specification of space and time variability of circulation and climate, see World Meteorological Organization Technical Note no. 79, *Climatic Change,* by J. Murray Mitchell, Jr., et al. (Geneva, 1966), pp. 72–75.
47. N. A. Bengtson, "Is the Rainfall of Nebraska Decreasing?" Nebraska Irrigation Association *Proceedings of the 43rd Annual Convention* (Lincoln, 1935), pp. 31–44.
48. Hurd C. Willett, personal communication, May 28, 1971.
49. See Chapter 2, figures 4 through 11.
50. See Chapter 2, figure 5 (p. 21).
51. See Chapter 2, figure 4 (p. 20).
52. Mitchell et al., *Climatic Change,* pp. 33–46.

53. Palmer's Meteorological Drought Index measures drought severity as represented by the degree of moisture anomaly for a given period compared with the climatically expected moisture supply for a particular region. For details concerning the computation of the drought values, see Wayne C. Palmer, *Meteorological Drought.*

54. Mitchell et al., *Climatic Change,* p. 45

55. Harry E. Weakly, "History of Drought in Nebraska," *Journal of Soil and Water Conservation* 17 (1962): 271, 273, 275; Harry E. Weakly, "Recurrence of Drought in the Great Plains," *Agricultural Engineering* 46 (1965): 85.

56. Harold C. Fritts, personal communication, September, 1971.

57. Thomas Kuhn, "Paradigms and Some Misinterpretations of Science," in *Philosophical Problems of Natural Science,* edited by Dudley Shapere (New York, 1965), p. 90.

CHAPTER 6

1. An examination of the exploratory process which considers its implications for the Lewis and Clark expedition of 1804–1806 is John Allen, "An Analysis of the Exploratory Process," *Geographical Review* 62 (1972): 13–39. See also John Allen, "Geographical Knowledge and American Images of the Louisiana Territory," *Western Historical Quarterly* 2 (1971): 151–70.

2. Merlin P. Lawson, "A Dendroclimatological Interpretation of the Great American Desert," *Proceedings of the Association of American Geographers* 3 (1971): 109–14.

3. Lewis, "William Gilpin," p. 43.

APPENDIX 2

1. John T. Roscoe, *Fundamental Research Statistics* (New York, 1969).

2. H. C. S. Thom, *Some Methods of Climatological Analysis,* World Meteorological Organization Technical Note no. 81 (1966), p. 18.

3. W. C. Krumbein and F. A. Graybill, *An Introduction to Statistical Models in Geology* (New York, 1965).

4. Roscoe, *Fundamental Research Statistics,* p. 54.

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Fort Washita
Jefferson Barracks
Saint Louis Arsenal

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