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SYNOPTIC CLIMATOLOGY OF THE WESTERN UNITED STATES IN RELATION TO CLIMATIC FLUCTUATIONS DURING THE TWENTIETH CENTURY

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ABSTRACT

An objectively derived catalogue of daily pressure patterns for 1899–1974 has been prepared for the western United States. The temperature and precipitation characteristics of the major types are described and a more detailed analysis for Colorado in extreme cold and warm months shows that the sign of the anomalies for each type is generally consistent with expectation based on the probable airflow patterns. A regression analysis of type frequencies versus temperature and precipitation anomalies for 1899–1970 at stations east and west of the Continental Divide in the Rocky Mountain states shows that useful explanation of variance is obtained only for temperatures in the transition seasons and for precipitation west of the Divide in winter and east of the Divide in spring. Within-type variability of the climatic characteristics is one source of the discrepancy. The results underline the problems encountered in trying to link climatic anomalies with atmospheric circulation characteristics.

KEY WORDS Synoptic climatology Western United States Recent climatic fluctuations Climatic anomalies

INTRODUCTION

The method of stratifying synoptic weather maps into types as a basis for climatic analysis, or for analogue forecasting, has a long history (see Barry and Perry, 1973). For the United States, Krick (1943) and Elliott (1943, 1949) prepared a catalogue of 3-day and 6-day weather sequences in the 1930's, for example. Based on patterns of surface and upper airflow, it was intended to provide a means of long range forecasting. With the advent of computer facilities, various objective typing methods have developed such as the correlation technique of Lund (1963), but the applications have been mainly limited to climatic description. The possibility of using synoptic catalogues to examine spatial aspects of climatic fluctuations has been little used in North America, although in Europe and the Soviet Union this approach has been common (Dzerdzeevski, 1968; Perry and Barry, 1973). This study outlines a classification of surface pressure types developed for the western United States and describes the application of the catalogue to an analysis of climatic trends in the twentieth century. Other classifications for the area using Lund's approach have been devised by Augulis (1969), Barry (1972), Hartranft *et al.* (1970), and Paegle and Kierulff (1973). These studies, including the present one, all approach the problem of map similarity based on the spatial *pattern* of the isobars. Blasing (1975, p. 99) notes that the natural modes of atmospheric behaviour show distinct recurring patterns rather than necessarily being constrained to be orthogonal.

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METHODS

MSL pressure data are used because they constitute the longest record of airflow patterns over western North America. The analysis is based on daily values at 35 points on a diamond grid covering the sector 20°–60°N, 95°–130°W (see Figure 1) for the period of Historical Weather Map Series and subsequent NMC analyses, i.e. January 1899–August 1974. The data set was made available by the National Center for Atmospheric Research, Boulder. The series has the period December 1944–December 1945, and 60 other days missing.

The catalogue of pressure patterns was developed using an objective technique of Kirchhofer (1973), with slight modifications. Kirchhofer's method, which he used to classify patterns of 500-mb heights over Europe, has the following steps:

1. Pressure data at grid points are normalized for each daily map.
2. Each day is compared with every other day on the basis of the sum of squares of differences between the grid points.
3. Using an empirically derived threshold value for the sum of squares, patterns are separated into 'similar' and 'dissimilar' ones.

The normalization process is as follows:

$$Z_i = (X_i - \bar{X})/s$$

where

Z_i = normalized value of the ith grid point
X_i = original value of the ith grid point
$\bar{X}$ = mean of the 35-point grid
s = standard deviation of the 35-point grid

The normalization retains the spatial pattern but removes the effects of pressure magnitude. This is desirable if the same types are to be applicable to all seasons, since synoptic pressure gradients are much stronger in winter than summer.

The similarity measure for any pair of pressure patterns is the sum of squares of pressure differences at the grid points. This score, S, is

$$S = \sum_{i=1}^{N} (Z_{ai} - Z_{bi})^2$$

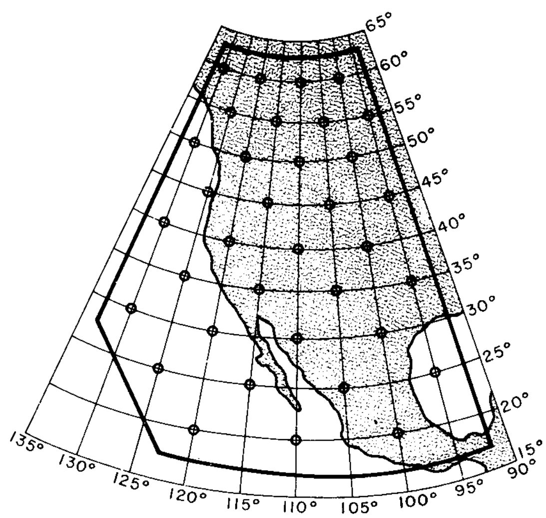


Figure 1. National Meteorological Center (NMC) grid points used in the surface pressure analyses

where

Z_{ai} = normalized grid value at point i on day a.
Z_{bi} = normalized grid value at point i on day b.
N = number of grid points;
$N = 35$ for whole pattern;
$N = 4$ for latitudinal zones (other than at 20°N where $N = 3$)
$N = 9$ for meridional zones (except the westernmost where $N = 8$)

The similarity measure between a pair of patterns is computed for all 35 grid points, as well as for 9 latitudinal and 4 meridional zones shown in Figure 1. The overall score is compared with an arbitrary threshold value of N, where $N = 35$, unless data are missing at points. In the case of the zone scores, a threshold value of $1{\cdot}8N$ (where $N = 3$ to 9) is used. The overall score and the score for each zone must not exceed their respective threshold values in order for the patterns to be accepted as similar. These threshold values were determined empirically by inspection of the results using several different values, initially based on those of Kirchhofer. For upper air maps, a lower threshold score must be used. As in the case of correlation coefficients, if too stringent a criterion is adopted, numerous well-defined but infrequently occurring types are obtained. Conversely, if the threshold value is set at a high S score, then few types with considerable internal variability are defined.

When all pairs of patterns have been compared, the pattern-day to which most other pattern-days are similar is designated the *key day* for Type 1. All Type 1 days are then extracted from the data set. The pattern-day with the next highest frequency of similar pattern-days is designated the key day for Type 2 and these days are then removed. This process is continued until all days are grouped into clusters of five or more. Pattern-days which are similar to fewer than four other days are consider 'unclassified'.

Due to the prohibitive computer cost of operating with the full record, a sample period of 60 months was selected to develop the key days of the classification. Five sets of each month of the year were chosen to include one extreme zonal pattern, one extreme meridional pattern and three intermediate cases, between 1950 and 1974, based on the month-by-month analyses of circulation published in *Monthly Weather Review*. The period was restricted to facilitate possible future analysis using upper air data in conjunction with MSL data. The procedure described was applied to the daily MSL pressure data and 31 *key day types* were generated from the 60-month record.

Obviously, numerous pattern-days score below the threshold value for more than one key day. These could be misclassified if they were entered in a large group and thus removed from the total data set before the type group to which they were *most* similar was processed. Therefore, the screening comparison is repeated, comparing each pattern-day against the 31 key days. A pattern-day is grouped with the key day against which it has the lowest overall score below the threshold value, with no zone score exceeding its appropriate threshold value.

For the 60-month *sample period*, 95·6 per cent of the 1827 days were classified into one of the 31 types, leaving 65 days unclassified. To classify the entire period 1899–1974, the days had only to be compared (using the similarity measure) with the key days, instead of with every day of the 75 years.* The steps for classifying the entire record follow those used for the 60-month subset. After normalization, scores are calculated. Each day is classified with the key day against which its score is the lowest and below the threshold value. Finally, the 31 types have been renumbered according to frequency rank such that type 1 has the highest frequency, etc. Ninety-three per cent of all days with data are classified into the 31 types. The frequencies range from a maximum of 2163 days (8·0 per cent of all days) for Type 1, decreasing almost linearly to the minimum of 51 occurrences (0·2 per cent of all days) for Type 31. Figure 2 illustrates six key-day patterns from the catalogue which are described below. A listing of the catalogue can be obtained from the authors, on request.

The mean score of the days occurring in each type ranges from 15 to 25. The mean score broadly

* The time take on the University of Colorado CDC 6400 for the 60-month sample was approximately 122 min. compared with only 60 min. for classification of the 75 years.

increases with type ranking, indicating decreasing within-group similarity, although the lowest score, 15·3, occurs with Type 7. This is a winter pattern dominated by a Mackenzie high and southeasterly geostrophic flow. Standard deviations of the scores are similar for all types, averaging approximately 5. The types show a rather low degree of day-to-day persistence, typically 20–30 per cent, in contrast with the much higher values, often in excess of 50 per cent, obtained by Moritz (1979) using an identical technique for Alaska. This represents a latitudinal contrast in synoptic pattern variability and persistence.

CLIMATIC CHARACTERISTICS OF SELECTED SYNOPTIC TYPES

The pressure pattern groupings must each be associated with a distinctive suite of weather/climate elements, if the catalogue is to be of practical value. In order to assess the degree of discrimination of climatic elements afforded by the catalogue, mean daily values of temperature and precipitation have been calculated for each type at 30 locations in the western United States (Figure 3). Fourteen stations are located east of the Continental Divide on the high plains, sixteen are west of the Divide. In view of the large area covered (32–49°N, 102–125°W), and the variety of climatic regimes in this region, substantial spatial variation in the distribution of weather elements associated with any synoptic type group is to be expected.

Means and standard deviations of daily maximum temperature with each type at each of the 30

Figure 3. Location map of stations used in the analysis of the circulation types

stations have been computed on a monthly basis for 1931–70. Maxima are less susceptible to local topoclimatic effects, such as low-level inversions, than mean daily temperature and, therefore, are more suitable for analysis. In the same manner, a measure of the 'precipitation efficiency' of each type has been determined. This is termed the specific precipitation density (SPD) defined by

$$\text{SPD}\,(\%) = \left(\frac{\text{mean daily precipitation for type } i}{\text{mean daily precipitation on all days}}\right) \times 100.$$

A precipitation day is defined as a day with ≥0·01 in (0·25 mm) of measured precipitation. If a type has 'average' precipitation characteristics, its SPD is equal to 100.

The climatic characteristics of the six types illustrated in Figure 2 can now be discussed. Their seasonal frequency is displayed in Figure 4 and selected maps of temperature anomaly and SPD patterns are given in Figures 5 and 6. These types have been selected to illustrate some of the more distinctive climatic patterns.

The most common type, which is a zonal pattern (Figure 2), is predominantly a cold season type. During winter and spring, it gives rise to generally warm, dry conditions as a result of widespread subsidence associated with a long-wave ridge aloft. Anomalies exceed +5 degrees in eastern Montana, declining southward and westward. Roswell, New Mexico, is apparently cool and wet as a result of moist southeasterly airflow. Type 1 is very dry throughout the year in all other areas except western Washington, where cyclones to the north play a role. Summer thunderstorms also account for higher values in the Great Basin in July. Type 1 is rather persistent, especially in association with Type 3, which resembles it (Figure 2). Type 3 is quite warm and very dry in all seasons from eastern Montana southward to New Mexico. In the Pacific northwest it is warm and wet during winter under southwesterly flow, but in this area during the remainder of the year it is cool and wet due to low pressure systems over British Columbia. In California it is cool and wet in all seasons except summer. The cyclonic influences with patterns of Type 3 evidently decrease southeastward. Conditions in the Great Basin with this type are close to seasonal averages.

Type 2, which is most common in the warm season (Figure 4) features a weak trough extending northward from Baja California and an anticyclone over western Canada (Figure 2). It gives cold and wet conditions east of the Divide in all seasons, with the largest anomalies in Montana and Wyoming (Figures 5(a), 6(a)). It is cold, but dry in the Pacific northwest in winter, and warm there in spring. California is warm and dry in all seasons, except for Salinas in winter. In January, the low over Baja California is sometimes a Pacific storm creating wetter than average conditions with this type in Utah and Arizona. High altitude areas of the east slope of the Rocky Mountains appear to be affected by upslope flow conditions associated with cut-off lows or upper troughs with Type 2.

Types 1–3 together account for almost 25 per cent of days in the period covered by the synoptic catalogue. Type 7 (Figure 2; Figures 5(b), 6(b)) gives cold conditions east of the Divide in winter and spring, associated with northerly flow and a shallow polar anticyclone. Anomalies decrease southward. Temperatures are above average west of the Divide, especially in the Great Basin, and below average on the west coast apart from the northwest, where it is warm in spring. Precipitation is high in California, reflecting Pacific lows entering the northwest, and winter precipitation is also high in the Great Basin. Type 7 is rare in summer (Figure 4), but at other seasons the amplified wave patterns associated with this type tend to be persistent. Type 8 (Figure 2), with an extensive low over the southern part of the area, has variable precipitation characteristics. It is wet in the north and dry in the southeast in all seasons (Figure 6(c)). It is also cold except for eastern Colorado and New Mexico (Figure 5(c)). Spring upslope regimes, giving cool wet conditions in the north, are represented as well as frontal patterns which produce warm, dry weather in the south. Conditions are most variable with Type 8 in Colorado, depending on the exact location of the low in this area. In summer, the low is sometimes a heat low. Temperatures with Type 8 tend to be higher than average east of the Divide, and lower to the west.

Type 10 with a low in the northern plains (Figure 2) is cold along the coast in all seasons, due to northwesterly flow (Figure 5(d)). Inland, it is warm in winter, but it is a cold type in the Great Basin in

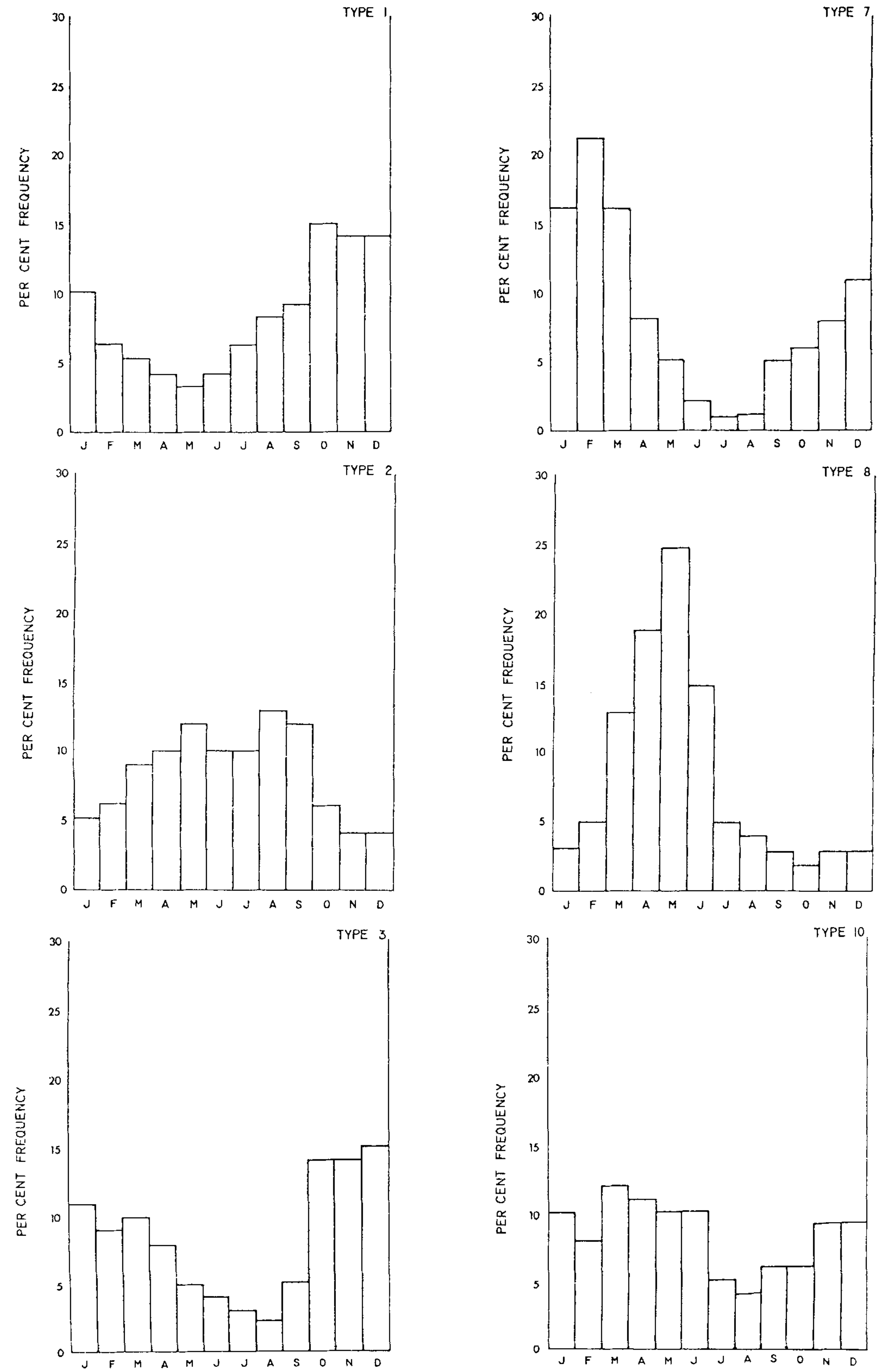
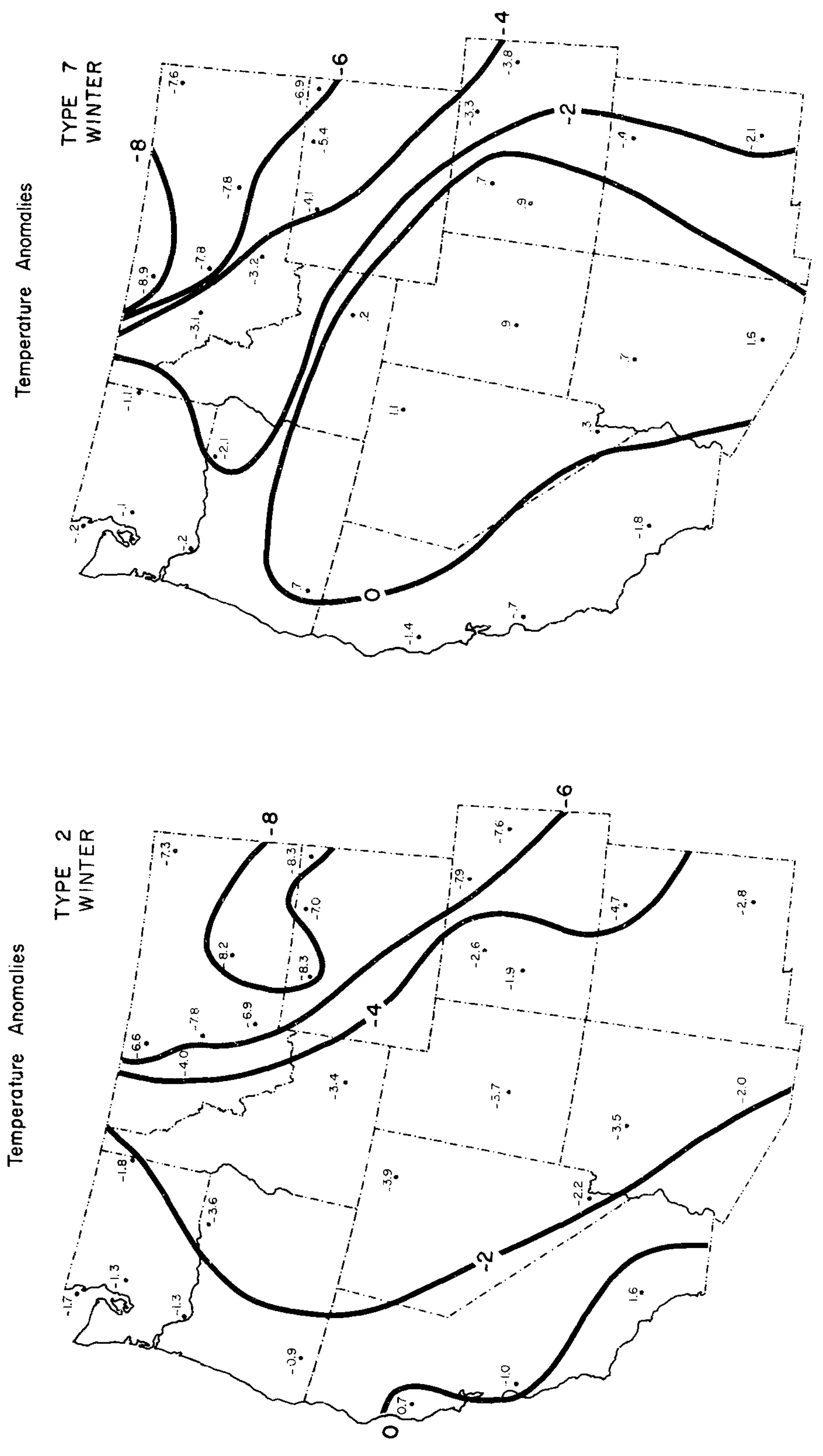


Figure 4. Seasonal frequency (per cent) of selected circulation types expressed as the average frequency of the type in a given month divided by its average annual frequency times one hundred


Temperature Anomalies
TYPE 7
WINTER
(b)
Temperature Anomalies
TYPE 2
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0
250
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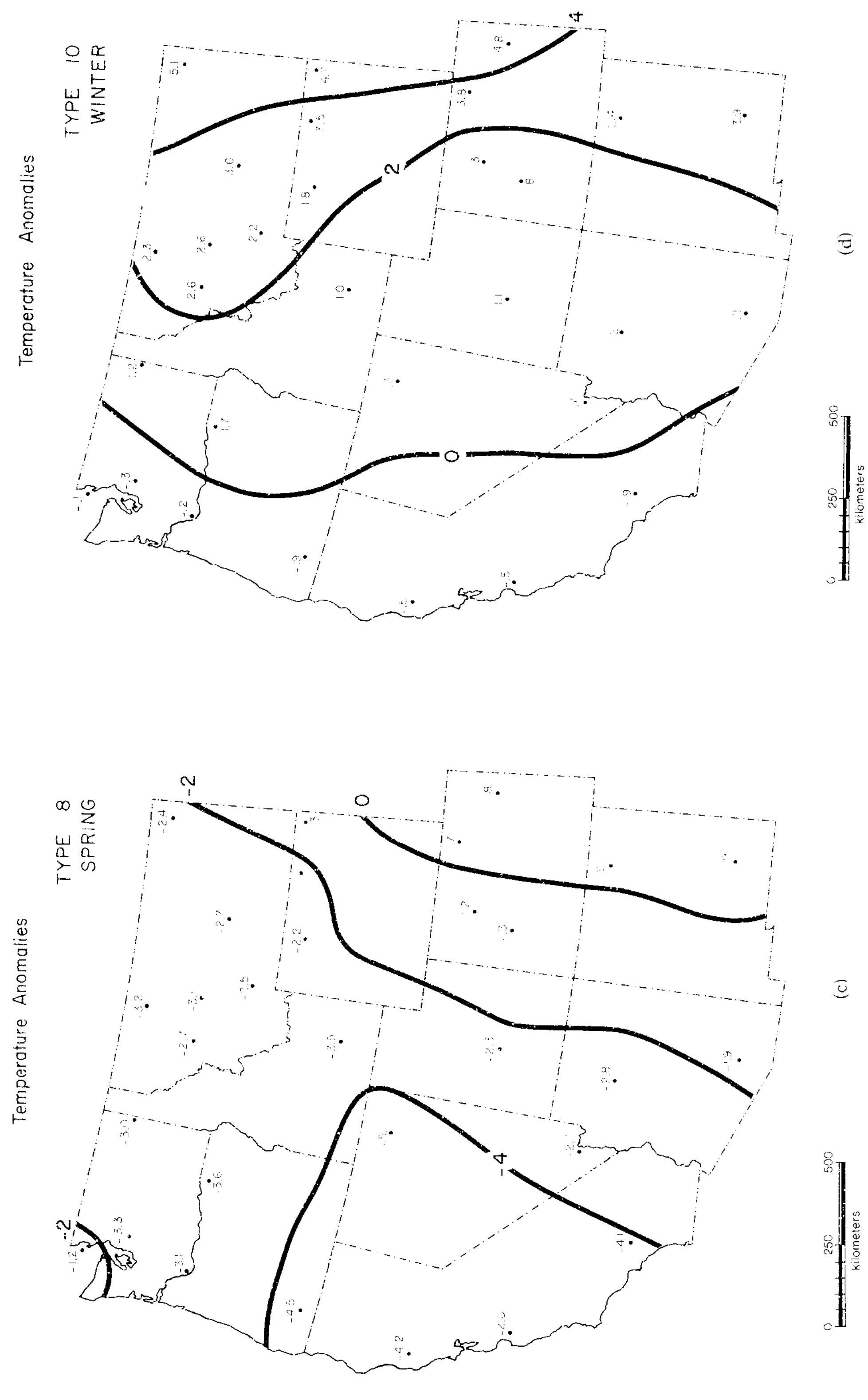
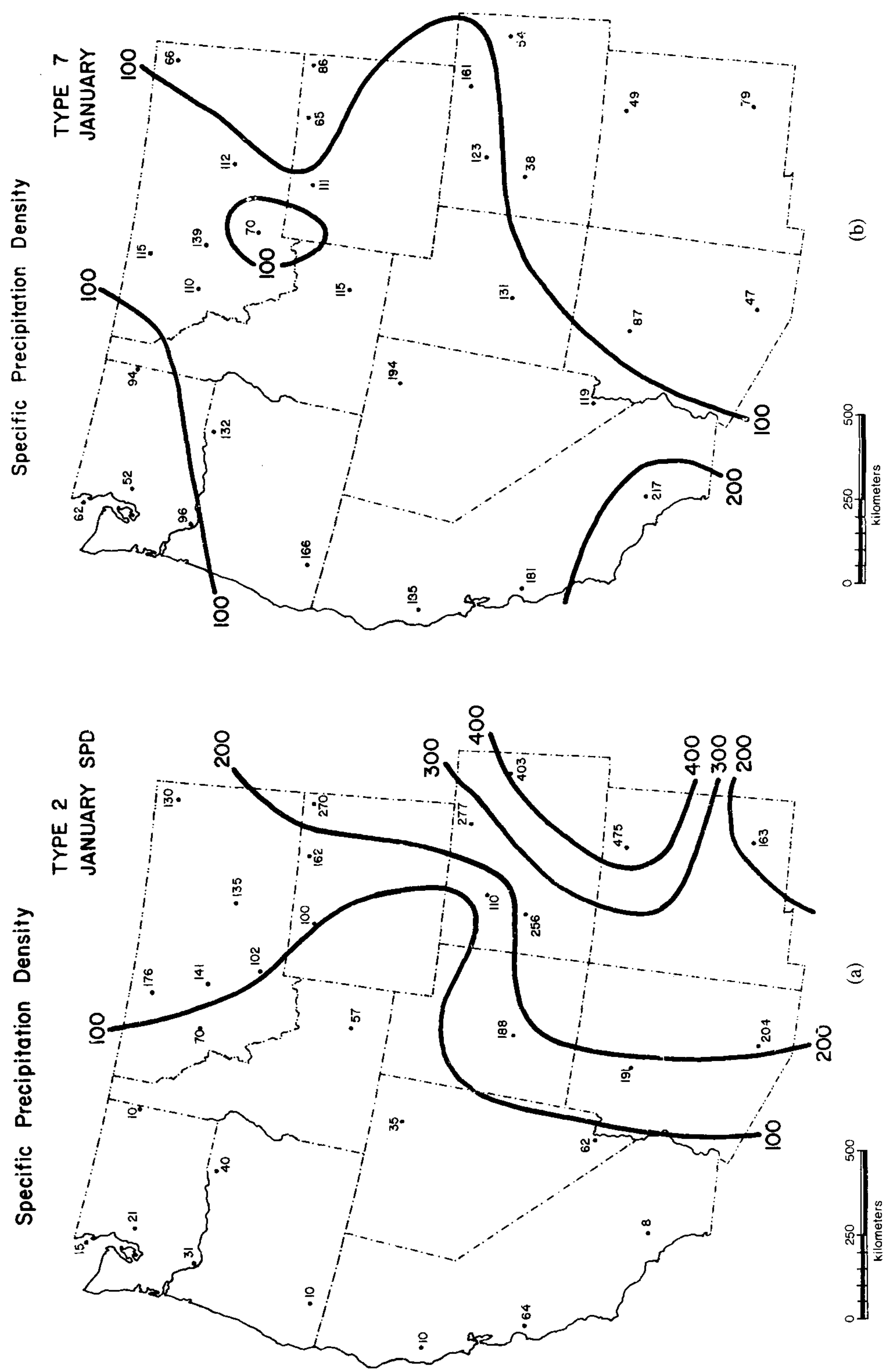


Figure 5. Seasonal temperature anomaly patterns for four circulation types: (a) Type 2, winter; (b) Type 7, winter; (c) Type 8, spring; (d) Type 10, winter


Specific Precipitation Density
TYPE 2
JANUARY SPD
0
250
500
kilometers
Specific Precipitation Density
TYPE 7
JANUARY
0
250
500
kilometers

(a)

(b)

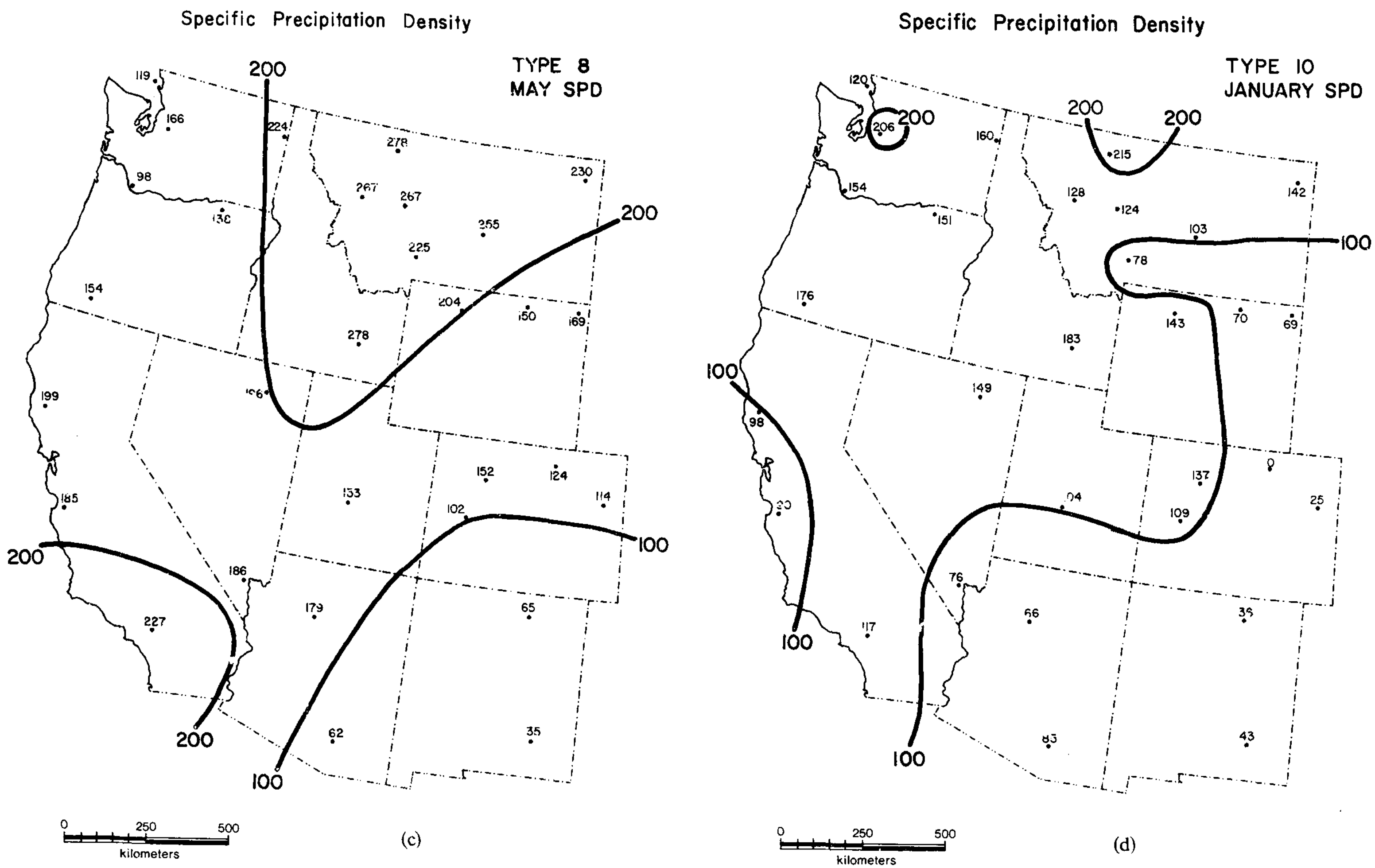


Figure 6. Seasonal patterns of specific precipitation density (see text) for four circulation types: (a) Type 2, January; (b) Type 7, January; (c) Type 8, May; (d) Type 10, January

all other seasons. Type 10 is wet in all months in the northwest due to frontal depressions. East of the Divide in Colorado and New Mexico it gives warm dry winter weather, often associated with downslope winds over the high plains (Figure 6(d)).

CLIMATIC TRENDS IN RELATION TO SYNOPTIC TYPES

Seasonal temperature and precipitation departures from the 1941–70 means have been determined for all long-term homogeneous records available in the Rocky Mountain states during the period 1891–1970 (Figure 7). The procedure for assessing homogeneity is described by Bradley (1976a). Details of the temperature data bank are given in Bradley (1980). The number of records increases from only a few in the early 1890s to 169 for precipitation and 129 for temperature by the 1920s. The number then remains approximately constant to 1970. About 60–65 per cent of the stations were operating for most of the period west of the Continental Divide.

Figures 8 and 9 show the composite series of 5-year mean temperatures and precipitation for 1891–1970 for stations located east and west of the Continental Divide by season: November–March (winter); April–May (spring); June–August (summer); September–October (autumn). Winter and spring coincide with the definitions of Mitchell (1976) based on air mass characteristics represented by equivalent potential temperatures. Mitchell considers that a summer pattern prevails from June–September, although he notes that September and June are to some extent transitional months.

For precipitation on both sides of the Divide, variability is at a maximum in autumn and a minimum in winter (Table I). Temperature variability is highest in spring east of the Divide, although autumn and winter values are of comparable magnitude. West of the Divide, highest temperature variability occurs in winter. The most striking and coherent anomalies evident in Figures 8 and 9 are the dry warm 1930s and the tendency for generally warmer conditions during the second half of the record, especially east of the Divide.

The correlation between monthly mean temperature and monthly precipitation is generally negative in a north–south zone centred on 105°W (Crutcher, 1978; Madden and Williams, 1978), and this is

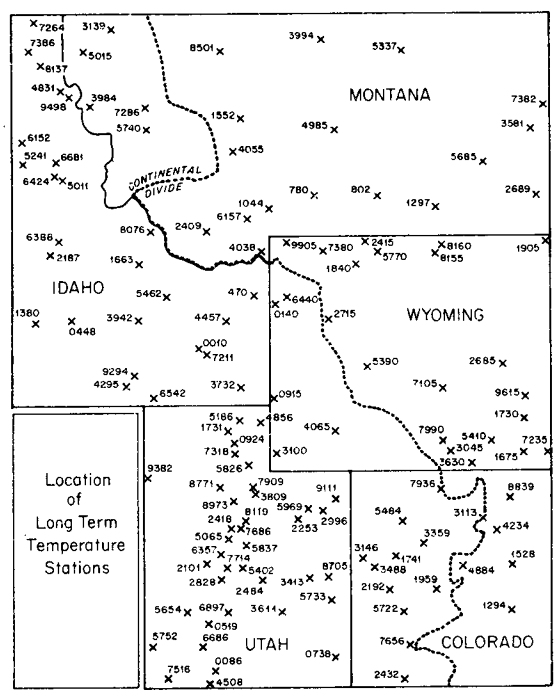


Figure 7. Location of long-term temperature stations used in the study. All records had at least 60 years of data. The stations are identified by the U.S. National Weather Service index number. Dashed line is the Continental Divide

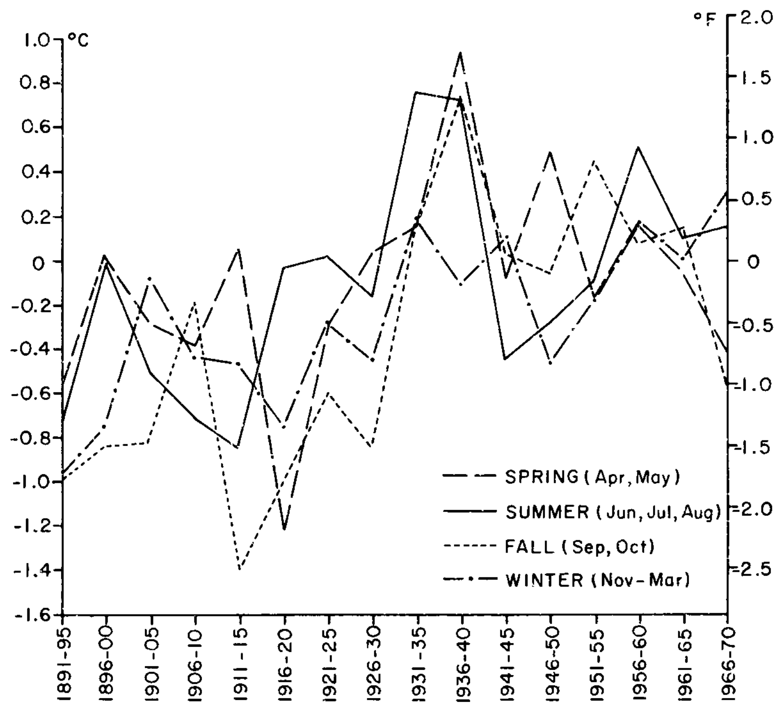


Figure 8. Five-year mean temperature departures, by season, from the means for 1941–70 for the stations shown in Figure 7. The number of records available increases from 6 in 1891 to 129 from 1920 on

confirmed for seasonal correlations at stations both east and west of the Divide, except east of the Divide in winter (Table II). This inverse relationship is not especially apparent visually in the seasonal trends shown in Figures 8 and 9, although it is evident in the annual graph prepared by Bradley (1980, Figure 5).

The climatic anomalies for each year have been compared on a seasonal basis with the frequencies of synoptic types 1–15 via a stepwise multiple regression analysis, in order to assess the degree of control exerted on the climatic trends by large-scale circulation patterns. Types 1–15 only are used because these account for 80 per cent of days in the record. Inclusion of the less frequent types in the regression analysis would lead to spurious correlations. Since many of the types give rise to distinctly different temperature and precipitation anomalies on either side of the mountains, the analysis has been performed separately for stations east and west of the Divide. Apart from examining the significance of the regression equations and the explained variance, attention has been given to the sign of the regression coefficients with respect to the observed anomalies of temperature and precipitation at stations east and west of the Divide.

Table III summarizes the seasonal regression equations for temperatures and precipitation in each year, 1899–1974 (excluding December 1944–December 1945). Confidence levels were determined by comparing the F-ratio to its expected value. According to Wetz (1964), the F-ratio should be at least four times the indicated F-table value for a multiple regression equation to be statistically significant. The highest explained variance and confidence levels (>95 per cent) are obtained for temperatures in autumn and spring. In the autumn, the same types appear in the regression equations for both sectors, with the same signs on the coefficients: Types 2, 4, 5 and 10 cold, Type 3 warm.

Although only six of the sixteen equations are statistically significant, the sign of the regression coefficient agrees in every case with the observed type characteristics in terms of both temperature and precipitation anomalies. This implies that the type frequencies do exert a control on the anomalies. For example, the equations for winter precipitation indicate that more frequent occurrences of Type 12 are

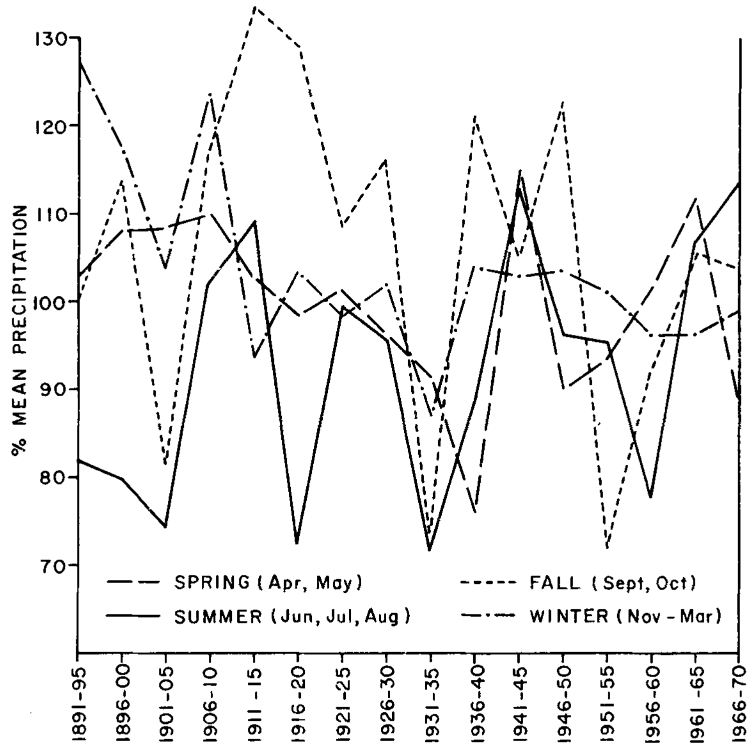


Figure 9. Five-year mean precipitation departures by season from the means for 1941–70. The number of records available increases from 9 in 1891 to ≥157 from 1920 on (see Bradley, 1980)

associated with dry winters east of the Divide. Type 12 is a blocking situation with high pressures over the northern plains which is indeed very dry east of the Divide. Similarly, Type 14 is wet on both sides of the Divide and Type 7 is wet in the west. Wet springs east of the Divide are highly correlated with more frequent Type 8 patterns, in accord with its upslope character. Type 2 is a major factor giving rise to cold spring weather in the east, and cold autumn weather on both sides of the Divide, as well as wet summers in the east. This pattern (Figure 2) implies more frequent polar air masses.

The weak relationships in summer are probably attributable to the slack pressure gradients, which affect the type selection, and the fact that anomalies of temperature and precipitation in the warm season are more dependent on vertical motion and cloudiness, due to local instability, than on airflow direction.

The regression equations provide a basis for examining anomalies of climate and circulation over the Rocky Mountain region. Clearly, in view of the vast area involved, local discrepancies from the overall anomaly patterns must occur, especially for precipitation (see Bradley, 1976b). Nevertheless, some of the large-scale controls and their temporal variability can be identified.

Table I. Average standard deviations of temperature (°C) and precipitation (percentage of 1941–70 mean) for stations east and west of the Divide, 1899–1974

	Temperature		Precipitation	
	West	East	West	East
Winter	0·7	0·7	20·2	20·0
Spring	0·6	0·7	30·4	26·7
Summer	0·4	0·5	32·1	24·8
Autumn	0·6	0·7	40·6	42·7

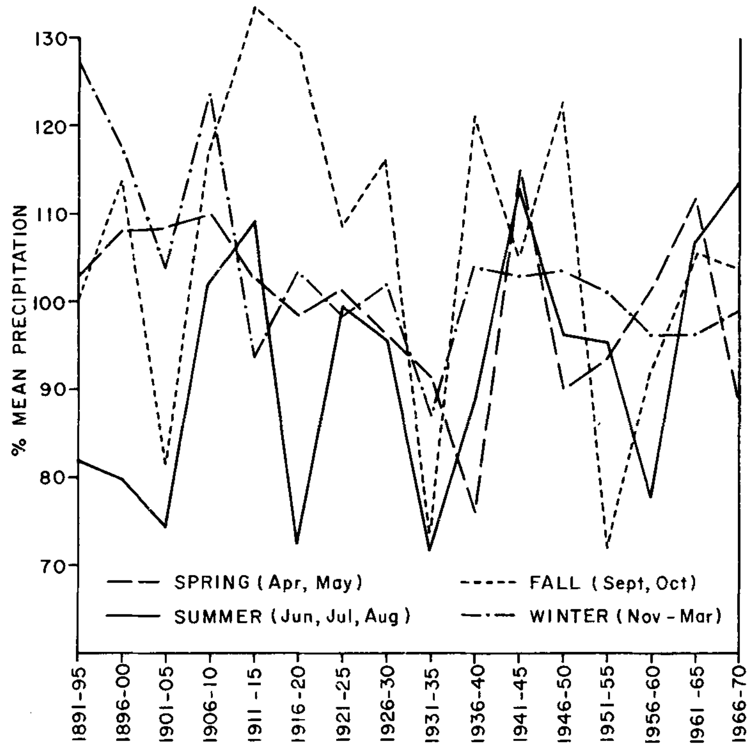


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Table II. Seasonal product moment correlation coefficients (r) between precipitation and temperature records, 1899–1974, for stations east and west of the Divide

	West	East
Winter	−0·38	−0·07
Spring	−0·42	−0·37
Summer	−0·48	−0·36
Autumn	−0·54	−0·48

It is recognized that the *frequency* of circulation patterns is only one component of interannual climatic variability and of short-term climatic fluctuations. *Within-type* variation, reflecting in part the differences in 'intensity' of a particular pressure pattern, must also be taken into account. Accordingly, for each mid-season month the ten warmest and ten coldest years during 1931–70 were selected from the climatic records for Colorado. Daily temperature data for Colorado stations located east and west of the Divide (Fort Collins and Grand Junction, respectively) have been used to test whether the frequency of synoptic types is significantly different between these two sets of years.

Table III. Regression equations for seasonal anomalies of mean temperature (°F) and precipitation (%) against frequencies of synoptic types at stations east and west of the Divide, 1899–1974

Precipitation: Regression equation	Correlation Coefficient	F Ratio	Confidence level
Winter			
East: $-1{\cdot}37F_{12}+1{\cdot}23F_{14}+105{\cdot}57=P(\%)$	0·40	7·1	
West: $0{\cdot}89F_7+1{\cdot}97F_{14}+74{\cdot}36=P(\%)$	0·51	12·8	95%
Spring			
East: $2{\cdot}84F_8+79{\cdot}37=P(\%)$	0·46	19·9	99%
West: $-7{\cdot}28F_6+109{\cdot}72=P(\%)$	0·29	6·9	
Summer			
East: $1{\cdot}19F_2-1{\cdot}07F_4+97{\cdot}53=P(\%)$	0·32	4·2	
West: $4{\cdot}09F_{10}+85{\cdot}81=P(\%)$	0·26	5·6	
Autumn			
East: $-2{\cdot}63F_1-3{\cdot}09F_6+144{\cdot}52=P(\%)$	0·30	3·5	
West: $-3{\cdot}91F_6-5{\cdot}33F_{10}+117{\cdot}03=P(\%)$	0·37	5·8	

Temperature: Regression equation	Correlation coefficient	F ratio	Confidence level
Winter			
East: $-0{\cdot}09F_2-0{\cdot}09F_6+1{\cdot}10=\Delta T$	0·36	5·3	
West: $-0{\cdot}07F_2-0{\cdot}06F_4+0{\cdot}87=\Delta T$	0·28	3·0	
Spring			
East: $-0{\cdot}16F_2-0{\cdot}14F_5-0{\cdot}15F_8+2{\cdot}68=\Delta T$	0·61	14·3	95%
West $-0{\cdot}10F_5-0{\cdot}14F_8+1{\cdot}48=\Delta T$	0·54	15·1	95%
Summer			
East: $0{\cdot}09F_3-0{\cdot}26=\Delta T$	0·25	5·1	
West: $-0{\cdot}09F_{10}+0{\cdot}31=\Delta T$	0·27	5·8	
Autumn			
East: $-0{\cdot}12F_2+0{\cdot}19F_3-0{\cdot}23F_4-0{\cdot}18F_5-0{\cdot}21F_{10}+0{\cdot}94=\Delta T$	0·68	12·1	95%
West: $-0{\cdot}07F_2+0{\cdot}11F_3-0{\cdot}22F_4-0{\cdot}11F_5-0{\cdot}27F_{10}+0{\cdot}97=\Delta T$	0·64	9·9	95%

The contributions of between- and within-type variance to the temperature difference between the two sets of extreme years have been calculated following the method described by Perry and Barry (1973). The total change in mean temperature between sets of equal length can be expressed:

$$\Delta\bar{T} = \sum_{i=1}^{k} [\Delta f_i (T_i + \Delta T_i)/n + f_i \, \Delta T_i/n]$$

where

f_i = frequency of type i in the first set of years
T_i = mean temperature of type i for the first set
n = number of days in either set of years
$f_i + \Delta f_i$ = frequency of type i during the second set of years
$T_i + \Delta T_i$ = mean temperature of type i during the second set.

The term $f_i \, \Delta T_i/n$, which is independent of any change in frequency, represents a component due to within-type changes of temperature. The first term on the right-hand side represents the effect on ΔT of a change in type frequency when a change occurs in the temperature in type i in the same period. For some purposes it may be of interest to separate $\Delta f_i T_i/n$ and $\Delta f_i \, \Delta T_i/n$.

Some results of the analysis are shown in Table IV. They indicate that while certain types do show considerable variability in their temperature characteristics in Colorado, others are very consistent.

The results in Table IV show that type 1 has a large variation in average temperature between years, except in August. Although this type averages warmer than normal over the long-term, it tends to become colder than normal during cold years. This is shown by high within-type variability (parameter *b*) in Table IV. Type 2, however, tends to remain cold even during 'warm' months, and changes in frequency of this type exert considerable control on temperature (as shown by parameter *a*). This is true on both sides of the Divide in Colorado. A frequency analysis of Type 2 occurrences during the ten warmest and coldest examples of each month shows that, without exception, Type 2 occurrences are more common during the cold cases. Similarly, Type 3 is on average much warmer than normal even during cold months, except in February.

Table IV. Contributions to the temperature differences between the 10 warmest and 10 coldest mid-season months, 1931–70, due to changes in type frequency (*a*) and to within-type variability (*b*)

Station	Type	February		April		August		October	
		a	*b*	*a*	*b*	*a*	*b*	*a*	*b*
Fort Collins	1	−1·2	−1·2	0·0	−0·3	−1·8	−0·2	−2·4	−1·1
	2	1·3	−0·1	1·5	−0·4	1·5	−0·3	2·6	−0·4
	3	−0·4	−0·6	−1·8	−0·4	1·8	−0·1	3·7	−0·6
Grand Junction	1	−1·2	−1·0	0·0	−0·4	−2·0	−0·2	−2·6	−1·4
	2	1·8	−0·2	2·1	−0·4	1·7	−0·2	3·2	−0·5
	3	−0·3	−0·7	−1·9	−0·3	1·8	−0·1	−3·9	−0·6

SUMMARY

A long-term, objectively derived catalogue of daily MSL synoptic pressure patterns for 1899–1974 for the western United States has been developed and their climatic characteristics described. Relationships between temperature and precipitation departures and the synoptic types at stations throughout the western United States show many features anticipated on the basis of the type patterns and the expected airflows associated with them. Consideration of type frequencies in a set of months with extreme positive and negative anomalies of temperature in Colorado demonstrates that the sign of the temperature anomalies occurring is consistent with expectation, although considerable within-type variation obviously exists in the characteristics of particular patterns. Regression analysis of type frequencies against temperature and precipitation anomalies for 1899–1970 at stations in the Rocky

Mountain states (treated separately for locations east and west of the Continental Divide) shows that such anomalies are partly attributable to the above/below-average frequency of circulation patterns, although other factors must also be involved, particularly within-type variability. An adequate understanding of this variability does not yet exist. Interestingly, the best results are for temperatures in the transition seasons and precipitation in spring in the east and winter in the west.

While the conclusions are less definitive than was hoped for in terms of the potential of the method for analysing climatic fluctuations, they illustrate some of the difficulties encountered in our attempts to link climatic anomalies with atmospheric circulation characteristics.

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