THE SEVERE WINTER OF 1976–77: PRECURSORS AND PRECEDENTS

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ABSTRACT

The severe winter of 1976–77 over the eastern United States was related to an exceptionally strong and unusual pattern of tropospheric winds and pressure anomalies that persisted from the previous October. The record bitter cold that occurred during January was additionally due to the southward displacement of the cold polar Low, normally found over Northern Canada, by what appears to have been the strongest blocking High ever observed over the Arctic region. A search of the records turned up several severely cold winters during the 20th Century, with that of 1917–18 being closest to the recent winter in severity, with similar antecedent and concurrent phenomena.

1. Introduction

Following a series of generally mild winters over the eastern United States beginning in 1971–72, the extremely cold winter of 1976–77 came as a rude shock to most people, causing fuel shortages and generally slowing, and in some areas, even crippling commerce and transportation. Due to its severity, the persistent and extreme cold seemed totally unprecedented and somewhat unexpected. Because of the serious economic impact of the winter weather, two questions have frequently been asked:

(1) How far ahead was, or might have been, the severely cold winter predicted?
(2) Was such a winter really unprecedented, or have similar winters occurred in the past?

This paper will attempt to provide at least partial answers to these two questions.

2. Atmospheric Circulation Preceding the 1976–77 Winter

As noted above, the 1976 77 winter was preceded by 5 consecutive generally mild winters over the eastern part of the country. The 5-year mean 700-mb height anomaly for the winters 1971–72 through 1976–77 is shown in Figure 1. It can be seen that heights were generally below normal over Canada and the North Atlantic, with a strong Icelandic Low and a generally contracted polar vortex (strongest westerlies at middle and high latitudes). The anomalous strength of the mid-latitude westerlies over the Atlantic sector is especially noteworthy. There was no evidence of high latitude blocking (anomalously high heights at polar latitudes) over the Western Hemisphere. Positive height anomalies over the central Pacific, southwest Atlantic and central Europe indicated stronger than normal subtropical Highs over both oceans, with a continental extension of the Azores High into Europe.

This pattern favors the containment of Arctic air at relatively high latitudes and anomalous advection of mild maritime air from the Gulf and south Atlantic over most of the United States east of the Mississsippi River. Colder than normal air would be favored only over portions of the Great Plains, Rocky Mountains and Great Basin area, and even that would not be too cold due to the lack of a long anomalous fetch directly from Arctic areas. Note that this 5-year mean circulation pattern has almost exactly the opposite departure from normal as that shown by Namias (1970) to have characterized the generally cold winters of the decade from 1960–61 throught 1969–70.

An evolution of the unusual atmospheric circulation patterns over the Northern Hemisphere can be traced forward from the summer of 1976 (Figure 2). A double-lobed strong polar Low as found over the Arctic, and faster than normal westerlies extended across the Pacific. Stronger than normal ridges were associated with persistent heat and drought over the north-central United States and adjacent areas of Canada, as well as the British Isles and Western Europe. In this latter area, some locations experienced the worst summer heat and drought in over 2 centuries. Perry (1977) believes the drought in England and Wales was also related to a marked eastward displacement of the Asian coastal trough, as well as the northward-displaced westerlies over the North Atlantic persisting from several previous seasons.

During the fall of 1977 (Figure 3), the circulation pattern became strongly amplified over most of the Northern Hemisphere. Strong troughs were located over the Aleutians and eastern North America, while a greatly amplified full-latitude ridge extended northward near the West Coast of North America. The subtropical highs over both the Atlantic and Pacific were stronger than normal, with generally fast westerlies across both oceans except for the eastern Pacific, where the flow became more meridional. The remains of the positive anomaly associated with the British drought had moved northward to an area extending from Greenland to Scandinavia, while a stronger than normal trough gave heavy rains that decisively broke the drought in western Europe.

Over the United States, the greater than normal component *of* northerly flow produced a persistently cold and dry fall, except along the southern border where moisture overrunning the cold air led to some rather heavy rains. The normal fall rainy season in the Pacific Northwest and British Columbia for all practical purposes, failed to begin as the strong ridge deflected Pacific storms northward to Alaska, where many places along the south coast had record heavy rains during the fall.

3. The Winter Circulation Pattern

The longitudinal positions of the troughs and ridges remained remarkably constant from fall to winter (Figure 4). The cyclonic circulation around the troughs intensified and expanded southward while a massive area of blocking filled the Arctic region with strong positive anomalies. The intense cyclonic circulation around the Aleutian Low covered nearly the entire pacific north of 30° latitude.

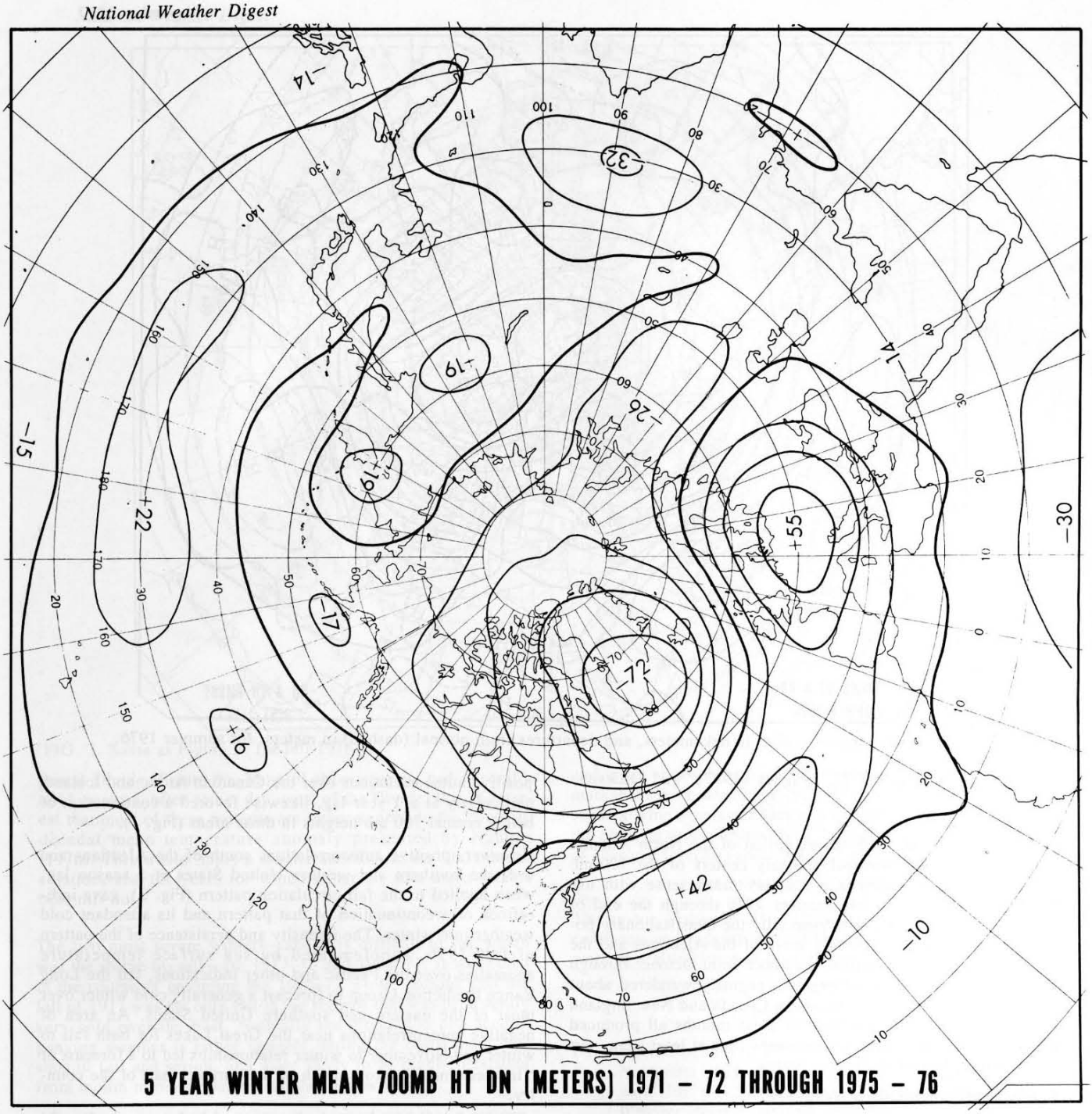

FIG. 1. Winter 5-year mean 700-mb height anomaly (meters) for the seasons 1971–72 through 1975–76.

The anomalies of temperature and precipitation were quite similar over the United States in fall and winter due to the persistence of the pattern. The continuing strong ridge over the Pacific Northwest deprived most of that area of a second season's quota of moisture—much of it normally in the form of snowpack in the mountains, needed for irrigating the following summer's crops.

The large positive anomaly and closed High over the Arctic primarily reflect events that began in late December and continued until early February. Discontinuous retrogression of the positive anomaly from the north Atlantic in the fall to southern Greenland by early January and the building of another positive anomaly to record strength near the Taymyr Peninsula led to a strong southward displacement of the North American cold polar low and its associated Arctic air mass during January, the most severe month of the winter. The band of fastest westerlies was, by then, displaced well south of normal (expanded polar vortex) in most sectors of the Northern Hemisphere. Preliminary studies by Quiroz (1977) and Taylor and Perry (1977) show that the unusual events in the troposphere were associated with a major stratospheric warming. Other detals of the winter weather as well as that for the preceding fall are given in the

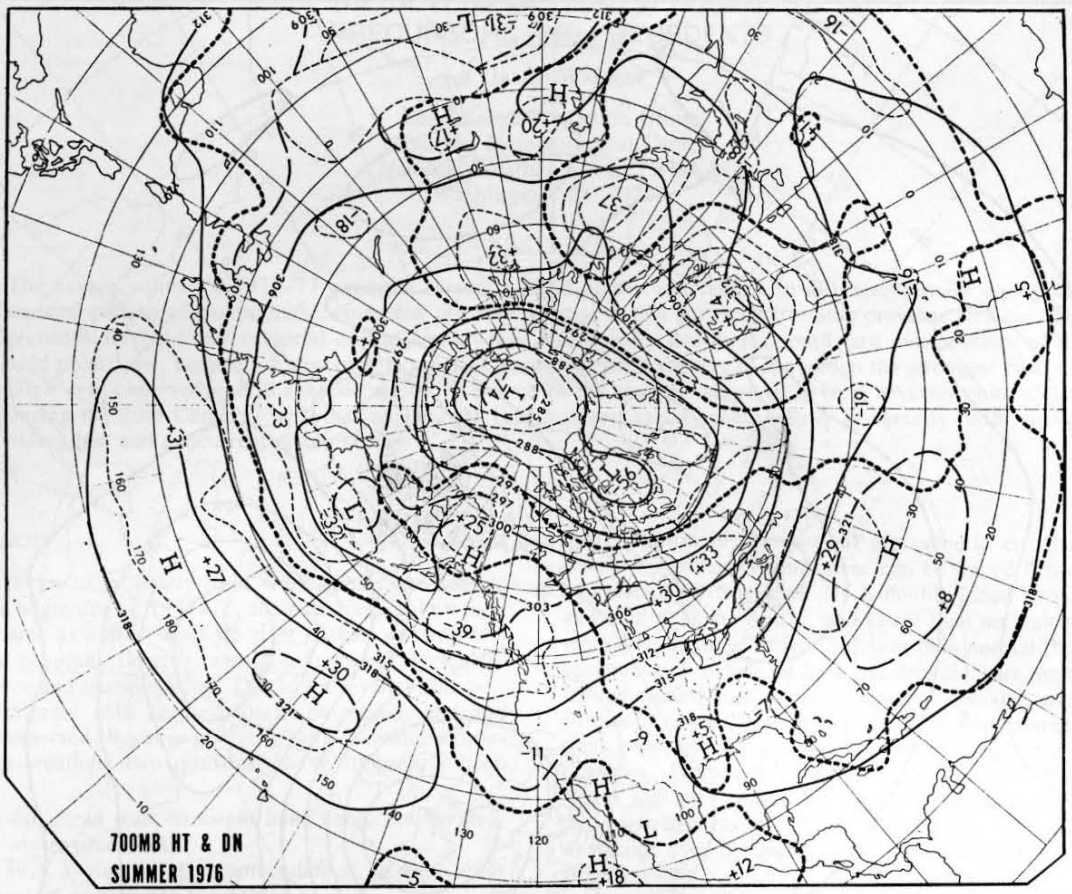

FIG. 2. Mean 700-mb contours (solid) in dekameters, and departures from normal (dashed) in meters, for summer 1976.

articles by Taubensee (1977), Wagner (1977), and Dickson (1977).

It is interesting that, with the exception of the North Atlantic positive center, the principal anomaly centers of the 700-mb circulation can be traced in a monthly mean sense with unbroken continuity from late summer 1976 through the end of winter 1977 (Figure 5). Note especially the quasistationary positions of the negative anomaly south of the Aleutians and the positive anomaly over British Columbia from October through February. The other strong negative anomaly wandered about within a limited area of southeastern Canada and New England during this time. The first four of these months all produced record cold monthly mean temperatures over at least some part of the eastern half of the United States.

4. Advance Indications of Winter–77

The primary tools used by the National Weather Service's Long Range Prediction Group in seasonal forecasting are local autocorrelations, at points around the Northern Hemisphere, of 700 mb heights from various preceding seasons with those of the season to be predicted. For winter, in the North American sector these are generally positive in certain key areas, with the strongest correlations relating the predictand winter with the winters 1 and 2 previous, as well as with the fall and November immediately preceding.

For instance, rather strong positive autocorrelations with the winters 1 and 2 years previous over the southern and eastern United States and the adjacent western Atlantic favored a continuation of the enhanced Bermuda High and southwesterly anomalous flow over the eastern United States. Fairly strong positive autocorrelations over the Canadian Arctic and Iceland, particularly at a 1 year lag, likewise favored a continuation of below normal 700 mb heights in those areas (Fig. 1).

However, positive autocorrelations south of the Aleutians and over the southern and western United States at 1 season lag, when applied to the fall circulation pattern (Fig. 3), gave indications of a continuation of that pattern and its attendant cold weather into winter. The intensity and persistence of the pattern of fall 1976, supplemented by sea surface temperature anomalies over the Pacific and other indications, led the Long Range Prediction Group to forecast a generally cold winter over most of the eastern and southern United States. An area of negative autocorrelations near the Great Lakes for both fall to winter and November to winter relationships led to a forecast of "indeterminate" across much of the northern part of the country.

The indications from the winter-to-winter autocorrelation patterns at 1 and 2 year lags, for a continuation of generally mild winters were in this case misleading, and therefore if a forecast had been attempted at the end of the summer, it would likely have been a poor one.

5. Other Severe Winters of the 20th Century

The unusual and record-breaking nature of the winter of 1976–77 prompted a search for similar persistently cold or severe winters over the eastern United States in the recent past. Readily available temperature anomaly charts and station data were on hand from about 1900, so the search was confined to the 20th Century. Six candidates for the dubious honor were found and calculations were done at a number of cities east of the Conti-

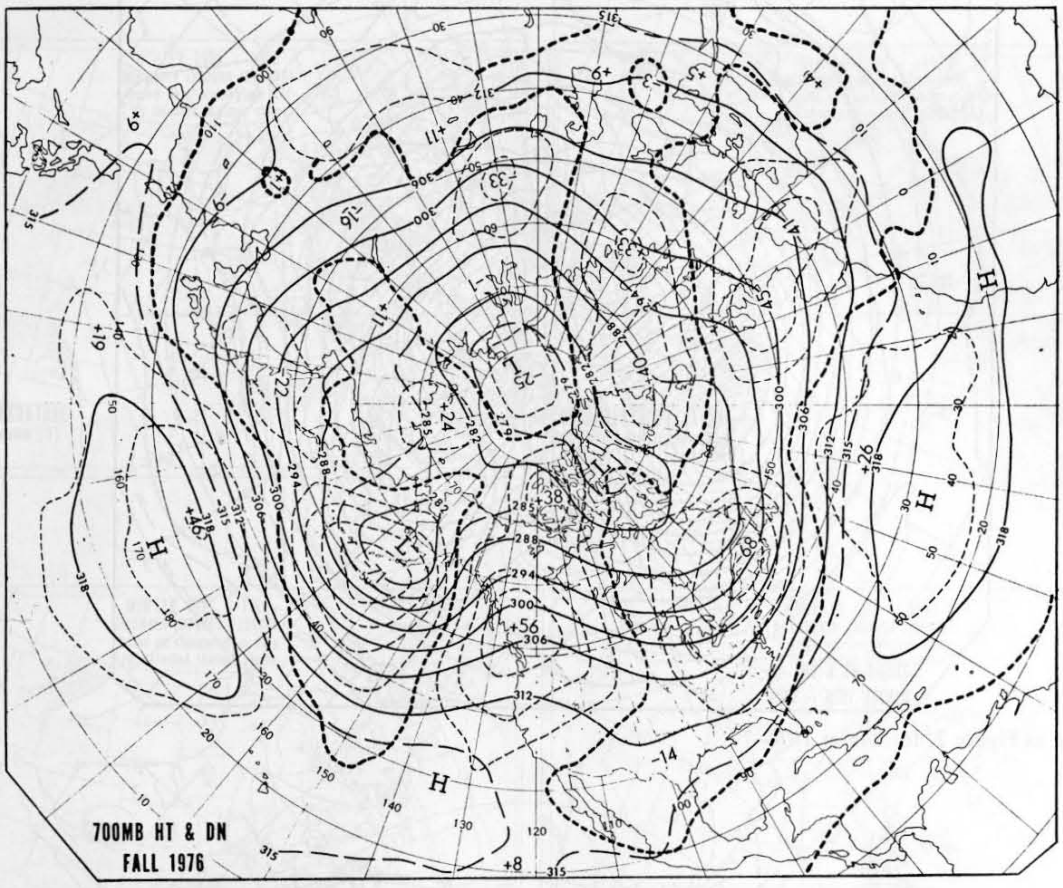

FIG. 3. Same as Figure 2, for fall 1976.

nental Divide (Figure 6). Most of these seasons had generally mild weather, often rather dry, west of the Divide. It is of interest that most of these patterns are rather similar to the 1960–70 decadal mean temperature anomaly presented by Namias (1970). This would imply a similar anomaly in the 700 mb circulation, and the years for which upper air data are available bear this out.

The two most severe winters—and it is difficult to say which was the worse overall—are 1917–18 and 1976–77. It was noted in the course of preparing the 1976–77 winter outlook that the fall of 1917 was the only fall in the records that was persistently very cold over the East. Normally the circulation and accompanying weather is rather variable during the transitional seasons of fall and spring, and more likely to be highly persistent from month to month during summer and winter.

After the forecast had been issued, it was found that a sea surface temperature anomaly pattern similar to that of 1976 had existed over the Pacific during the fall of 1917, and subsequent examination of the few available surface reports from Greenland and northern Canada showed a marked rise in sea level pressure in those areas toward the end of December 1917, just before the coldest weather of that winter hit New York City (Figure 7). Although the timing of some of the cold spells was different, the overall similarity of the two winters is demonstrated by this daily temperature comparison. Particularly noteworthy are the nearly continuous below normal temperatures from late December to early February and the moderation around the second week of February.These bits of evidence suggest that similar energy interactions may have been occuring between the atmosphere and the Pacific Ocean, and the lower and upper atmosphere over the Artic region, during the two remarkable severe winters of 1976–77 and 1917–18. The rarity of such extreme events and lack of a quantitiative understanding of the physical processes involved, however, precludes the making of seasonal forecasts specifying the severity of cold expected.

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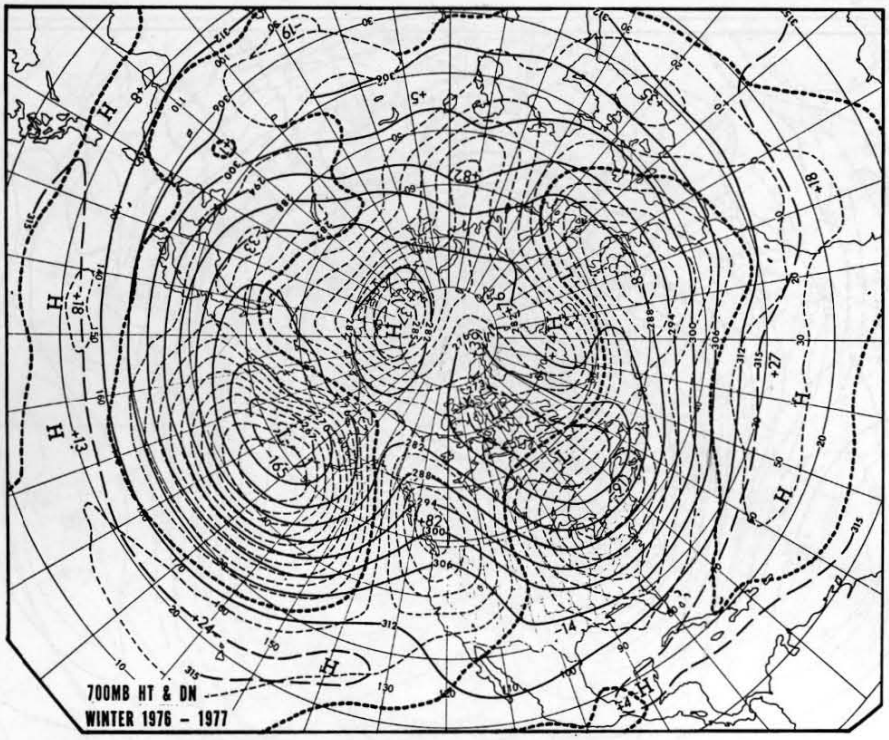

FIG. 4. Same as Figure 2, for winter 1976–77.

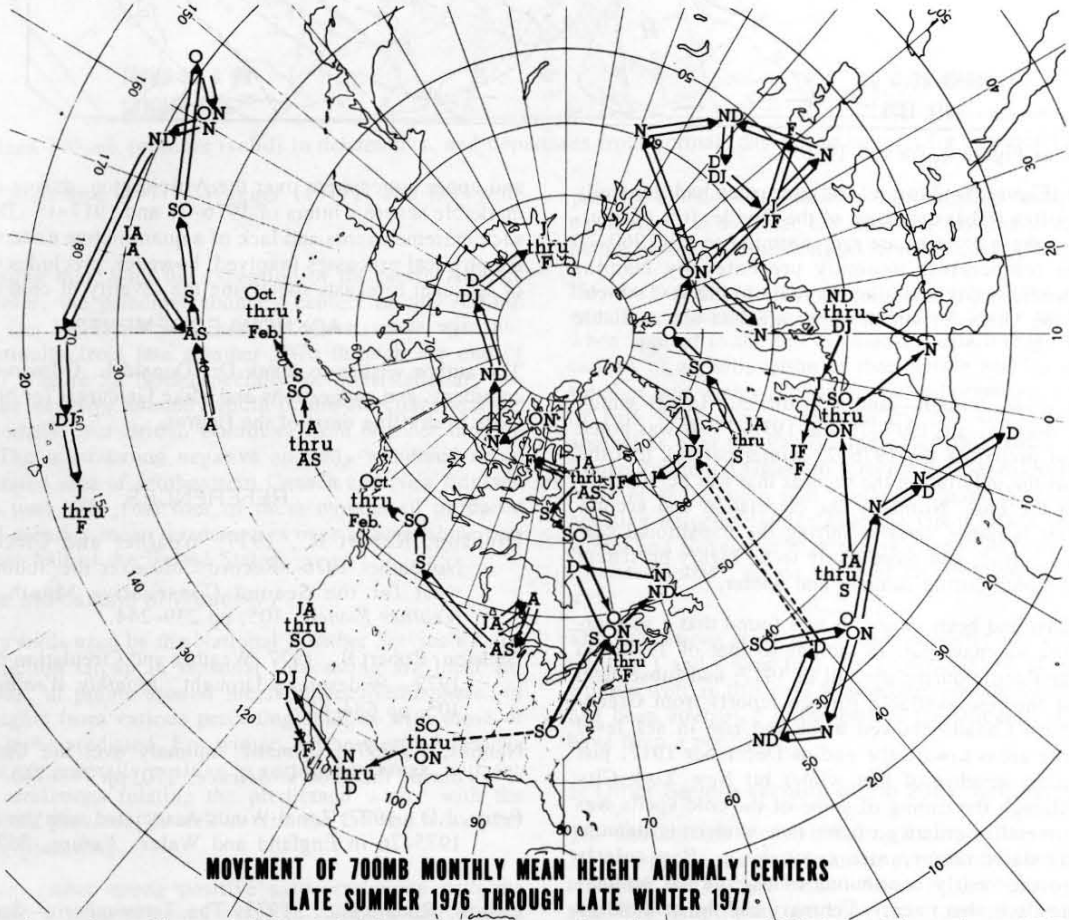

FIG. 5. Locations of monthly mean 700-mb height anomaly centers from late summer 1976 through late winter 1977. Single letters refer to full calendar months; double letters, to periods from mid-month to mid-month. Single arrows show paths of negative anomalies and double arrows show paths of positive anomalies. The quasi-stationary center over California was negative.

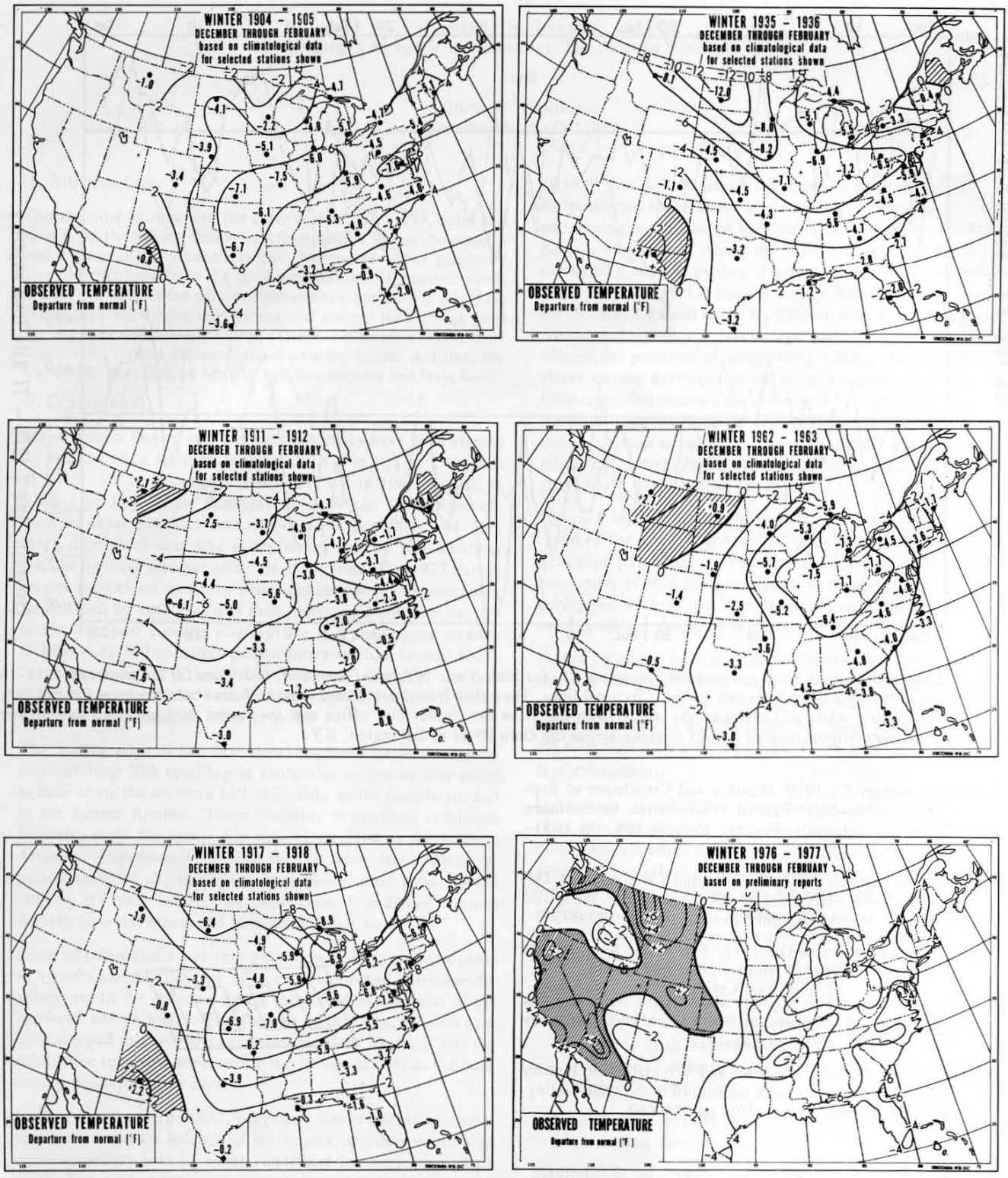

FIG. 6. Temperature anomalies (°F) for the 6 coldest winters of the 20th Century over the United States east of the Continental Divide. The normal used to compute all the maps is the current 30-year climatological normal, based on data from 1941 through 1970.

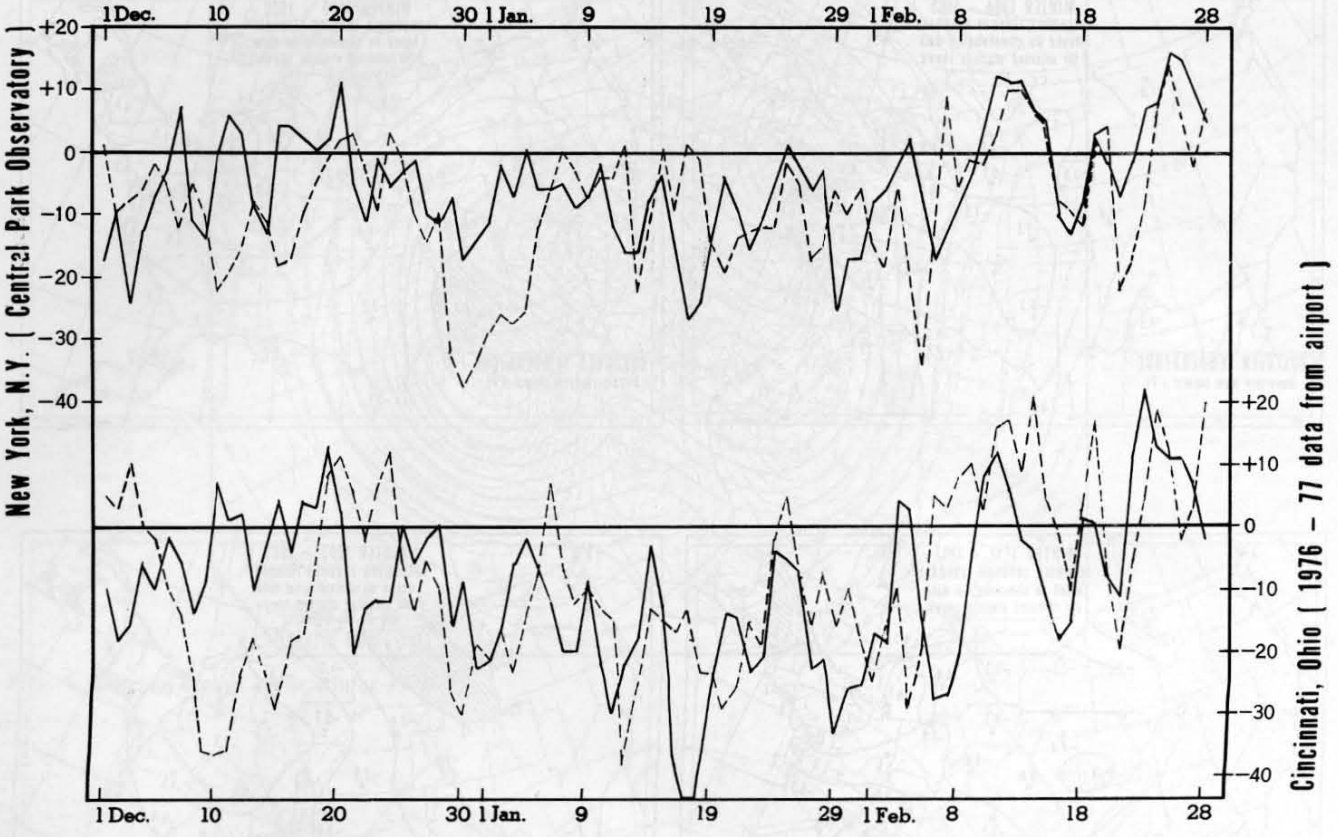

FIG. 7. Comparative daily mean temperature anomalies (°F) for New York, NY, and Cincinnati, OH. Data for the winter of 1917–18 are shown by dashed lines and 1976–77 by solid lines. The entire New York record is taken from observations at Central Park observatory while at Cincinnati the earlier data are from the former city office and the recent data are from the Greater Cincinnati Airport located a short distance across the Ohio River at Covington, KY.

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