The Role of January in the Character of Recent Winters in the United States

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ABSTRACT

The separate contribution of December, January and February temperature to the net seasonal anomaly for the 1975–76 through 1981–82 winter seasons is analyzed. It is found that the January departures contributed by far the most toward making these seven winter seasons well below average in much of the contiguous United States, particularly in the eastern half of the country.

Each of these Januaries averaged from below to much-below the long-term average. By contrast, the Decembers and Februaries ranged from much-below to much-above the long-term mean.

Intraseasonal relationships were explored to see what role monthly persistence may have played during these seven winters. It was found that although there was a general tendency for anomalies to persist *in sign* from one month to the next, particularly in the eastern third and the far West of the United States, the coldness of the Januaries appears to be the result of an intensified meridional circulation occurring for the most part, during the calendar month of January.

1. Introduction

The severity of recent winters has been costly to the nation, both from the immediate economic losses incurred (e.g., lost production, greater heating costs, greater municipal outlays, etc.) and from the delayed effects as the short term impacts work their way through the national economy (see, e.g., Changnon, 1979; NOAA, 1981, 1982).

By the same token, due to extensive coverage of anomalous weather events by the news media and from direct experience of these events, people in the United States and Canada perceive the climate to be changing (Harrison, 1982; Changnon, 1982).

Diaz and Quayle (1978, 1980) placed the severity of the 1976–77 through 1978–79 winter seasons in the contiguous United States within the context of about a century of previous records. They concluded that these three winter seasons could, indeed, be regarded as a unique event. Namias (1978) and others have examined various factors that contributed to the development of these severe winters.

The purpose of this study is to show that the character of the recent cold winters has been set primarily by the Januaries. During the winters (December–February) of 1975–76 through 1981–82 most or all of the Januaries in the eastern half of the contiguous United States averaged below the long-term mean. By contrast, the December and February anomalies varied from much-below to much-above normal. This observation was the main motivation for undertaking this study.

2. Data

The data consisted of monthly mean temperatures for each of the 48 contiguous states (NOAA, 1981) through 1982 and 700 mb geopotential height over North America using a set of 55 gridpoints from the NMC octagonal grid also available through 1982. The 700 mb data were obtained from the National Center for Atmospheric Research (NCAR), Boulder, Colorado.

For the 37-year period, 1946–82, the rank of each January and February temperature anomaly was calculated (1946–81 for December). The cumulative departures for each of the three months separately for the period since the 1975–76 winter were calculated, plotted and analyzed. Monthly departures were calculated from the 1895–1981 long-term average. A period of 30 years immediately preceding the seven years in question was selected for analysis of the distribution of monthly extremes, first because "normals" are based on such time intervals and second, because it was thought to be long enough to contain a variety of seasonal outcomes.

Normalized departures of 700 mb height were calculated using the means and standard deviations based on the 33-year period 1947–79. Data from 1980–82 were not included in the averaging because these years were not available when the initial computer runs were made.

The area of the contiguous United States with snowdepth of one inch or more for these seven winter seasons was determined from the weekly snowcover maps published in the *Weekly Weather and Crop Bulletin* published by the National Weather Service, NOAA. The area given by the weekly chart closest to the end of each December and January was used. Percent variations from average refer to the 7-season sample (100% meaning the coverage was equal to the 7-season mean). Percent of total area for each season present over the

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eastern and western halves of the country is shown to gauge regional response.

3. Analysis

Figure 1 shows the accumulated monthly departures from the mean for each month, December 1975–81 and for January and February 1976–82. It is obvious that, on average, the bulk of winter's negative anomaly was contributed primarily by the month of January.

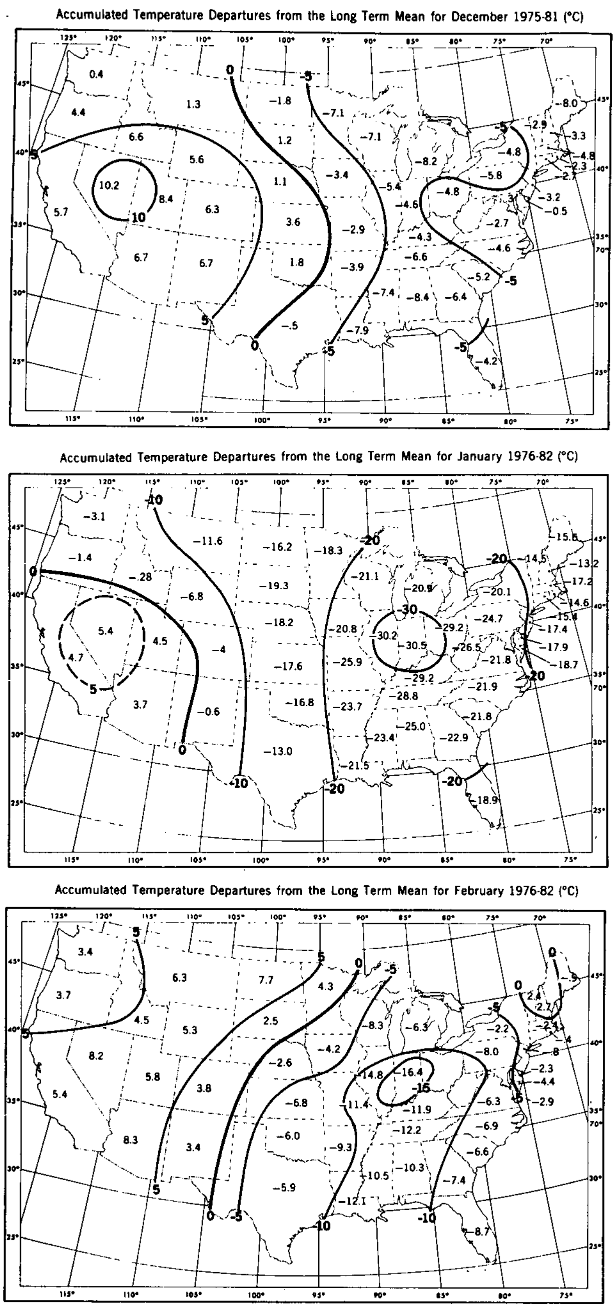

FIG. 1. Cumulative temperature departures (°C) for each month December, January and February for the 1975–76 to 1981–82 winter seasons.

TABLE 1. Three-class regional contingency table for December-to-January mean monthly temperature departure. Asterisks denote significant (at 1% level) chi-square value. The total number of observations is shown in parenthesis.

Region 1 (Northeast)*	B	N	A	(77)
B	30	1	2	
N	21	10	1	
A	1	8	3	

Region 2 (East North Central)*	B	N	A	(28)
B	12	1	0	
N	4	3	3	
A	0	3	2	

Region 3 (Central)	B	N	A	(49)
B	22	0	0	
N	18	5	0	
A	0	4	0	

Region 4 (Southeast)	B	N	A	(42)
B	17	3	0	
N	11	6	0	
A	3	2	0	

Region 5 (West North Central)	B	N	A	(35)
B	9	0	0	
N	9	1	4	
A	2	6	4	

Region 6 (South)*	B	N	A	(42)
B	11	5	0	
N	12	5	1	
A	1	4	3	

Region 7 (Southwest)*	B	N	A	(28)
B	5	0	0	
N	2	5	1	
A	0	6	9	

Region 8 (Northwest)	B	N	A	(21)
B	3	0	1	
N	3	1	1	
A	2	4	6	

Region 9 (West)	B	N	A	(14)
B	1	0	0	
N	1	2	0	
A	2	1	7	

By comparison, the Decembers averaged only slightly below normal in the eastern United States and likewise slightly above normal in the West.

The February anomalies in the East averaged about half way between the December and January values. December and February averaged about the same in the West, with January only slightly cooler. At first, it was thought that feedback effects from the extensive snow cover during these years (Wiesnet and Matson, 1979) may have been at least partly responsible for the larger mean February anomalies. A positive feedback operating between above normal snow cover in January and below average February temperature is apparent in the work of Wagner (1973); Dickson and Namias (1976); Namias (1978); Walsh and Tucek (1981); and Walsh *et al.* (1982) among others.

However, as will be shown below, this connection is plausible in only some of these seven seasons. Figs. 2a and 2b illustrate the variability of snowcover at the

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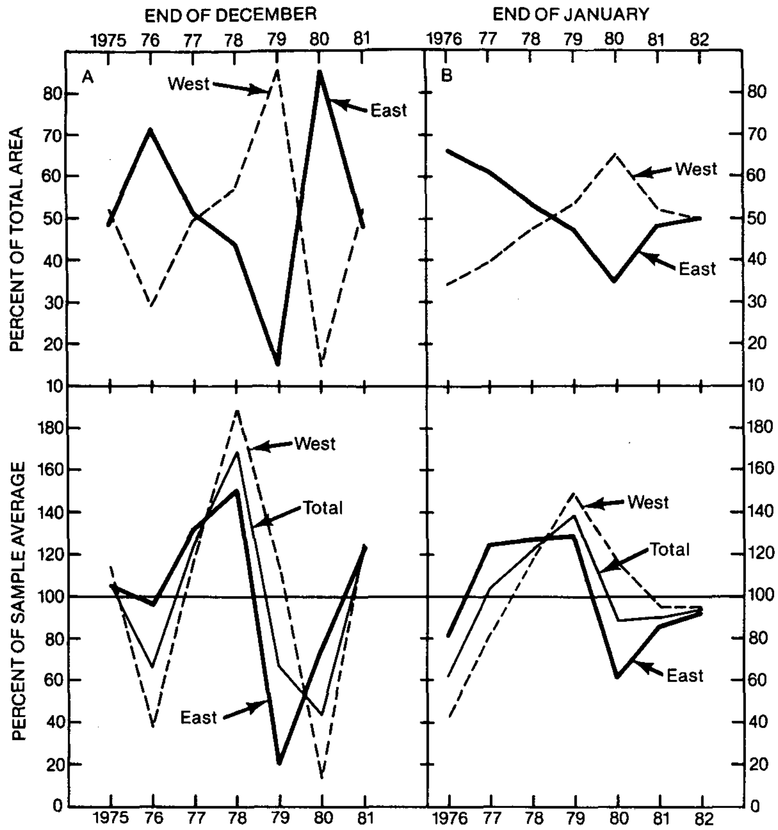

FIG. 2. Percentage of snowcover area in the eastern and western United States at the end of December and January for the seven years shown. See text for details.

end of December and January, respectively. The area of the contiguous United States reporting equal to or greater than one inch snow depth was determined separately for the region east and west of 100°W. The results are shown in terms of the percent of total snow cover for each season and as a percent of the seven-year mean for each month and region.

The top panels show the percent of total snowcover area within the region west or east of the hundredth meridian. The bottom panels show the relative area percentages during each year relative to the seven-year average. It appears that snowcover at the end of the preceding month was not a *reliable* indicator of the subsequent month's temperature anomaly. While every January was colder than normal, only four out of seven Decembers had above average snowcover at month's end. Above average snowcover in the West was present in December 1981, but January of 1982 was mild in the western United States. Only the cold Januaries of 1978 and 1979 were associated with the development of a large snowcover area at the end of the preceding month.

Snowcover was also extensive at the end of January of 1978 and 1979 which were followed by cold Februaries, but it was also above average at the end of January 1977 which was followed by a mild February in the East. Foster *et al.* (1983) analyzed the relationships between snowcover in the autumn months and subsequent winter temperature over interior continental areas of North America and Asia. They found that in North America, preceding snowcover was a poor predictor of both January and winter mean temperature. However, the association was significantly better for contemporaneous variations, accounting for approximately 50% of the winter temperature variance.

The sample size based on these seven seasons is too small to be conducive to any generalizations. To increase the sample size, the states were grouped into nine regions following Karl and Koscielny (1982) and Diaz (1983). A three-class contingency table was prepared for December–January and January–February temperature for the seven seasons 1975–76 through 1981–82. The results are shown in Tables 1 and 2.

It should be noted that, while substantial one month persistence is evident in these tables, some of it clearly derives from the spatial correlation inherent in the regional groups. Chi-square values were calculated for each regional entry in the tables; however, even after pooling several states together, many of the contingency tables still contained too few entries in some of the cells so that the chi-square values were either meaningless or unreliable. For those few regions where this was not the case every chi-square value was significant at the 1% level. The regions were the Northeast, East-

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TABLE 2. As in Table 1 except for January to February temperature.

Region 1 (Northeast)*	B	N	A	(77)
B	11	18	25	
N	18	1	0	
A	4	0	0	

Region 2 (East North Central)	B	N	A	(28)
B	10	3	4	
N	2	0	5	
A	1	1	2	

Region 3 (Central)	B	N	A	(49)
B	24	8	8	
N	7	1	1	
A	0	0	0	

Region 4 (Southeast)	B	N	A	(42)
B	17	9	4	
N	8	1	3	
A	0	0	0	

Region 5 (West North Central)	B	N	A	(35)
B	11	5	4	
N	2	2	3	
A	0	1	7	

Region 6 (South)	B	N	A	(42)
B	16	4	4	
N	9	1	4	
A	0	2	2	

Region 7 (Southwest)	B	N	A	(28)
B	3	3	1	
N	3	4	4	
A	0	3	7	

Region 8 (Northwest)	B	N	A	(21)
B	2	3	3	
N	2	1	2	
A	0	3	5	

Region 9 (West)	B	N	A	(14)
B	2	1	1	
N	0	1	2	
A	0	3	4	

North Central, South and Southwest for December–January temperature and the Northeast for January–February temperature. These have been identified by an asterisk in Tables 1 and 2. Because of the spatial homogeneity of temperature within the regions, the true statistical significance of these chi-square values is actually lower than 1%. The asterisks in Tables 1 and 2 are meant only to be indicative of substantial month-to-month persistence in the period studied.

Lag-one correlation coefficients were also computed for each state for December to January and January to February temperature using the 37-year period 1946–47 to 1981–82. These are shown in Fig. 3. Again, a significant amount of persistence is present in these months in the eastern United States and in the Pacific coast states (particularly in California) during these years.

However, the magnitude and extent of the January anomalies and to a much lesser extent the February anomalies in the eastern United States, as illustrated in Fig. 1, appear to be associated with more than simple atmospheric circulation persistence or snowcover feedback mechanisms. Fig. 4 shows the five coldest and five warmest Decembers, Januaries and Februaries between 1946 and 1982 for the contiguous United States. In most states in the eastern half of the country at least three of the five coldest Januaries since 1946 have occurred since 1976. In some states (e.g., Alabama, Illinois, Iowa, Missouri and North Carolina) it is four out of five.

The following points can be made from the data in Fig. 4. In the eastern United States the coldest Januaries since the end of World War II have occurred since 1976. The Januaries of 1963 and 1970 were also notably cold. In the West, the notable cold years were 1949, 1950 and 1979. In the western United States the period since 1976, while only moderately above normal on average, has exhibited large interannual variability; for example, 1979 was, as noted, very cold, but 1980 and 1981 were very warm. January 1978 was also above normal in California.

Decembers have an altogether different mix of extreme years. In the cold category there is 1950, 1958, 1963, and 1976 in the East; 1948, 1967, 1972 and 1978 in the West. Cold Februaries in the East are those of 1958, 1978 and 1979; and 1949, 1956 and 1969 in

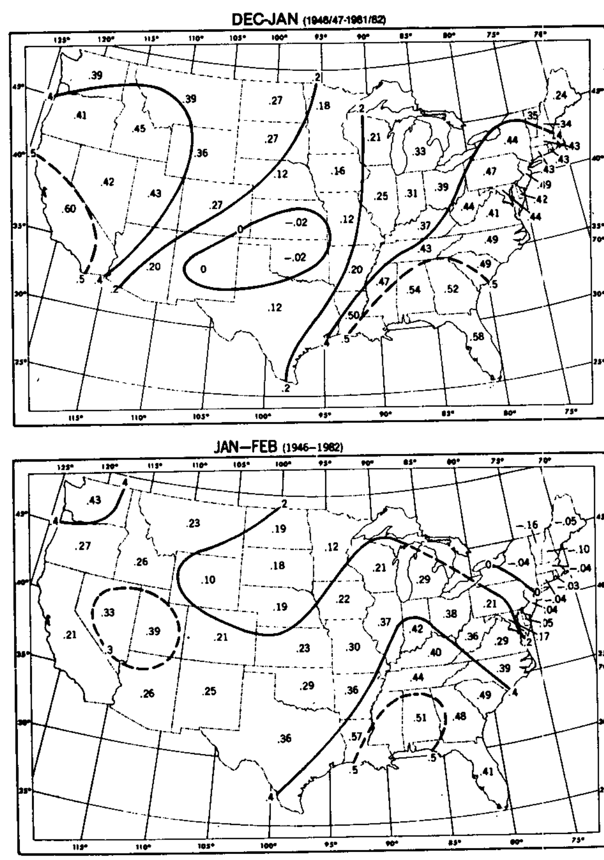

FIG. 3. Lag-one correlation coefficient for December to January (top) and January to February (bottom) temperature.

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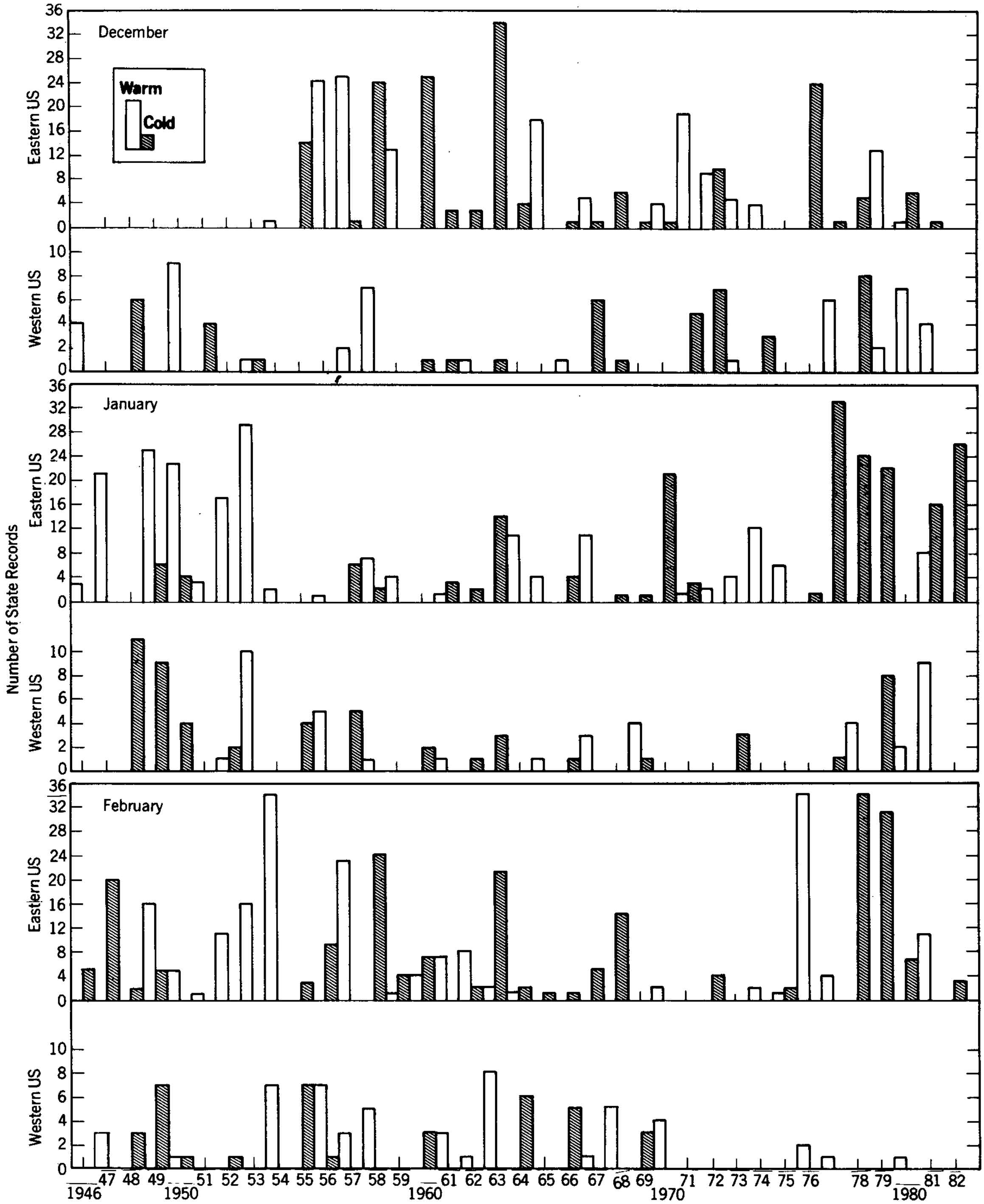

FIG. 4. Annual number of western and eastern states recording monthly temperature in the five warmest or five coldest categories during the winters of 1946–47 to 1981–82.

the West. In the central United States, 1978 and 1979 were also very cold.

An interesting arrangement emerges from these monthly rankings. The colder Decembers occur generally before 1976 throughout the country, mostly during the 1960s. In contrast most of the cold Januaries have occurred since 1976, while February extremes are split between the period since 1976 and in the 1960s.

Most of the warm Januaries occurred in the East between 1949 and 1953, inclusive. Warm Decembers were more common from 1946–60 in most of the

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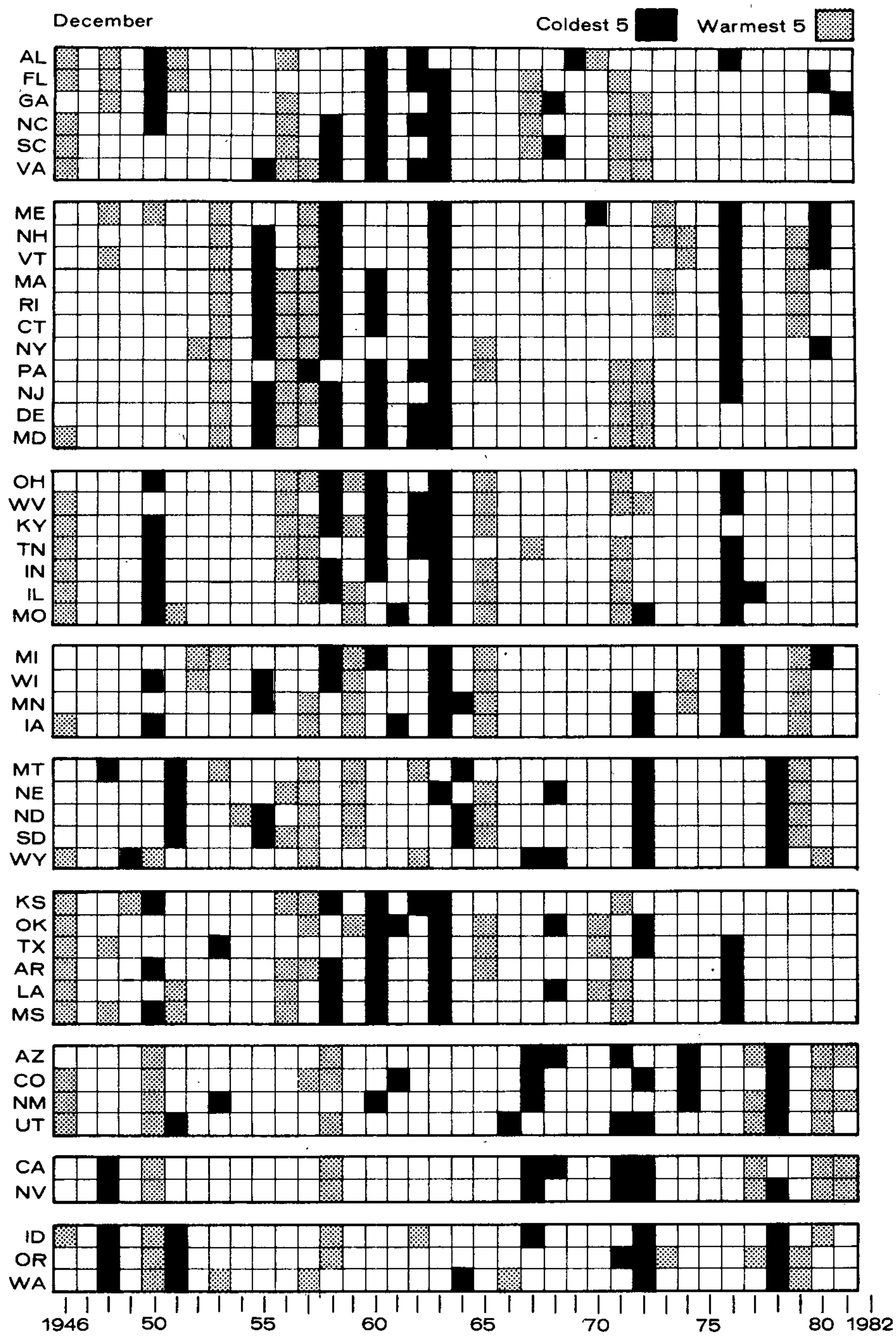

FIG. 5. The regional distribution of the five coldest and five warmest Decembers, Januaries and Februaries since 1946.

country with 1971 and 1972 being very warm in the East. February was warmer than normal most frequently in the 1950's. Fig. 5 further summarizes the information in Fig. 4 in terms of the frequency of anomalous years for each of the nine U.S. regions.

A point should thus be made about the apparent inconsistency between the extreme rankings (Figs. 4 and 5) and the persistence results that show nonnegligible month-to-month persistence (Tables 1 and 2 and Fig. 3).

On average, there is some *regional tendency* for winter monthly temperature, divided into equally probable terciles, to be in the same class as the month preceding it. No such tendency is noted for the occurrence of extreme values (taken here as the five coldest and warmest in a group of 36 seasons).

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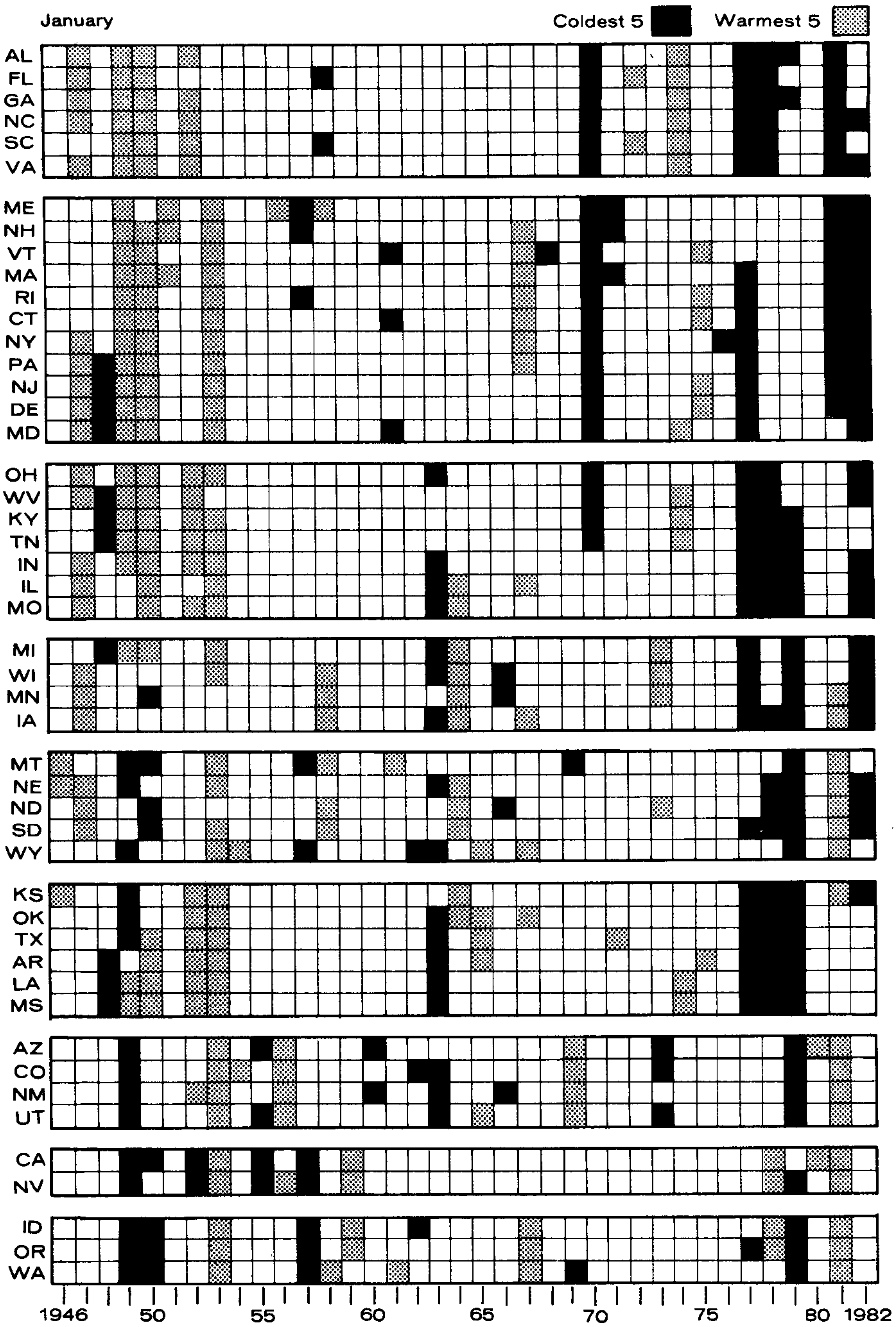

FIG. 5. (*Continued*)

The spatial and temporal variations in winter (December–February mean) temperature anomaly patterns were illustrated by Diaz and Fulbright (1981), who showed how the frequency of occurrence of the first two U.S. winter temperature eigenvectors, which emphasize east–west temperature gradients, had exhibited a well-marked tendency, going from mainly positive anomalies in the East in the 1940s and 1950s to negative anomalies thereafter.

The reasons for prolonged anomalous periods (at the seasonal time scale) alternating between the eastern and western parts of the United States are multiple and complex. North Pacific sea surface temperature (SST) may play a role in these fluctuations through feedback mechanisms in the atmospheric circulation. In two studies of SST, 700 mb height and seasonal temperature in the United States, Douglas *et al.* (1982) and Diaz and Namias (1983) have shown coincidental

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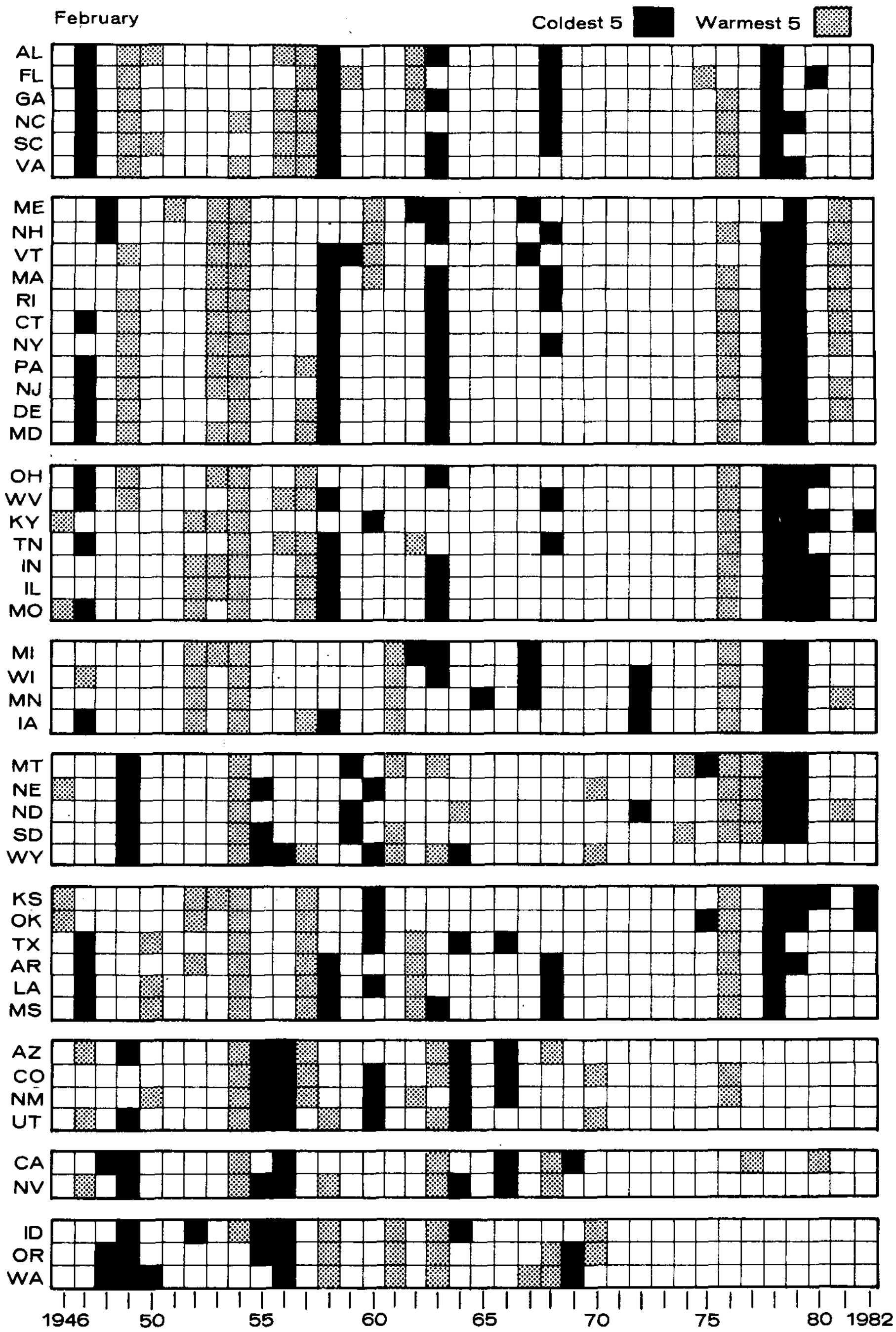

FIG. 5. (*Continued*)

large-scale variations in SST and 700 mb heights since 1947. It is generally consistent with the timing of the persistent (in the sense of recurrent) winter season temperature anomalies.

Following the suggestions of one of the reviewers, I calculated the average normalized departures of the 700 mb height field over North America and adjacent waters for each month December through February 1975–76 to 1981–82 inclusive (Fig. 6).

The results are quite interesting in that the January anomaly map closely resembles the PNA pattern identified by Wallace and Gutzler (1981) and associated with the Southern Oscillation by Horel and Wallace (1981). By contrast the anomaly patterns for the other two months do not exhibit any clear pattern, except that in February the Aleutian low expanded in size, extending into western North America.

In general, the greatest weekly departures during the

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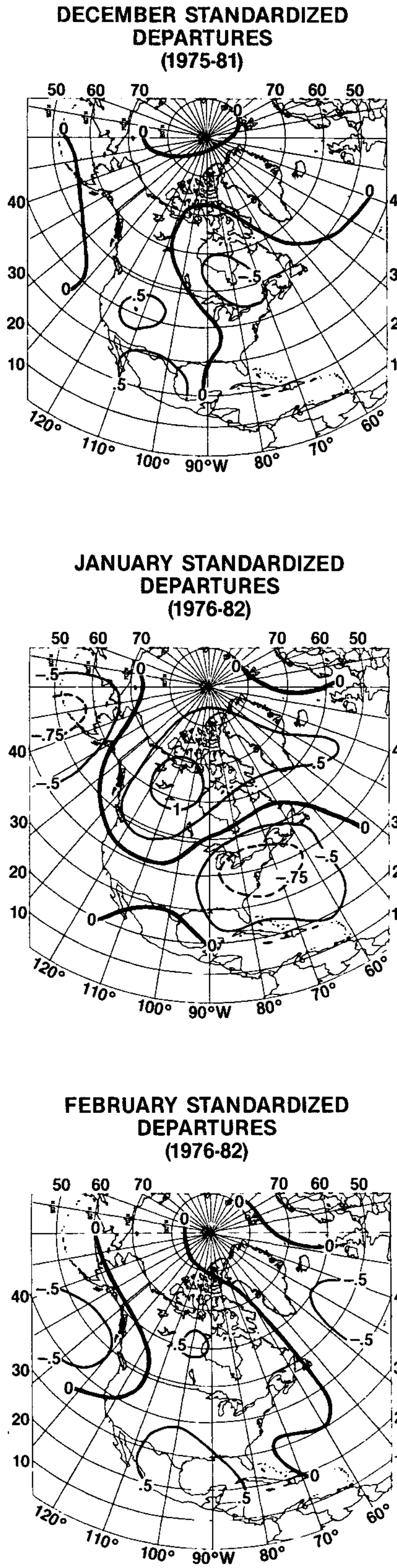

FIG. 6. Average standardized departures for December 1975–81 (top), January (middle) and February 1976–82 (bottom).

period of study occurred from late December to mid-February. This is also near the time of greatest southerly extension of the Northern Hemisphere westerlies. As the theoretical work of Opsteegh and Van den Dool (1980), Hoskins and Karoly (1981) and Webster (1981); and the observational study of Horel and Wallace (1981) has shown, this is the time that is most propitious for a mid-latitude response to tropical forcing. Fritz (1982) found little similarity between December 700 mb height patterns and those of January and February in the Northern Hemisphere. He suggested that an average of January and February 700 mb heights over the North Pacific would likely show a better correlation with Pacific SST than an average which includes the month of December. Fritz suggested that the reason for the apparent decoupling of December and the subsequent winter months may be due to the different monthly atmospheric response to surface heating.

4. Conclusions

This analysis showed that the very cold Januaries that occurred from 1976–82, particularly over the eastern two-thirds of the United States, were the principal contributor to the development of below average *seasonal* temperature in these areas. However, appreciable regional persistence of the sign (if not the intensity) in temperature anomaly was evident for both December to January as well as for January to February.

Since 1946, the occurrence of extreme monthly winter temperature anomalies have tended to occur in different groups of years for January and February compared to December.

The year-to-year consistency displayed by January since 1976 is reflected in the 700 mb anomaly field. The pattern that emerges by averaging the anomalies for the seven years strongly resembles the PNA pattern identified in previous teleconnection studies. The connection disappears for December and February.

It is noted in passing that various measures of the Southern Oscillation (SO), namely the difference in sea level pressure between Tahiti and Darwin, Australia; the frequency of highly reflective clouds along the equatorial Pacific and equatorial Pacific SST anomalies have suggested a prolonged period with conditions more typical of the negative phase of the SO (in the pressure gradient sense). The development of a major SO–El Niño event in 1982–83 actually had the effect of pushing anomalous rainfall along the equatorial region farther to the east than had been the case for several years, with the apparent termination of the cold midwinter spell of the previous seven years. The winter of 1983–1984 saw a record cold December over much of the nation followed by a mixed January (albeit one which was below normal in the eastern United States) and near normal February. The nature

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and causes of intraseasonal variability is an important area affecting the ultimate skill of seasonal forecasts.

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