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# Climatological Summaries of the Lower Few Kilometers of Rawinsonde Observations

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# Climatological Summaries of the Lower Few Kilometers of Rawinsonde Observations

by

George C Holzworth and Richard W Fisher

Meteorology and Assessment Division
Environmental Sciences Research Laboratory
Research Triangle Park, North Carolina 27711

U S ENVIRONMENTAL PROTECTION AGENCY
Office of Research and Development
Environmental Sciences Research Laboratory
Research Triangle Park, North Carolina 27711

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## AFFILIATION

Messrs. Fisher and Holzworth are meteorologists in the Meteorology and Assessment Division, Environmental Sciences Research Laboratory, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711. *They are on assignment from the National Oceanic and Atmospheric Administration,* U.S. Department of Commerce.

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## ABSTRACT

Summaries of rawinsonde measurements taken twice daily at 76 United States Weather Service stations including Puerto Rico are presented on national maps. The summaries are based mainly on analyses of the lower 3 km of each sounding. The data include the percentages of all inversions, surface-based and elevated inversions separately, inversion thicknesses and the heights of elevated inversion bases. Also included are percentages of high relative humidities within inversions and in adjacent layers, along with percentages of wind speeds in five categories at the surface and 300 m above the surface for surface-based, elevated, and no-inversion cases. Finally, lapse rates are characterized within and below inversions, and in specified layers through 1500 m for soundings with no inversion. Representative data are isoplethed for illustrative purposes, but many figures are without isopleths because no single variable is generally representative. Some general conclusions are: 1) inversions are virtually always present at most locations; 2) they are almost always greater than 100 m thick and may be more than 1000 m thick; 3) shallow inversions (less than 500 m) tend to be more intense (large $\Delta T/\Delta H$); 4) the highest relative humidities occur at the surface, especially in surface-based inversions; 5) wind speeds with surface-based inversions are generally slower at the surface than at 300 m and the most common surface speed-class is 2.6-5.0 m/sec. Although the data presented in this study were developed for use in investigations of the transport and diffusion of atmospheric pollutants, they should be of considerable interest to others concerned with characteristics of the atmospheric boundary layer.

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86. Percentage of winter 2315 GMT soundings with no inversion below 3000 m AGL and an average relative humidity >69% (left) and >89% (right) in the layers 1-100, 101-250, 251-500, 501-750, 751-1000, and 1001-1500 m AGL (bottom to top). Isopleths are for an average relative humidity >69% in the layer 251-500 m AGL. See Figure 2 to identify peripheral stations. 116

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91. Percentage of spring 1115 GMT soundings with an inversion base at the surface and wind speeds at the surface (left) and at 300 m AGL (right) in the ranges calm, 0.1-2.5, 2.6-5.0, 5.1-10.0, and >10.0 m/s (bottom to top). See Figure 2 to identify peripheral stations. 121

92. Percentage of summer 1115 GMT soundings with an inversion base at the surface and wind speeds at the surface (left) and at 300 m AGL (right) in the ranges calm, 0.1-2.5, 2.6-5.0, 5.1-10.0, and >10.0 m/s (bottom to top). See Figure 2 to identify peripheral stations. 122

93. Percentage of autumn 1115 GMT soundings with an inversion base at the surface and wind speeds at the surface (left) and at 300 m AGL (right) in the ranges calm, 0.1-2.5, 2.6-5.0, 5.1-10.0, and >10.0 m/s (bottom to top). See Figure 2 to identify peripheral stations. 123

94. Percentage of winter 2315 GMT soundings with an inversion base at the surface and wind speeds at the surface (left) and at 300 m AGL (right) in the ranges calm, 0.1-2.5, 2.6-5.0, 5.1-10.0, and >10.0 m/s (bottom to top). See Figure 2 to identify peripheral stations. 124

95. Percentage of spring 2315 GMT soundings with an inversion base at the surface and wind speeds at the surface (left) and at 300 m AGL (right) in the ranges calm, 0.1-2.5, 2.6-5.0, 5.1-10.0, and >10.0 m/s (bottom to top). See Figure 2 to identify peripheral stations. 125

96. Percentage of summer 2315 GMT soundings with an inversion base at the surface and wind speeds at the surface (left) and at 300 m AGL (right) in the ranges calm, 0.1-2.5, 2.6-5.0, 5.1-10.0, and >10.0 m/s (bottom to top). See Figure 2 to identify peripheral stations. 126

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104. Percentage of summer 2315 GMT soundings with an elevated inversion base 1-3000 m AGL and wind speeds at the surface (left) and at 300 m AGL (right) in the ranges calm, 0.1-2.5, 2.6-5.0, 5.1-10.0, and >10.0 m/s (bottom to top). See Figure 2 to identify the peripheral stations. 134

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108. Percentage of spring 2315 GMT soundings with no inversion below 3000 m AGL and wind speeds at the surface (left) and at 300 m AGL (right) in the ranges calm, 0.1-2.5, 2.6-5.0, 5.1-10.0, and >10.0 m/s (bottom to top). See Figure 2 to identify the peripheral stations. 138

109. Percentage of summer 2315 GMT soundings with no inversion below 3000 m AGL and wind speeds at the surface (left) and at 300 m AGL (right) in the ranges calm, 0.1-2.5, 2.6-5.0, 5.1-10.0, and >10.0 m/s (bottom to top). See Figure 2 to identify the peripheral stations. 139

110. Percentage of autumn 2315 GMT soundings with no inversion below 3000 m AGL and wind speeds at the surface (left) and at 300 m AGL (right) in the ranges calm, 0.1-2.5, 2.6-5.0, 5.1-10.0, and >10.0 m/s (bottom to top). See Figure 2 to identify the peripheral stations. 140

## SECTION 1

## INTRODUCTION

In analyzing environmental impacts of air pollutants the transport and diffusion properties of the atmosphere are always of utmost importance; in many cases transformation and/or removal processes are equally important. For incorporating these processes into impact evaluations the available meteorological information is seldom optimum, even in designed experiments. In actual situations analysts rely heavily for data upon the hourly surface-based observations taken at many airports by the National Weather Service (NWS) or by the Federal Aviation Administration. A shortcoming in using these data is that in some situations they are not representative of important processes above the near-ground layer. This difficulty is offset somewhat by the NWS upper-air sounding program. Although these measurements are taken only at 12-hourly intervals at stations spaced on the order of 300 km, the vertical dimension of measurement is invaluable. The objective of this report is to present summaries of the lower few kilometers of upper air data that may be important in evaluating environmental impacts of air pollutants.

The NWS upper-air sounding program employs rawinsondes to determine vertical profiles of pressure, temperature, humidity, and wind. One of the rawinsonde-measured variables that is often studied is temperature structure, especially temperature inversions because of their marked inhibiting effects on vertical motion. The frequency of ground-based or very low-level inversions has been determined for the contiguous United States by Hosler (1961) and for Canada by Munn et al. (1970). But there is considerable additional useful dispersion information to be extracted from the rawinsonde observations; for example, characterization of elevated inversions, inversion thicknesses, and temperature structure in the absence of inversions, as was done to some extent by Bilello (1966) for some Arctic stations. In addition, data on winds aloft are important in pollutant transport, while moisture content is pertinent to the atmospheric transformation of certain pollutants as well as in evaluating the impact of cooling towers. Although certain of these variables (some of which have been determined from sources other than rawinsondes, e.g., towers) can be found in local studies of environmental impact, comprehensive national summaries are rare. The data in this report are for the United States, including stations in Alaska, Hawaii, and Puerto Rico.

The rawinsonde is a balloon-borne, shoe box-size package containing miniaturized instruments that measure and semi-continuously radio the pressure, temperature, and humidity to a ground station where the balloon is simultaneously tracked by a radio direction finder in order to compute the wind speed and direction. In the lower troposphere the balloons rise at a rate of 5 m/sec. The temperature sensor has a lag of no more than 6 sec at pressures greater than 700 mb, (i.e., at heights below 3 km where our interest lies for sea level locations). At several western stations where the elevation is 1500 m or more, soundings to 3000 m above the surface result in pressures as low as 500 mb. However, the additional estimated instrument lag will not significantly affect comparisons with lower elevation stations (Ference, 1951; Badgley, 1957). The 6-sec lag means that in the lower troposphere the sensor detects 63 percent of an instantaneous temperature change in no more than about 30 m. Considering all reasonable possibilities, the over-all probable error in rawinsonde temperatures is about ± 0.5°C (Ference, 1951). In reporting these sounding data, small details are omitted. The NWS assumes that the temperature varies linearly between adjacent levels, but sufficient levels are required so that no temperature on the actual sounding deviates by 1°C or more from the reported sounding. Although the overall probable error in pressure measurements is estimated to be no more than ± 2 mb up to the 700-mb level (about 3 km above mean sea level), the incremental probable error between successive pressure measurements is believed to be ± 0.5 mb (Ference, 1951). The least accurate rawinsonde measurement is relative humidity; its accuracy is difficult to define because of the complex nature of contributing factors. However, if the sensor is not subjected to condensations, the relative humidity probable error is estimated to be ± 2.5 percent for temperatures to -10°C and a humidity range of 15 to 96 percent (Ference, 1951). The relative humidity data presented in this report have been averaged over various layers. The accuracy of rawinsonde winds is also very difficult to evaluate because of the number of factors involved, their range of values, and possible combinations. An obvious important factor is the accuracy of the azimuth and elevation angles; the overall probable error is estimated to be ± 0.05 degree with elevation angles above 6 degrees (Ference, 1951). At lower angles the tracking accuracy deteriorates rapidly because of ground reflections. For our interest in the lower few kilometers the wind errors are not believed to be significant. The surface wind measurement is taken directly from an anemometer.

Rawinsonde observations are scheduled internationally for 0000 and 1200 GMT daily to determine the atmospheric structure at levels well up into the stratosphere. We are, of course, interested in the lowest few kilometers of the soundings. That the soundings are taken only twice daily is a shortcoming for our purposes because of the typical large diurnal variation that occurs in the near boundary layer. However, it is fortunate that in much of the United States the 1200 and 0000 GMT local sounding times are close to the usual times of greatest stability (near sunrise) and instability (mid-afternoon), respectively. On the other hand, some subtle but distinct advantages of rawinsonde data are that they extend through the layers of interest, they were taken uniformly at widely distributed locations, and the data are readily available.

# SECTION 2

# DATA PROCESSING

In order to properly interpret the data in this report it is necessary to understand the processing details. The processing occurred in two steps. First, each sounding was analyzed to extract and archive the desired information. Then the extracted data were summarized in a climatological format by observation time, season, and station. A third step consisted of machine plotting certain of the summarized variables on maps for analyses. Since the archived records of each rawinsonde observation include far more information than required for the purposes of this report, each sounding was analyzed to retain only pertinent data.

## *TEMPERATURE*

In processing the temperature data, no more than one temperature inversion was specified for each sounding. Isothermal layers were treated as inversions. For soundings with complicated or multiple inversions an arbitrary definition was used to simplify them. The processed inversion base was the lowest inversion base within 3000 m of the surface (all heights are with respect to surface elevation unless stated otherwise). The processed inversion top was that inversion top with the maximum actual temperature within 4500 m of the surface. Examples of this processing scheme are shown in Figure 1.

For soundings with no inversion within the lower 3000 m, values of $\Delta T/\Delta Z$ were determined for the layers 1-100, 101-250, 251-500, 501-750, 751-1000, and 1001-1500 m. The required temperatures at specified heights were determined by simple interpolation between the significant points of each rawinsonde observation.

## RELATIVE HUMIDITY

Relative humidity was processed to give average values for the inversion layer, the subinversion layer in the case of elevated inversions, and the 300-m layer above the top of ground-based inversions; for no-inversion soundings the average relative humidity was for the same layers as for $\Delta T/\Delta Z$ (above). In determining layer averages of relative humidity, the values at the bottom and top of a specified layer were obtained by simple interpolaton between the nearest significant points. Where additional humidity values were given within a specified layer, that layer was broken into sublayers; the average for a sublayer was the average of the humidity values at the bottom and top of the sublayer. The average for the entire specified layer was determined from the sublayer averages, weighted for their thickness with respect to that of the specified layer.

## WINDS

Wind direction and speed were processed to give values at ground level and 150, 300, 600, 900, and 1200 m above ground level (AGL). These heights were usually different from those of the archived sounding data (surface, 150, and 300 m AGL; 500, 1000, 1500, etc., msl; and at standard pressure levels of 1000, 950, 900, 850, etc., mb). The processed wind values were obtained by interpolation; details are given by the National Climatic Center in their summaries for individual stations (see Appendix A).

The pertinent data on temperature, relative humidity, and wind that were determined for each sounding were used to generate various other variables (e.g., inversion thickness, temperature increase with height, etc.) that were also stored on magnetic tape. These data were summarized into climatological formats, and are selectively used in this report. APPENDIX A describes these formats and their availability. APPENDIX A also lists the stations and periods for which summaries have been prepared.

## SECTION 3

## GENERAL DISCUSSION

Figure 2 identifies all of the stations for which data are presented in this report. The two Hawaiian stations, seven Alaskan, and San Juan, Puerto Rico are plotted along the periphery of the map. San Diego is plotted immediately below southern California to avoid overprinting of the Santa Monica data.

For most stations the period of record summarized is the 5 years, 1960 through 1964, with exceptions indicated on Figure 2 and in Table A-6. The only station with all summarized soundings outside the period 1960-1964 is Wallops Island, Virginia. These years were selected to coincide with those used earlier in climatological estimates of mixing heights (Holzworth, 1972). The extent to which the data for 1960-1964 are sufficiently representative is open to debate. However, participants at a recent conference on air quality modeling guidelines (Roberts, 1977) generally concluded that for their purposes a 5-year record was adequate.

While the routine rawinsondes were released at the same Greenwich Mean Time (GMT) every day, the angle of the sun with the horizon, of course, varied from day-to-day throughout the year. Climatically, the effect of variable solar surface heating results in significant seasonal variations in the thermal structure of the lower atmosphere. To demonstrate the possibility of this effect, the solar elevation angle for the middle day of each meteorological season (i.e., January 15, April 15, July 15, and October 15) at the customary rawinsonde release times (i.e., 1115 and 2315 GMT) are presented in Figures 3 - 10. Notice that on January 15 at 1115 GMT (Figure 3) the only station where the sun is above the horizon is San Juan, but even there only the beginning of surface heating is expected. On the other hand, in the West and North, sunrise is hours or more away and the full effect of long-wave radiational cooling has not yet been realized. On January 15 at 2315 GMT (Figure 7) the sun is near the horizon through the middle of the 48 states so that long-wave cooling is well under way over the northeastern states, has barely begun along the Pacific Coast, and hasn't even started in Hawaii.

On July 15 at 1115 GMT (Figure 5) solar heating has begun in the northeastern states, but is still hours away in the western states, except Alaska. North of the Arctic Circle the sun remains above the horizon on some summer days, but nevertheless marked diurnal variations can occur in the temperature structure near the ground. On July 15 at 2315 GMT (Figure 9) the sun is above the horizon at every station, except San Juan. Long-wave cooling is about to begin along the Atlantic seaboard, but throughout much of the West maximum temperatures for the day are just about to be reached. Solar elevations on October 15 at 2315 GMT are shown in Figure 10.

Since the possible number of rawinsonde-derived variables and combinations thereof is very large, only the more important ones were selected for presentation in this report. Even so, there are 100 data maps. They fall into three main groups, depicting the characteristics of (1) vertical temperature structure (2) relative humidity for certain configurations of temperature structure, and (3) wind speeds for certain configurations of temperature structure. In order to present as much potentially useful information as possible some maps include up to 14 pieces of data for each station. However, no more than one set of isopleths appears on each map; on some maps no isopleths are presented. The variables that were selected for analyses were chosen to illustrate the general patterns of the data, but are not necessarily indicative of isopleth analyses for other variables on the same maps. Furthermore, the isopleths should be used cautiously, especially in non-uniform and irregular terrain where values for particular variables may change significantly over short distances. In this regard, it should be pointed out that in areas of irregular terrain most rawinsonde stations are located in valleys; none are located on mountain peaks or ridges where the climate is typically very different from that of nearby valleys. In addition, most rawinsonde stations are located in suburban or rural areas and seldom show marked effects of densely built-up areas. Except where urban effects do show up explicitly in the data, no attempts have been made to incorporate urban effects into the isopleth analyses. Attempts to infer data values at locations beyond the rawinsonde sites should only be done with great care and with knowledge of the climate in the surrounding area.

In general, there is so much information on the charts presented in this report that it is difficult to pick out all of the potentially important features, let alone comment on them. Rather, only limited discussions are presented, leaving further interpretations to the reader. In such considerations it is well to keep in mind that the individual variables and their values are only parts of a completely internally consistent set of data.

All of the climatic data on Figures 11 - 110 are in percentage values rounded to the nearest whole number, and are with respect to the total number of observations. For practical purposes missing observations were zero at all stations. In this report the seasons are defined as December + January + February = Winter, March + April + May = Spring, etc.

## CHARACTERISTICS OF VERTICAL TEMPERATURE STRUCTURE

### All Inversions

Most of the data in this report are concerned with describing the vertical temperature structure of the lower atmosphere. The first group of maps gives the percentages of all soundings with at least one inversion (i.e., surface-based or elevated) within 3 km of the surface. For 1115 GMT the data are only presented annually (Figure 11) since seasonal variations are slight. From Figure 11 it is clear that morning soundings without an inversion are uncommon. Even in tropical San Juan inversions occur in 69 percent of the observations. The lowest frequency in the contiguous 48 states is just under 70 percent at Tatoosh Island; the lowest at any station is 57 percent at nearby Annette, Alaska. These relatively low frequencies are attributed to the common occurrence of storms along this part of the Pacific Coast. Undoubtedly, the major reason for the high frequency of inversions at 1115 GMT is that even during the summer the sun is only slightly above the horizon over about half of the United States (see Figures 3 - 6), thus limiting solar heating.

At 2315 GMT the seasonal variation of all inversions (Figures 12 - 15) is considerably greater than at 1115 GMT. In general, for the contiguous 48 states the occurrence of all inversions at 2315 GMT is greatest in winter (Figure 12), least in summer (Figure 14), and intermediate during the transition seasons (Figures 13 and 15). In winter the frequencies exceed 70-80 percent everywhere east of the Rockies, including San Juan, and along the Oregon-California coastal regions. Even over the Rockies the frequencies exceed 50 percent, except in the extreme south. The relatively low winter occurrences, around 60 percent, over Washington extend north along the Pacific Coast through Annette (50 percent) and Yakutat (62 percent), but then increase to 94 percent at Anchorage. Although Anchorage is a major seaport, it lies at the upper end of Cook Inlet and is rather well sheltered by mountains from the storms that are common throughout the nearby ocean.

For most stations the lowest occurrence of all inversions at 2315 GMT is during summer (Figure 14). Over much of the Rockies the frequencies are less than 30-40 percent, ranging down to only a few percent. This dearth of inversions within 3 km of the surface is due to the high solar elevation at 2315 GMT (Figure 9), the high altitude of the terrain, and aridity of the region, all of which enhance the transfer of solar radiation to the surface where it heats the ground, which heats the air. Along the California-Oregon-Washington Coast and along the northern Atlantic Coast the frequencies of all inversions at 2315 GMT show only slight seasonal variations. However, along the California Coast the highest frequencies, nearly 100 percent, occur in summer, reflecting the well-known subsidence or marine inversion that prevails in summer. Along the immediate coast of the northern Atlantic the summer frequencies are only slightly less than in winter, but unlike winter they drop off rapidly to the west.

The relatively high frequencies of about 50 percent over the upper Midwest (Figure 14) are interesting because a physical explanation for their occurrence is not understood. The large frequencies in Hawaii, even with high sun, are caused by the trade-wind inversion, which is negligibly affected by surface heating over the ocean. The low frequencies north along the Alaskan Coast, Annette to Yakutat to Anchorage, apparently do reflect the effects of large heating at the surface and a high sun at observation time. This effect among Alaskan stations culminates at Fairbanks which has an inversion within 3 km of the surface in only 24 percent of the summer afternoon soundings. The comparatively high frequencies of inversions at Nome, Barrow, and Barter on the immediate coast of Alaska are attributed to ice-covered or very cold adjacent waters and frozen ground. Generally, the frequency of all inversions is greater in autumn (Figure 15) than in summer, following the seasonal solar cycle.

Surface-Based Inversions

Figures 16 - 19 show the 1115 GMT seasonal distributions of surface-based inversions. Since at this time the sun is above the horizon only over the eastern half of the contiguous 48 states, it is not surprising that surface-based inversions are common throughout the year. Frequencies exceeding 90 percent occur over the Rockies in all seasons, but are most abundant in summer and autumn (Figures 18 and 19). Ground- (or surface-) based inversions in the morning are also generally common throughout the year over the southern Appalachians and coastal Piedmont with frequencies of around 60-70 percent. There is an interesting secondary maximum of morning surface inversions over the central Midwest in summer (Figure 18). These high values extend southward to Lake Charles with a frequency of 94 percent, which contrasts sharply with values of only 15 and 21 percent at nearby San Antonio and Burwood. Notice that this curious pattern is also apparent in spring and autumn (Figures 17 and 19). The reason for such large variations over relatively short distances is not understood (the summaries have been double-checked), but the patterns compare favorably with data presented by Hosler (1961).

Areas with relatively few ground-based inversions throughout the year are centered along the Washington Coast and in the vicinity of New York City (i.e., in the soundings from J. F. Kennedy Airport). The former are readily attributed to the occurrence of dense clouds and fast winds associated with storms, while the latter is thought to reflect effects of intense human activity (e.g., the urban heat island), perhaps augmented by the distribution of water temperatures in the vicinity of New York City. Another interesting feature of ground-based inversions in Figures 16 - 19 is the variation along the California Coast from around 70 percent in winter to less than 20 percent in summer. This is caused, of course, by the predominance of the well-known (elevated) subsidence or marine inversion during summer (Neiburger et al, 1961). The low frequency of ground inversions in the vicinity of the Great Lakes during winter reflects the effects of cold Canadian air streaming southward over the relatively warm lakes, which generate dense low clouds and frequent snow flurries.

The occurrence of surface-based inversions in the morning at San Juan varies from 70 percent in winter to 22 percent in summer, as expected from the variation in solar elevation at observation time (1115 GMT). The same sort of seasonal variation also occurs at Lihue, although the actual frequencies are generally somewhat less, ranging from 46 percent to 22 percent. Compared to San Juan, these fewer occurrences are due to the shorter duration of long-wave cooling since late afternoon/early evening. Such cooling is more effective at higher elevations, especially in the tropics, and manifests itself at lower elevations by cool drainage flows. This effect shows up very markedly at Hilo on Hawaii Island, not far from Lihue on Kauai Island. Hilo is near the base of Mauna Loa (4171 m above sea level) and has seasonal frequencies of morning ground-based inversions that are surprisingly high, but vary only relatively slightly, between 90 and 78 percent. At the Alaskan stations the highest frequencies of morning ground-based inversions generally occur in winter and the lowest in summer, largely as a consequence of the solar cycle. However, there are clearly regional differences that reflect the local climate.

Figures 20 - 23 show the seasonal frequencies of surface-based inversions at 2315 GMT. At this observation time the local time varies from mid-afternoon in summer along the Pacific Coast of the contiguous 48 states to post-sunset in winter over the eastern states (see Figures 7 - 10). The general effects of such variations can be seen in the distributions of surface-based inversions, although there are also clear indications of local climate effects. At 2315 GMT surface-based inversions are most extensive over the contiguous 48 states during winter (Figure 20). Only in the southwestern region and southern Florida are the frequencies less than 10 percent; they exceed 50 percent only along and near the Atlantic Coast. Again, the data suggest effects of anomalous heating in the vicinity of New York City. The isopleth patterns for spring and summer (Figures 21 and 22) are very similar with significant occurrences of surface-based inversions only in the vicinity of the Atlantic Coast. The autumn (Figure 23) distribution of evening ground-based inversions is clearly intermediate between those of summer and winter, and largely demonstrates the effects of enhanced long-wave cooling as the sun sets earlier.

At San Juan the seasonal frequencies of ground-based inversions at 2315 GMT follow those at Miami rather closely. The frequencies at the two Hawaiian stations are in very close agreement with those along the California Coast. The Alaskan stations generally show ground-based inversion frequencies increasing with latitude in all seasons but, as expected for most stations, the highest frequencies occur in winter and the lowest in summer.

Elevated Inversions

Since the frequency of all inversions (i.e., elevated plus ground-based) at 1115 GMT has been shown (Figure 11) to be uniformly high (i.e., exceeding 80-90 percent at almost all stations), those regions with high frequencies of ground-based inversions must have low frequencies of elevated inversions and vice versa. Thus, Figures 24 - 27 are in a sense "mirror images" of Figures 16 - 19, respectively, and deserve only a few additional comments. It should be kept in mind, however, that in analyzing each sounding only the main inversion was counted (see SECTION 2). This means that secondary inversions, necessarily of the elevated variety, may occur more often than indicated, but only when a surface-based inversion is present.

In Figures 24 - 27 in the vicinity of New York City notice the anomalously high frequencies of elevated inversions (at J. F. Kennedy Airport). This feature lends further support to the possibility mentioned earlier that it is caused by an urban (megalopolitan) heat island. For example, the input of anthropogenic heat near the surface (and/or the retardation of cooling) tends to raise the height of the base of ground-based inversions. Consequently, there are relatively fewer ground-based inversions and more elevated inversions, as shown clearly by the data in this report.

The relatively high frequencies of morning elevated inversions that occur in central Texas are not understood any better than the low frequencies of ground-based inversions in the same area. But there seems to be little likelihood that they are caused by an urban heat island.

The frequencies of elevated inversions at 2315 GMT are shown in Figures 28 - 31. Unlike the comparatively sparse occurrence of surface-based inversions at 2315 GMT (Figures 20 - 23), elevated inversions have frequencies of more than 10 percent at all stations, except those in the Rockies during summer. This indicates the intense surface heating that occurs and that typically extends through very deep layers (i.e., at least 3 km). Notice that this surface heating effect over the Rockies also shows up clearly in the patterns for spring and autumn (Figures 29 and 31), but is somewhat complicated in winter (Figure 28). In all seasons the frequencies of elevated inversions at 2315 GMT are relatively high over the upper Midwest; they are relatively low over the central Appalachians and to some extent extending south and north (i.e., in those areas with relatively high frequencies of ground-based inversions at 2315 GMT (Figures 20 - 23). The most consistently high values occur along the California Coast, where they exceed 70-80 percent in all seasons. The most complicated and seasonally-variable patterns occur along and in the vicinity of the Gulf and Atlantic Coasts. Apparently, this is caused by various combinations of seasonal variations in solar elevation at 2315 GMT, seasonal lag in ocean temperatures, contrasts between coastal water and land temperatures, and effects of local and regional climate.

At 2315 GMT the frequencies of elevated inversions (Figures 28 - 31) at San Juan decline steadily from 59 percent in winter to

24 percent in autumn. The reasons for this variation are not known, but it agrees qualitatively with the complex variations along the Gulf and south Atlantic Coasts. Both Hawaiian stations have relatively high frequencies of afternoon (in fact, near mid-day) elevated inversions throughout the year with percentages mostly in the 70s and upper 60s due to the trade wind inversion. The three more southerly Alaskan stations, Annette, Yakutat and Anchorage, have afternoon elevated inversion frequencies ranging from 21 to 50 percent with no clear consistent dependence on solar elevation (as there is for surface-based inversions). The remaining four more northerly Alaskan stations have an interesting and readily explainable (for the most part) seasonal variation of afternoon elevated inversion percentages. Generally, the frequencies increase from winter to spring, decrease from spring to summer, remain about the same from summer to autumn (except at Fairbanks), and decrease from autumn to winter. The main reason for this variation is the solar elevation (see Figures 7 - 10). At these four Alaskan stations in winter the sun is always near the horizon at 2315 GMT and surface-based inversions are relatively common, precluding the counting separately (by the criteria used in this study; see SECTION 2) of elevated inversions. During spring the sun is for the most part well above the horizon at 2315 GMT (local times at the four stations are 1215 or 1315), nocturnal ground-based inversions have not been completely eliminated, but surface heating has eroded their bases so that they appear as elevated inversions. Thus, the frequencies increase from winter to spring. From spring to summer the frequencies decrease because summer solar heating is so effective that some inversions have been eliminated, and long-wave radiational cooling hasn't begun at 2315 GMT. From summer to autumn the frequencies of elevated inversions near noon local time increase sharply at Fairbanks, but remain about the same at the other three stations, Nome, Barrow, and Barter. This increase at Fairbanks is attributed to the sun reaching a sufficiently high elevation to convert nocturnal surface-based inversions into elevated inversions and being high enough at observation time to prohibit the formation of surface-based inversions. That this is more likely at the beginning of the autumn season than at the end is indicated by much higher frequencies of surface as well as elevated inversions in autumn compared to summer (see Figures 22, 23, and 30, 31). At Nome, Barrow, and Barter, each on the coast, the autumn frequencies are about the same as in summer. This is thought to be caused by the general seasonal lag in cooling of the oceans. From autumn to winter elevated inversion frequencies at 2315 GMT decrease markedly at all four of the more northerly Alaskan stations. The main cause of this variation is the sun being very near the horizon at observation time, resulting in an enhanced occurrence of ground-based inversions. The entire seasonal variation that has been described for the four more northerly Alaskan stations is also true to some degree for Anchorage, but is moderated by effects of the ocean.

Heights of Tops of Surface-Based Inversions

Figures 32 - 35 show the seasonal frequencies of all 1115 GMT soundings with a surface-based inversion and with the top at least through the indicated heights. It should be realized that if the frequency of surface-based inversions is small, the frequency of the heights of their tops is necessarily small also. For reference, the frequencies of surface-based inversions is shown in the figures to the left of each station. As a general rule, the data indicate that practically all surface inversions are at least 100 m deep. In Figures 32 - 35, the isopleths show the frequencies of surface-based inversions with tops at least 250 m above the surface. In the contiguous 48 states the greatest frequencies occur in summer over the central intermountain plateau with values barely exceeding 60 percent. Values exceeding 50 percent over large regions occur in all seasons except spring. The larger frequencies generally occur over inland regions, except in summer large values are also found over the northern Great Lakes. This effect of the relatively cool water surfaces is very probably much more prevalent than indicated by the spacing of data points in this report (e.g., see Lyons and Olsson, 1973), and exemplifies the sort of attention to local climatic features that should be made in interpolating/extrapolating from the data presented here.

At San Juan and the two Hawaiian stations surface-based inversions are rarely as deep as

250 m; the more northerly Alaskan stations, especially during winter, have frequencies of that depth exceeding 50 percent. At Fairbanks in central Alaska winter conditions are optimum for development of deep radiation inversions; the tops of such inversions exceed 250 m in 76 percent of all observations and they exceed 1500 m in 16 percent of all observations, more than at any other station. Within the contiguous 48 states surface-based inversions with their tops above 1500 m occur in a few percent of all 1115 GMT soundings at almost all stations during winter; at International Falls and Caribou the percentages are 12 and 10. Such deep inversions are least common during the summer season when they occur only at a few stations, notably in Oregon.

At 2315 GMT ground-based inversions generally are relatively weak, although they occur fairly often in winter and autumn at the more easterly and northerly stations; they are rather uncommon in summer and spring when they are mainly confined to the region from the Appalachians to the East Coast (see Figures 20 - 23). Figure 36 shows the annual frequencies of ground-based inversions at 2315 GMT and the frequencies of the heights of such inversion tops. As depicted by the isopleths, ground-based inversions with tops at least 250 m above the surface occur in more than 10 percent of all 2315 GMT soundings only in the immediate vicinity of the Atlantic Coast. As expected, deep surface-based inversions at 2315 GMT are fairly common at the more northerly Alaskan stations. Obviously, their greatest occurrence is during the winter season.

### Heights of Bases of Elevated Inversions

Figure 37 shows the annual frequencies of all 1115 GMT soundings with elevated inversions (seasonal frequencies were discussed in connection with Figures 24 - 27) and with inversion base heights in the specified ranges above the surface. Generally, these elevated inversion base heights are spread over the entire range of specified values. Exceptions occur at the Hawaiian stations, especially Lihue, and at San Juan where most of the elevated inversion base heights are in the two highest intervals, 1001-2000 and 2001-3000 m above the surface. At the two most northerly Alaskan stations, Barter and Barrow, most elevated inversions are in the two lowest intervals, 1-250 and 251-500 m, but they also occur over the entire range of specified heights. Along the California Coast the subsidence inversion base height of roughly 500 m readily shows up in the data. Throughout many of the Plains states the most common elevated inversion base height is in the range 251-500 m with a frequency of around 10 percent. The northeastern states have relatively frequent occurrences of elevated inversions in the lower height ranges and there is also a comparatively large occurrence in the range of 1001-2000 m for which the isopleths are shown. Notice the 10-percent isopleth along the Washington Coast, and that it is consistent with the data for nearby Annette.

Figures 38 - 41 show the seasonal frequencies of all 2315 GMT soundings with elevated inversion base heights in the indicated increments. Most stations have some occurrences in all height increments. Generally, the highest frequencies occur in the range 1001-2000 m, but there are many locations where other height ranges predominate. Isopleths are shown for inversion base heights of 1001-2000 m in order to illustrate the continuity of the data, but this is not meant to imply that the same patterns apply for other inversion heights. For example, high frequencies of elevated inversion bases relatively close to the ground are confined to the California Coast, especially during summer (Figure 40). An excellent description of spatial and temporal variations of this inversion base-height over the Los Angeles Basin has been given by Edinger (1959).

There is so much information in Figures 38 - 41 (and in other figures that follow) that it is difficult to comment on all the potentially significant features, and no attempt will be made to do so.

### Thicknesses of Elevated Inversions

Figures 42 - 45 show the seasonal frequencies of all 1115 GMT soundings with an elevated inversion and with the thicknesses of such inversions (i.e., the height of the top minus that of the bottom) exceeding the indicated values. Isopleths illustrate the frequencies of elevated inversion thicknesses that exceed 500 m. Notice that the area with frequencies exceeding 10 percent is most extensive in winter (Figure 42) and smallest in summer (Figure 44) but the highest frequencies by far occur during summer along the California Coast.

Figures 46 - 49 are the same as the previous four, except these are for the 2315 GMT soundings. Qualitatively, the seasonal variation of the isopleth patterns is much like that for the 1115 GMT soundings (Figures 42 - 45).

Intensities of Surface-Based Inversions

In this report inversion intensities are defined arbitrarily in terms of the average rate of temperature increase through the inversion layer. It is an average rate because it is determined from temperatures only at the base and top of each inversion, although there may be sublayers with differing rates. Inversion intensities were classified as follows:

| Rate of Temperature Increase | Inversion Intensities |
|---|---|
| >6.00°C/100 m | Very Strong |
| 2.83 to 6.00°C/100 m | Strong |
| 1.15 to 2.82°C/100 m | Moderate |
| 0.48 to 1.14°C/100 m | Weak |
| 0.00 to 0.47°C/100 m | Very Weak |

Figures 50 - 53 show the seasonal frequencies of all soundings at 1115 GMT with a surface-based inversion and inversion intensities in the specified classes for inversion thicknesses of 500 m or less and of more than 500 m. Notice that in these figures the sum of all individual frequencies for each station gives the frequency of all ground-based inversions (except for rounding to the nearest whole percent). The data indicate that, generally, ground-based inversion thicknesses of 500 m or less have greater frequencies and intensities than deeper ground-based inversions. The more northerly Alaskan stations are exceptions in that during winter they have considerably more deep than shallow ground-based inversions, although the more intense inversions are still the shallower ones. Almost all stations have some relatively shallow ground-based inversions with intensities in all classes through very strong. On the other hand, no station has any relatively deep ground-based inversions that are classed as very strong; many stations don't even experience any strong intensities. Clearly, the overall tendency for surface-based inversions at 1115 GMT is to have greater intensities associated with shallower inversions.

In Figures 50 - 53 the isopleths are for the percentages of ground-based inversions no deeper than 500 m with a moderate inversion intensity (middle value, left side of each station). These conditions were selected for isopleth analysis because of their relatively high frequency of occurrence. Over the Rockies and much of the Midwest these conditions are most prevalent in summer and least prevalent in winter. The strong isopleth gradient in the vicinity of Louisiana during summer (Figure 52) is a reflection of a relatively high frequency of ground-based inversions at Lake Charles, as discussed in connection with Figure 18.

Figure 54 shows values of the same variables as the previous four figures, except these are on an annual basis and for soundings at 2315 GMT. Since ground-based inversions are uncommon at this observation time, except at some Alaskan stations in the colder months, the frequencies are for the most part very low. As shown by the isopleths, there are only a few stations with barely a 10-percent frequency of afternoon/evening ground-based inversions that extend through no more than 500 m and that have an intensity of moderate.

Intensities of Elevated Inversions

Figures 55 - 59 are similar to the previous series, except these are for the intensities of elevated inversions. Isopleths are for inversions with an intensity of weak and with thicknesses of 500 m or less. Figure 55 shows the isopleths and annual data for 1115 GMT soundings. Notice that there are relatively few elevated inversions at this time in the general vicinity of the Rocky Mountains and relatively more along the Atlantic Coast. Of those inversions that do occur at 1115 GMT, most have a thickness of 500 m or less with intensities of very weak and weak but almost all stations experience some very strong intensities. On the other hand, for inversion thicknesses greater than 500 m no station experiences any intensities of very strong and few report any that are classed as strong. The two more northerly Alaskan stations, Barter and Barrow, are exceptions in that they have more deep than shallow thicknesses of elevated inversions. For the same reason Santa Monica and San Diego, California are almost exceptions due to the relatively deep and intense subsidence inversion that predominates along the California Coast during summer. It is also interesting to note the disparity between the data for Lihue and Hilo, Hawaii, due essentially to the predominance of surface-based inversions at Hilo. In general, the thickness and intensity characteristics of elevated inversions at 1115 GMT are much like those of ground-based inversions.

At 2315 GMT (Figures 56 - 59) there are generally considerably more elevated inversions than at 1115 GMT, but otherwise the thickness and intensity characteristics are rather similar. For example, at most stations there are more thin (<500 m) than thick (<500 m) elevated inversions and the thinner ones tend to be more intense, although relatively few occur with an intensity of very strong. At most stations the most common intensity of elevated inversions is very weak.

Figures 56 - 59 include the seasonal isopleths of the frequency of weak intensity inversions with thicknesses of 500 m or less at 2315 GMT. In winter (Figure 56) most frequencies are around 10 - 20 percent; they are lower along the coastlines, except along the California Coast. Notice that values for the Hawaiian stations are quite similar to those for stations along the California Coast. Similarly, there is good agreement between San Juan and Miami. Spring (Figure 57) is much like winter although the area with frequencies less than 10 percent has grown larger. This trend continues into summer (Figure 58) at which time there are few stations with thin elevated inversions of weak intensity. However, along the California Coast in summer the most frequent inversion intensity is moderate for both thick and thin inversion layers. The autumn isopleth pattern (Figure 59) is much like that of summer.

### Superadiabatic Temperature Differences in No-Inversion Soundings

Thus far the discussions have been concerned with the characteristics of temperature inversions. In this subsection and in the one that follows the emphasis is on superadiabatic temperature differences as they occur in soundings with no inversion and in soundings with elevated inversions. Superadiabatic is defined here as a temperature decrease with height exceeding 1.20°C/100 m. Isopleths have been omitted from this series of maps because no one set of data stands out as occurring more frequently than another. Figures 60 - 63 show the seasonal percentages of 2315 GMT soundings with no inversion below 3000 m and with superadiabatic temperature differences in the specified layers. Notice that these temperature differences are determined from the temperatures at the tops and bottoms of the layers; therefore, they are averages. It should be emphasized that because of the lag in rawinsonde temperature sensors, superadiabatic conditions tend to be underestimated (i.e., the soundings are often more unstable than indicated)!

Figure 60 shows that during winter, 2315 GMT soundings with no inversion are unusual--and superadiabatic conditions are even more unusual--except in the West. But even there, such unstable conditions are confined mainly to the lowest layer, 1-100 m; they occasionally extend through the layer 101-250 m but rarely higher. Following the solar cycle the frequencies increase during spring (Figure 61) and reach a maximum in summer (Figure 62) when there are five stations in the Rockies (Glasgow, Winnemucca, Grand Junction, Winslow, and Albuquerque) with superadiabatic frequencies of 10 percent or more (with respect to all soundings) in the layer 251-500 m. In this same region there are a few stations that have superadiabatic frequencies of a few percent in the layer 501-750 m and a very few with one-percent frequencies in the 751-1000-m layer. Notice in Figure 62 that along the California Coast there are very few soundings with no inversions and therefore the occurrence of associated superadiabatic conditions is nil. The Hawaiian stations and the more southerly Alaskan stations all have significant frequencies of superadiabatic temperature differences, at least in the 1-100-m layer, unlike the relatively very low frequency at San Juan which resembles the values along the south Atlantic seaboard.

During autumn (Figure 63) the data are much like those for summer although the frequencies tend to be somewhat less, due essentially to the lower solar elevations at observation time. The effect in the eastern states of lower solar elevations contributing to less instability than would have occurred with higher sun (i.e., comparable to those at 2315 GMT in the West) is indicated in Figure 64. The data in this figure are the same as in Figure 62 (summer, 2315 GMT), except these are for a temperature decrease with height of more than 0.80°C/100 m (in Appendix A neutral conditions are defined as temperature decreasing with height in the range 0.81-1.20°C/100 m). Figure 64 shows that at most western stations, especially in the Rockies, the stabilities of practically all lower layers of no-inversion soundings are near neutral or less stable. But proceeding eastward the frequencies drop off progressively, indicating the effects of surface cooling by observation time. It is speculated that if soundings in the eastern United States were taken at comparable solar times to those in the western mountains, the frequencies of superadiabatic conditions in the East would be greater than indicated, but would not exceed values over the mountains. This is because the transmission of solar radiation to the mountains and its absorption there is enhanced by the elevation, aridity, and nature of the surface.

Since at 1115 GMT there are few stations with more than a very few percent of no-inversion soundings (see Figure 11), there are even fewer occurrences of associated superadiabatic conditions. At 1115 GMT no-inversion soundings are more common along the Oregon-Washington-southern Alaska Coasts where seasonal frequencies reach 20-40 percent. Even so, superadiabatic conditions in such soundings are rare and are confined essentially to the layer 1-100 m.

Superadiabatic Temperature Differences Below Elevated Inversions

The data in this subsection are similar to those in Figures 60 - 63, except these are for superadiabatic conditions in the entire layer beneath elevated inversion bases and they are broken down by inversion base heights. Thus, except for the lowest layer (1-100 m), where inversion bases seldom occur, the temperature differences in this subsection are necessarily averaged over deeper layers than in the previous subsection. Figures 65 - 68 show the seasonal frequencies of a temperature decrease with height exceeding 1.20°C/100 m in the layer beneath elevated inversions, by inversion base height, for 2315 GMT soundings. Notice that for each station, within rounding errors, the sum of figures on the left gives the total percentage of all soundings with an elevated (above surface) inversion base within 3000 m of the surface. The corresponding figures on the right of each station give the percentages of all soundings with an elevated inversion base in the indicated height range and with a superadiabatic temperature difference in the layer below the inversion. Thus, the proportion of those inversion base heights that subtend a superadiabatic layer may be readily determined.

Figure 65 shows the data for winter soundings at 2315 GMT. In general, although elevated inversions are fairly frequent at most stations, superadiabatic conditions in the layers below them hardly occur at all in the East and occur occasionally in the West. The effects of differing solar elevations show up again and in addition there is the effect of superadiabatic conditions being more likely in layers closer to the surface (i.e., in the layer beneath lower inversion base heights. For example, in Figure 65 at stations in the West, the highest proportions of inversions that are underlain by superadiabatic layers are for the lower inversions. The average temperature change below higher level inversions is seldom superadiabatic. Notice that this effect is especially pronounced at Santa Monica and San Diego where the 2315 GMT soundings practically always have an elevated inversion, a comparatively high proportion of which have bases at low levels. On the other hand, the Hawaiian stations and San Juan have mostly high level inversions, rarely with superadiabatic layers (as defined here) below. It is interesting that all of the Alaskan stations have some occurrences of superdiabatic conditions below inversions--even in winter.

Proceeding to spring (Figure 66) there is a general tendency for inversion bases to occur at higher levels and for a high proportion of superadiabatic conditions in the layers below, especially below low-level inversions. This is particularly evident at the northern Alaskan stations. Over the Rockies the effects of increasing solar radiation lead to a marked decrease in frequency of inversions below 3000 m. By summer (Figure 67) there are very few inversions within 3000 m of the surface at 2315 GMT over the Rockies, in accord with the afternoon mixing height calculations of Holzworth (1972). In the East, especially along the middle and northern Atlantic Coasts, there are some occurrences at 2315 GMT during summer of superadiabatic conditions below the lower elevated inversions. This effect is very pronounced along the Pacific Coast, particularly of California, where there is a high frequency of inversion bases within 500 m of the surface, of which an exceptionally high percentage are underlain by superadiabatic conditions. To a significant, but lesser degree, this is also true at the two most northerly Alaskan stations. The data for autumn (Figure 68) are generally intermediate between summer and winter.

Although elevated inversions at 1115 GMT do occur frequently at some some stations in some seasons (see Figures 24 - 27) only very rarely are they associated with superadiabatic temperature differences in the underlying layer. For example, at Oakland, elevated inversions with bases below 500 m occur in 45 percent of all 1115 GMT summer soundings, but the underlying layer is superadiabatic in only slightly more than one percent of all soundings. Curiously, the two more northerly Alaskan stations, Barter and Barrow, have by far the highest seasonal frequencies of elevated inversions at 1115 GMT with superadiabatic conditions below, about 7 percent at both during summer.

RELATIVE HUMIDITY VS VERTICAL TEMPERATURE STRUCTURE

Two principal processes for which relative humidity is an important factor are atmospheric chemical transformations (e.g., sulfur dioxide to sulfate aerosol) and enhanced fog and cloud formation as a result of cooling tower emissions. Although the figures include frequencies of relative humidities exceeding 69 and 89 percent for ground-based as well as layers aloft, the isopleth analyses focus on humidities exceeding 69 percent in the ground-based layer. It should be emphasized that the relative humidities are averages for the layers being considered (see SECTION 2) and such layers may display considerable internal variation. This is particularly true of ground-based radiation type inversions in which the relative humidity (and often the absolute humidity) profiles are typically mirror images of the temperature profiles. Largely, because of this phenomenon the average relative humidity of the layers considered here seldom exceeds 89 percent.

Within Surface-Based Inversions

Figures 69 - 72 show the isopleths of seasonal percentages of all 1115 GMT soundings with a surface-based temperature inversion in which the relative humidity exceeds 69 percent. Obviously, the frequency of such conditions is limited by the frequency of surface-based inversions (Figures 16 - 19). Generally, at 1115 GMT in all seasons (Figures 69 - 72) the occurrence of surface-based inversions with an average relative humidity greater than 69 percent is comparatively high in the vicinity of the south Atlantic and Gulf Coasts, and extending inland over Oregon and Washington. In addition, during summer (Figure 71) there is a distinct high-frequency area extending northeastward from Lake Charles, whose value of 92 percent is the highest for any station. The second highest summer value, 82 percent, occurs at Hilo. In fact, all seasonal values at Hilo range from 77 to 88 percent. The disparity between the data for Hilo and nearby Lihue has already been discussed in terms of surface-based inversion frequencies. Nevertheless, the occurrence at Hilo and Lake Charles of high percentages of surface-based inversions with very high proportions of relative humidity exceeding 69 percent is difficult to explain. The intense isopleth gradients along the Texas-Louisiana Coast during summer are apparently related to the distribution of surface-based inversions as discussed in connection with Figure 18. Those regions generally associated with comparatively low frequencies of ground-based inversions that have average relative humidities exceeding 69 percent are over the Rockies, especially in the south and along their eastern slopes into the Plains, along the Washington Coast, and in the vicinity of New York City. The latter small area is due to the anomalously low frequencies of surface-based inversions that occur there.

The distribution of 2315 GMT soundings with a surface-based inversion and an average relative humidity exceeding 69 percent is shown in Figure 73 on an annual basis since such conditions are so unusual. The only places where the values exceed 10 percent are along the Atlantic Coast, along the central Gulf Coast, and at the two more northerly Alaskan stations, Barter and Barrow. An obvious main reason for the low values is the local times, late afternoon/evening, when the soundings are made. At these times the surface temperatures would still be somewhat high and the relative humidities would necessarily be low.

## Below Elevated Inversions

Figures 74 - 77 show the seasonal percentages of all 1115 GMT soundings with an elevated inversion (i.e., with a base between 1 and 3000 m) for which the average relative humidity in the subinversion layer and within the inversion layer exceed 69 and 89 percent. Isopleths are shown for average relative humidities exceeding 69 percent in the subinversion layer. Most of these isopleth patterns, except perhaps for the East Coast, are very similar to the corresponding seasonal ones for the frequencies of all elevated inversions (Figures 24 - 27). Notice the intense gradient in summer (Figure 76) along the California Coast in the transition zone between moist marine air and arid continental air. Actually, this gradient may in fact be more intense than indicated in the figure (as well as in the same area of other figures). In general, a high proportion of morning elevated inversions has average relative humidities in the underlying layer that exceed 69 percent. This is also true to a considerable extent for those stations plotted around the periphery of the figures.

Figures 78 - 81 are the same as the previous series, except these are for soundings at 2315 GMT. For the most part the data and analyses for 2315 GMT are quite similar to those for 1115 GMT. The most prominent exception occurs during the summer (Figure 80) over Texas where a relatively high frequency in the morning (1115 GMT) is completely absent in the evening (2315 GMT). Also in summer the intense gradient along much of the California Coast in the morning is limited more to the south in the evening. In general, similarities between the isopleth patterns of elevated inversion frequencies and of elevated inversions with average relative humidity in the layer below exceeding 69 percent are not as great at 2315 GMT as at 1115 GMT, especially for the eastern United States (e.g., see Figures 78 - 81 and 28 - 31; 74 - 77 and 24 - 27).

## For No Inversion

Figures 82 - 85 show the seasonal frequencies of all 1115 GMT soundings with no inversion below 3000 m and with average relative humidities in specified layers exceeding 69 and 89 percent. An interesting feature of these charts for both observation times and for both humidity classes is the general uniformity of the frequencies throughout the lower 1500 m of the soundings. This is not surprising since for no-inversion soundings, a rather uniform vertical distribution of moisture is generally expected. Isopleths are shown for percentages of relative humidity exceeding 69 percent in the 251-500-m layer, but clearly the isopleths are typical of most layers that were considered. In viewing this series of charts it should be kept in mind that the upper limiting value for any entry is the percentage of no-inversion observations. Thus, at 1115 GMT only a few locations have no-inversion percentages greater than 30 on an annual basis (see Figure 11). Accordingly, there are only a few stations in California, Oregon, Washington, Alaska, and Hawaii where more than 10 percent of all 1115 1115 GMT winter soundings have no inversion and an average relative humidity greater than 69 percent in the 251-500-m layer (as well as for most layers considered; see Figure 82). At the stations along the Pacific Coast these relatively moist conditions are associated with synoptic-scale storms that frequent the region. The spring chart (Figure 83) is very similar to that for winter, except the moisture is greater in the tropics and in the region south of the eastern Great Lakes. The occurrence of no-inversion soundings at 1115 GMT with comparatively high relative humidities reaches a maximum in summer (Figure 84) along the Gulf and Atlantic Coasts. Notice on this chart that during the summer there is less uniformity in the frequencies among the layers for each humidity class than during any other season. There are more occurrences of relatively high moisture at low levels than at high levels; for example, at Burwood for humidities exceeding 69 percent and at Jacksonville for humidities exceeding 89 percent. Also, notice that during summer all but the two most northerly Alaskan stations have at least 10 percent of all 1115 GMT soundings with no inversion and relative humidities greater than 69 percent for layers below 1500 m. The data for autumn (Figure 85) are much like those for winter (Figure 82) with few locations having more than 10 percent of all 1115 GMT soundings with no inversion and with relative humidities greater than 69 percent. But notice that the frequencies remain comparatively high at most Alaskan stations.

Figures 86 - 89 are for the same criteria as the previous four, except these are for 2315 GMT soundings. The corresponding seasonal data and isopleth patterns are remarkably similar for the two observation times. This happens over the 48 contiguous states in spite of the fact that there are generally considerably more no-inversion cases at 2315 GMT (see Figures 12 -15) than 1115 GMT (see Figure 11). It occurs in general because a large proportion of no-inversion soundings at 2315 GMT are comparatively dry (e.g., over the Rockies especially during summer; see Figures 14 and 88). On the other hand, for the Alaskan, Hawaiian, and San Juan stations the frequencies of soundings with no inversion and comparatively high humidities are markedly greater at 2315 GMT than at 1115 GMT. Furthermore, at these stations there is a tendency for more high humidities at higher levels in the 2315 GMT soundings.

WIND SPEED VS VERTICAL TEMPERATURE STRUCTURE

In general considerations of transport and diffusion the vertical structure of the wind is at least as important as the temperature structure. As described in Appendix A, considerable details are given in the original summaries on wind structure through 1200 m (above the surface) as a function of temperature structure. But because there are so many variables and because the winds, especially directions at low levels, are highly dependent upon local features, data are presented only on wind speeds at the surface and at 300 m above the surface. These data are subdivided according to soundings with a surface-based inversion, an elevated inversion, or no inversion. "Surface" winds refer to fixed sensors mostly at 6-8 m above ground although some may have been higher. No isopleth analyses are presented because generally at each station significant values occur for several of the speed classes.

For Surface-Based Inversions

Figures 90 - 93 show the seasonal frequencies of all 1115 GMT soundings with an inversion base at the surface and with surface and 300-m winds in the indicated speed classes. Notice that on these charts the sum of all surface wind speed frequencies and of all 300-m wind speed frequencies each are equal to the frequencies of all ground-based inversions.

Figure 90 indicates that at 1115 GMT during the winter, surface-based inversions are generally associated with considerably faster winds at 300 m than at the surface. For example, at Nashville, Tennessee, the frequency of speeds in the classes, calm, 0.1-2.5, and 2.6-5.0 m/sec are each greater at the surface than at 300 m and the frequency of speeds in the classes 5.0-10.0 and >10 m/sec are each greater at 300 m than at the surface. For most stations the most common speed class of surface winds with surface inversions is 2.6-5.0 m/sec. Amarillo, Dodge City, Ely, Great Falls, and Nome are exceptional for their relatively high frequencies of surface speeds exceeding 5.0 m/sec. On the other hand, Medford and Lander (both located within bowl-shaped terrain) are exceptional for their high frequencies of surface and 300-m speeds less than 2.6 m/sec--optimum conditions for atmospheric stagnation. Medford and Lander also have by far the highest frequencies of winter soundings with surface inversions and calm surface speeds; other stations with relatively high frequencies are Salem, Winnemucca, Oakland, Albany, Yakutat, Fairbanks, and San Juan.

While there are some variations, the general features of wind speed characteristics with inversions based at the surface at 1115 GMT in winter are similar to those in the other seasons. Notice that during summer mornings (Figure 92) Medford experiences surface inversions with surface wind speeds less than 2.6 m/sec in 62 percent of the observations! In general, there tend to be more slow surface speeds with surface inversions during summer than winter, especially in the eastern United States.

Figures 94 - 97 are the same as the previous four except these are for 2315 GMT, afternoon/evening, soundings. As mentioned in discussions of the data presented earlier, the values on these charts are highly dependent on seasonal changes in solar elevation at the sounding time. Accordingly, the highest frequencies of surface inversions at 2315 GMT occur during winter in the more eastern and northern stations, and the lowest frequencies occur during summer with hardly any. Where and when surface inversions do occur at 2315 GMT, e.g., mainly during winter and autumn (Figures 94 and 97), the frequencies of speeds in the classes calm, 0.1-2.5, and 2.6-5.0 m/sec almost invariably are greater for surface than for 300-m winds, and in the classes 5.1-10.0 and >10.0 m/sec the frequencies are usually greater for 300-m winds than for surface winds. Also notice on these figures that during winter and autumn most stations experience relatively few calm surface winds; surface speeds are most commonly in the speed range 2.6-5.0 m/sec. Thus, either the formation of radiation inversions beginning around sunset does not require exceptionally slow surface winds or the drainage winds that are often associated with radiation inversions develop rather quickly. It is worth noting that the high frequencies of extreme stagnation conditions (a low-level inversion with surface and 300-m winds <2.6 m/sec) mentioned earlier for Medford and Lander in connection with the 1115 GMT soundings occur in only around 1 percent of the 2315 GMT soundings at Lander and not at all at Medford during spring and summer. At these stations the greatest frequencies of extreme stagnation at 2315 GMT occur in winter with 19 percent at Lander and 7 percent at Medford. These are probably the limiting percentages that extreme stagnation (as defined here) may be expected to persist through at least one complete diurnal cycle at these stations. As expected, the indicated stagnation conditions are not at all so unusual at some Alaskan stations, especially during winter when they may persist for days.

For Elevated Inversions

The next series of charts is similar to the last series, except this one is for elevated inversions; the charts show percentages of all soundings with an elevated inversion base 1-3000 m AGL with surface and 300-m wind speeds in specified classes. Since most stations have comparatively few elevated inversions with base heights 300 m or less, the wind data for the surface and the 300-m levels both generally may be considered as being below the inversion base. There are some exceptions, however; notably for 1115 GMT soundings on an annual basis (see Figure 37) at Barter and Barrow where elevated inversions occur in about 50 percent of the soundings and of those elevated inversions about 30 percent have bases in the range 1-250 m. Somewhat similar exceptions also occur in the 2315 GMT soundings, mainly at the California stations and at some Alaskan stations in certain seasons (see Figures 38 - 41).

As a general rule for 1115 GMT soundings, the main difference in both surface and 300-m wind speeds between inversions based at the surface (Figures 90 - 93) and aloft (i.e., 1-3000 m; Figures 98 101) is that the winds with elevated inversions have higher frequencies of faster winds. The differences are typically greater for the surface wind than for the 300-m wind. For example, at 1115 GMT during winter (Figure 90) Columbia, Missouri has inversions based at the surface in almost 50 percent of the observations. With respect to these same low-level inversions the speeds exceed 5.0 m/sec in 3 percent of the surface wind observations and in 74 percent of the 300-m wind observations. But of those soundings with elevated inversions (Figure 98), 5.0 m/sec is exceeded in 46 percent of the surface wind observations and in 84 percent of the 300-m wind observations. As a consequence of the comparatively fast wind speeds associated with 1115 GMT elevated inversions, speeds less than 2.6 m/sec generally occur relatively seldom with these elevated inversions. At many locations the frequencies don't exceed a few percent, even at stations where elevated inversions are rather common. But as usual there are exceptions, notably at Medford during winter (Figure 98), at the California coastal stations throughout much of the year (Figures 98 - 101), and to some extent at a few mid-continental and Alaskan stations in certain seasons.

The seasonal distribution of surface and 300-m wind speeds with elevated inversions at 2315 GMT are shown in Figures 102 - 105. At this observation time elevated inversions are generally much more common than at 1115 GMT, except over the Rockies during summer. As usual, the 300-m speeds are typically faster than the surface speeds. At both elevations speeds less than 2.6 m/sec occur with surprisingly high frequencies during winter (Figure 102) over much of the Rockies, to some extent along the Pacific Coast, and at Anchorage and Fairbanks. The frequencies of slow wind speeds with elevated inversions at 2315 GMT are comparatively low during spring and summer (Figures 103 and 104), except at some Alaskan stations. During autumn (Figure 105) the frequencies of elevated inversions with wind speeds less than 2.6 m/sec are comparatively high at several stations scattered throughout the continental states; the highest frequencies occur at Medford, 37 percent for surface winds and 33 percent for 300-m winds.

For No Inversions

The distributions of surface and 300-m wind speeds for 1115 GMT soundings with no inversion below 3000 m are shown annually (Figure 106) since no-inversion soundings generally occur infrequently at this observation time (e.g., see Figure 11). The most notable exceptions are at Anchorage, Yakutat, Annette, Tatoosh, El Paso, Burwood, Tampa, Miami, Hatteras, New York City, Buffalo, and San Juan. At most of these places the most frequent surface speed is 2.6-5.0 m/sec and the most frequent 300-m speed is somewhat faster.

The distributions of surface and 300-m wind speeds for 2315 GMT soundings with no inversion are shown seasonally in Figures 107 - 110. As may be deduced from Figures 12 - 15, at 2315 GMT soundings without inversions are most common in all seasons over the Rockies where the frequencies generally exceed 90 percent during winter. No-inversion soundings at 2315 GMT barely occur along the California Coast during summer and at the more northerly Alaskan stations, especially during winter. As with the other wind charts already discussed, no isopleths are shown for the no-inversion cases since the speeds typically occur over broad ranges. As was generally found with inversions, the 300-m speeds are usually faster than the surface speeds when inversions are absent. At most stations the most frequent surface speeds are in the range 2.6-5.0 m/sec while the 300-m wind speeds most frequently are in the range 5.1-10.0 m/sec. At many stations during winter the surface and 300-m wind speeds with no-inversion soundings (Figure 107), tend to be somewhat faster than with elevated inversions (Figure 102) but during summer (see Figures 109 and 104) the differences are small.

## SECTION 4

## SUMMARY AND CONCLUSIONS

Most studies of the transport and diffusion of man-made air pollution are concerned with the properties of the lowest few kilometers or so of the atmosphere. In general, direct measurements of atmospheric structure are restricted to a few tens of meters, or at most a few hundred meters above the surface--except for the routine balloon-borne rawinsonde measurements of the National Weather Service. Over the years a format/method (described in the Appendix) was developed for summarizing these sounding data from individual stations for use in air pollution studies. The purpose of this report is to present some main features of those summaries on maps of the United States. Together, these maps represent a climatological atlas of atmospheric features that are important in pollution dispersion within the lower few kilometers of the atmosphere.

Detailed data are presented in this report on three important parameters, temperature structure or stability, wind speed, and relative humidity. The latter is important in pollutant transformations as well as fog and cloud formation. With few exceptions the summarized data are based on soundings taken twice daily over at least 5 years at 76 locations. The balloon-borne sensors were released near 2315 and 1115 GMT, which generally conform to local times of instability and stability, respectively. In order to view the sounding data in regard to potential effects of solar heating and long-wave radiational cooling, solar elevation angles are presented for both balloon release times on the middle day of each season.

Although this report includes 100 maps of rawinsonde-derived data, they represent only a portion of the potentially useful information in the original data tabulations. Some of the maps are isoplethed to illustrate spatial continuity and variations, but no attempt was made to isopleth all of the parameters that are presented.

All of the rawinsonde data are presented in percentages with respect to the total number of soundings at each observation time, seasonally or annually.

Most of this report is devoted to descriptions of the vertical temperature structure of the near-surface atmosphere. Generally, it is found that inversions in this layer are the rule at 1115 GMT in all seasons. This is also generally true for soundings at 2315 GMT, except during summer, when only northern Alaska, the immediate Pacific Coast, the upper Atlantic Coast, and the upper Midwest have inversions in more than half the observations. The Rocky Mountain region has by far the lowest frequency of inversions at 2315 GMT in all seasons; they occur in less than half the soundings in all seasons except winter. Surface-based inversions predominate at 1115 GMT (morning), except in the extreme Northwest and around New York City where elevated inversions are more common. At 2315 GMT (afternoon) surface-based inversions are most frequent in the East, especially during winter and autumn, largely as a consequence of low solar elevations at observation time. Conversely, elevated inversions are generally most prevalent during the afternoon and particularly along the California Coast where the frequencies exceed 80 percent during summer.* Most of the data in this report show reasonable spatial and temporal continuity in regard to well-known climatic features. However, there are some unexplainably (to us) large differences in percentages of of surface and elevated inversions across the Louisiana and Texas Gulf Coast area, primarily during summer mornings, that serve to point out that the data are most representative of those locations where the observations were taken.

*It should be noted that in this report no more than one inversion is tabulated per sounding. The base of that inversion is defined as the base of the lowest inversion within 3000 m of the surface and the top as that of the inversion with the highest actual temperature within 4500 m of the surface. Thus, some elevated inversions could be neglected.

The tops of surface-based inversions are most always greater than 100 m and sometimes range to at least 1500 m AGL. Such deep inversions usually occur during winter mornings and are most prevalent at International Falls, Caribou, and the more northerly Alaskan stations.

The bases of elevated inversions generally have some occurrences at all levels to 3000 m at both observation times, but there are distinct regional and seasonal variations in their vertical distribution. Overall, elevated inversions are more frequent at 2315 GMT; they are virtually always thicker than 100 m and have a tendency toward greater thicknesses in the colder the colder seasons during both mornings and afternoons. However, even in winter at most locations fewer than half of the soundings have elevated inversions that are thicker than 500 m. Although the spatial extent of such inversions is least during summer, the highest frequencies at individual locations occur then, exceeding 50 percent at Santa Monica and San Diego at both observation times.

Five classes of inversion intensity (i.e., $\Delta T/\Delta Z$) are specified with an overall range from 0.00 to >6.00 °C/100 m. For surface-based inversions the intensities are typically greater for thicknesses less than 500 m than for thicknesses more than 500 m. No station has any surface-based inversion intensities in the most extreme class for thicknesses exceeding 500 m. For elevated inversions the intensities vary with thickness in the same manner as for surface-based inversions, but the intensities are characteristically less for elevated inversions.

Soundings with no inversion, which are most common during summer afternoons, have relatively frequent occurrences of superadiabatic conditions ($-\Delta T/\Delta Z$ > 1.2 °C/100) in the layer 1-250 m AGL; such instability infrequently reaches heights greater than 1000 m AGL, mostly over the Rocky Mountains. Superdiabatic conditions also occur beneath elevated inversions with relatively higher frequencies in the shallower subinversion layers.

Average relative humidities in inversions and in adjacent layers have some interesting distributions. As might be expected, surface-based inversions with higher relative humidities are most frequent in coastal areas throughout the year, but also in the Midwest and East during summer and autumn. Surface-based inversions are almost invariably more humid than are the 300-m layers immediately above them. For elevated inversions the subinversion layer is typically more humid than the inversion layer, but the differences are less pronounced than for surface inversions and the layer immediately above. For no-inversion soundings high relative humidities occur with rather equal frequencies in sublayers through 1500 m AGL. This uniformity is somewhat more consistent for afternoon than for morning soundings.

Wind speeds at 300 m AGL are generally faster than surface speeds although this is more apparent in the presence of an inversion. Calms at 300 m at any time are rare except at a few stations. The most frequent wind speed range is 2.6-5.0 m/s at the surface but is quite variable at 300 m. Faster wind speeds at the surface generally occur more frequently in the Plains and the Pacific Northwest, especially when there is no inversion.

Many of the descriptions and most of the conclusions in this report are highly generalized. As such they should be considered as guidance. In particular, those data for individual stations are most representative of those locations and interpolation/extrapolation to other places should be done with utmost care.

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## APPENDIX A

## DATA FORMATS AND AVAILABILITY

This appendix provides detailed descriptions of the processed sounding data that are stored on magnetic tape, of the climatologically summarized data stored as hard copy, the stations and periods of record that have been summarized, and the availability of the data.

### FORMATS OF INDIVIDUALLY PROCESSED SOUNDINGS

Table A-1 shows an example of a page of computer printout of processed sounding data stored on magnetic tape. One line is used for each sounding. Missing data are indicated by 9s. The stored data for each sounding are each in one of three possible formats, depending on whether the sounding showed (1) a surface-based inversion, (2) an inversion base aloft within 3 km of the surface, or (3) no inversion within 3 km. Table A-2 shows details of the three possible formats.

#### Surface-Based Inversions

In Table A-2 in the format example for surface-based inversions, 23066 (STA) is the WBAN station number, Grand Junction, Colorado; 60 (YR) is the year, 1960; 02 (MO) is the month, February; 18 (DA) is the day of month; and 12 (HR) is the scheduled rawinsonde observation time, 1200 GMT. In the United States it has been common practice to release the rawinsonde balloons about 45 minutes before the scheduled times. Continuing with the first example, 120 (SFC) is the surface wind direction in whole degrees; 8.0 (SPD) is the surface wind speed in m/sec; and the directions and speeds at 150, 300, 600, 900, and 1200 m AGL are given in the same manner as surface winds.

Continuing with the example for surface-based inversions, 00000 (at left side of the third line in Table A-2) is the height (m) of the inversion base; 00109 is the height of the inversion top; the second 00109 is the inversion thickness, $\Delta Z$; 7.8 is the temperature (°C) at the inversion base; -7.0 is the temperature at the inversion top; .8 is the temperature at inversion top minus that at inversion base, $\Delta T$; .0073 is $\Delta T/\Delta Z$ (°C/m) through the inversion; 53.2 is the average relative humidity (percent) through the inversion; .0 at this entry indicates a sounding with a surface-based inversion; 49.4 is the average relative humidity in the 300-m layer immediately above the inversion top; .0, .0, and .0000 at their respective entries indicate a sounding with a surface-based inversion; and 1 indicates a sounding with an inversion base in the lower 3 km of the atmosphere.

#### Elevated Inversions

The format for elevated inversions is the same as that for surface-based inversions, except, as shown in Table A-2, line 6, the ninth through thirteenth entries for elevated inversions are different. 72.8 (Table A-2, line 6, ninth entry) is the average relative humidity in the entire layer beneath the inversion base; .0 at this entry indicates a sounding with an elevated inversion; 7.9 is the surface temperature; -11.6 is the inversion base temperature minus the surface temperature, $\Delta T$; and -.0060 is $\Delta T/\Delta Z$ for the entire layer beneath the inversion base.

#### No Inversion

For soundings with no inversion in the lower 3 km, the format for entries through the 1200-m wind speed (Table A-2, lines 7 and 8) is the same as for soundings with inversions. The remaining entries for no-inversion soundings (Table A-2, line 9) are as follows: the first six entries, -.0033 through -.0079, give values of $\Delta T/\Delta Z$ (°C/m) for the consecutive layers 1-100, 101-250, 251-500, 501-750, 751-1000, and 1001-1500 m; the second six entries, 52.5 through 53.5 give average relative humidity (percent) for each of the same layers as indicated for $\Delta T/\Delta Z$; the last two entries, NONE and 2, designate a sounding with no inversion in the lower 3 km.

### FORMATS OF SUMMARIES OF PROCESSED SOUNDINGS

The processed sounding data were summarized and printed in three formats, one each for temperature structure, relative humidity, and winds by temperature structure. The summaries for each station are by season (Dec, Jan, Feb = winter; etc.), by total period of record, and by observation time.

#### Temperature Structure

Table A-3 is a copy of the summary of temperature structure characteristics as measured from Pittsburgh, Pennsylvania (STATION 94823) during the autumn season (Sept, Oct, Nov). The time (00) is 0000 GMT, which is the scheduled synoptic observation time; this means the balloons were actually released about 1815 EST. The period of record, which is given only on the cover page of the summaries, is the 5 years, 1960-1964. All of the percent frequencies are with respect to the total number of soundings that were made. Values are rounded to the nearest tenth of a percent.

Approximately the upper three-fourths of Table A3 is used to summarize temperature inversion conditions (i.e., $\Delta T/\Delta Z \geq 0.0000$ °C/m). It gives the frequency of inversion base heights (across the top) by inversion thickness (DELTA HEIGHT) and by classes of $\Delta T/\Delta Z$ through the inversion layer. These classes of $\Delta T/\Delta Z$ are specified at the bottom of the page on the left under DELTA T/H INVERSION LAYER. Classes A-C each have an angular spread on an adiabatic diagram of 22.5 deg; classes D and E each have a spread of 11.25 deg.

Table A-3 indicates that 26.3 percent of the observations detected a surface-based inversion; most of these (20.6 percent) had a thickness of 101-250 m; and for most of the latter that $\Delta T/\Delta Z$ class was A or B (8.2 percent each), indicating weak or very weak inversion intensities. An inversion base within 3000 m of the surface occurred in 76.6 percent of the observations. An inversion base above the surface, but within 3 km of the surface, occurred in (76.6 minus 26.3) 50.3 percent of the observations. Elevated inversion bases occurred most frequently (13.0 percent) in the range 1001-1500 m, followed closely by the range 1501-2000 m (12.1 percent).

The next lower one-eighth of Table A-3 (SFC-BASE OF INVER) shows the frequencies of $\Delta T/\Delta Z$ classes for the entire layer beneath an inversion base, according to inversion base height (given near top of page). The $\Delta T/\Delta Z$ classes for lapse conditions are given at the bottom of the page under DELTA T/H NO INVERSION. Notice that class B includes the standard atmosphere value of $\Delta T/\Delta Z = -0.0065$ °C/m and class C is centered on the dry adiabatic rate.

The last one-eighth of Table A-3 (NONE) is for observations with no inversion in the lowest 3 km. It gives the frequencies of $\Delta T/\Delta Z$ classes (DELTA T/H NO INVERSION) for the same layers as used for inversion base heights through 1500 m, as indicated at the top of the summary. In Table A-3 notice that 23.4 percent of the observations (given in lower right of table) had no inversion in the lower 3 km. The total frequency of $\Delta T/\Delta Z$ classes for each specified layer of no-inversion soundings is therefore 23.4 percent, allowing for slight deviations due to rounding.

In the extreme lower right of Table A-3, the value .4 indicates that the ratio of soundings with incomplete temperature data (e.g., sounding terminated below 3000 m) to those with sufficient temperature data is 4/1000 or 0.4 percent.

Relative Humidity

Table A4 is a copy of the relative humidity summary for Pittsburgh, autumn, 0000 GMT soundings. It gives the percent frequencies (in tenths) by relative humidity classes (defined at bottom of table) of the average humidity in certain layers, according to whether or not a temperature inversion occurred in the lower 3 km. In Table A-4 the last line (NONE) is for no-inversion soundings; the average relative humidities are for the layers indicated at the top of the table under DELTA HEIGHT. For example, no-inversion soundings with an average relative humidity of class 2 (40-69 percent) in the layer 1-100 m occurred in 10.2 percent of the observations.

The remainder of Table A-4 is for inversion soundings. The percent frequencies of average relative humidities in the layers specified at the bottom of the table are given by inversion base height (left column) and inversion thickness (DELTA HEIGHT). For surface-based inversions the average relative humidities are for the entire inversion layer (I) and for the 300-m layer immediately above (A) the inversion top. For elevated inversions the average relative humidities are for the entire layer below (B) the inversion base as well as for the inversion layer.

Winds by Temperature Structure

Table A-5 is a copy of the last part of the wind summary for Pittsburgh, autumn, 0000 GMT soundings. The table gives a brief wind rose (defined at bottom of table) for the surface each of the levels, 150, 300, ..., 1200 m, above station elevation, according to whether soundings included (ALL INVERSIONS) or did not include (NO INVERSION) an inversion base in the lower 3 km. The percent frequencies of occurrence are given to the nearest tenth and, as for all summaries, are with respect to the total number of observations that were taken. The LINE TOTALS in Table A5 are for all wind levels together and may be interpreted as a summary of average wind directions for the 1200-m layer. The LINE TOTAL percentages (as other subtotals in the summaries) are based on LINE TOTAL frequency counts with respect to the grand total frequency count. Thus, the given LINE TOTAL percentages are more precise than the sum of percentages on a line divided by six (i.e., the number of wind levels).

In Table A-5, the last row, MISSING TOTAL, gives the percent frequency of all missing wind data for each level with respect to the total number of observations taken. Missing wind data are not broken down according to temperature structure.

As mentioned earlier, Table A-5 includes only the last part of a complete wind summary. The other parts give wind roses like those in Table A-5, except they are by classes of inversion base height and inversion thickness as follows:

| Inversion Base Height (m) | Inversion Thickness (m) |
|---|---|
| Surface-100 | 1-100 |
| 101-250 | 101-250 |
| 251-500 | 251-500 |
| 501-750 | 501-750 |
| 751-1000 | 751-1000 |
| 1001-3000 | 1001-1500 |

Thus, in addition to the two broad temperature structure classifications in Table A-5, provision is made for 36 more. However, it is not unusual for many of the classifications to have few or no entries, depending on season, observation time, and location.

DATA AND AVAILABILITY

All of the data that have been described were prepared by the National Climatic Center (NCC) under Job. No. 13105, "Inversion Study," and are available from the NCC (Federal Building, Asheville, N.C. 28801) at the cost of reproduction. These data are as follows:

- Listings of processed data for each sounding are available on magnetic tape or as hard-copy printout.
- Summaries in percentage values for season, total period, and each observation time are available on hard copy. For one observation time a complete summary requires 75 pages (10 x 17 3/4 inch), five each for temperature structure and relative humidity, and 65 for winds by temperature structure. Summaries in terms of actual frequency counts can be prepared when specifically requested.

The stations (and other pertinent information) for which soundings have been processed and summarized to date are listed in Tables A-6 and A-7. Table A-6 is for those stations that routinely took two soundings every day as part of the regular upper-air synoptic network. For these stations, entirely missed soundings or soundings with incomplete temperature data (e.g., soundings terminated at a low level that precludes complete determination of temperature structure) were rare. In cases of incomplete temperature data the last digit of the data listing for individual soundings (see Table A-2) is a "3."

Table A-6 includes the same 62 stations (each for the corresponding period of record, and for a few additional separate periods) that were used to develop climatological values of mixing height and wind speed for the contiguous United States (Holzworth, 1972). Thus, the mixing height data and those described herein supplement each other. Sequential listings of individual mixing height and wind speed values for the stations and period of record used by Holzworth (1972) are available on magnetic tape from the NCC.

Most of the periods of record indicated in Table A-6 are for the years 1960-1964. It will be recalled that 1964 is the last year for which NWS hourly surface weather observations were keypunched and published as Local Climatological Data Supplement. Since 1964 only three-hourly observations have been digitized and published. In recent years, however, NCC customers have had many of the hourly observations digitized. 1964 is also the last year for which winds aloft were routinely digitized by constant height.

Table A-7 lists those stations that took soundings in support of air pollution control activities. Most of the soundings were taken by NWS teams known as Environmental Meteorological Service Units (EMSU). The soundings were "low-level" because ordinarily they were terminated at about 3 km above the station. The ascent rate of the balloons was usually around 2.5 m/sec or half as fast as routine soundings. The radiosonde equipment that was used was comparable to that used for regular synoptic soundings, except that winds aloft were commonly determined by tracking the radiosonde balloon with a theodolite instead of the radio direction finder used with rawinsondes. Thus, for low-level soundings the wind observations were dependent on cloudiness, and in some cases were sparse and biased.

Low-level soundings were scheduled to be taken twice daily on regular work days (i.e., Mon-Fri) and in addition as required during air pollution episodes (see footnotes in Table A-7). However, additional soundings were seldom required and in some cases scheduled soundings were not taken due to personnel limitations. The total number of low-level soundings may be determined accurately from summaries in terms of actual frequency counts In such a case the last point of the sounding was processed as the inversion top, and in the data listings for individual soundings (see Table A-2), was designated by a "4" as the last digit. Such cases were also summarized separately in tables (identical to Tables A-3, A-4, and A-5) denoted at the top by a "T." In these T-tables the percent frequencies are also with respect to the total number of observations that were taken. If copies of the T-tables are desired, they should be specifically requested.

Since the low-level sounding data were obtained over a relatively short time period and did not follow the rigorous requirements of the regular synoptic sounding program, they were instead of percent frequencies. Such actual frequency counts would also be useful in evaluating those wind summaries with extensive missing data.

As indicated in Table A-7 the two sounding times were rather loose; they were usually around sunrise and noon LST. Both soundings were taken in one eight-hour shift and thus the clock times tended to be somewhat earlier in summer than in winter. In the NCC summaries listed in Table A-7, the "near-sunrise" soundings are indicated as "01" and the "near noon," as "02."

Since the low-level soundings only sampled the lower 3 km of the atmosphere, a problem arose in those cases where the last point of a low-level sounding was the maximum actual temperature of that sounding (see Section 2). not considered suitable for analyses with the regular sounding data, which forms the main body of this report. However, the low-level sounding data are described here since they may be very useful in specific applications.

The NCC is prepared to process and summarize sounding data in addition to those listed in Tables A-6 and A-7 at the cost (to the customer) of computer time and data handling.

TABLE A-1. PHOTOCOPY OF ONE PAGE OF COMPUTER PRINTOUT OF PROCESSED RAWINSONDE MEASUREMENTS THAT ARE STORED ON MAGNETIC TAPE. FOR DETAILS SEE TABLE 2 AND TEXT.

```
STA YR MO DA HR SFC  SPD 150  SPD 300  SPD 600  SPD 900  SPD1200  SPD    1
23154 60 01 01 00 040 2.0 020 3.0 352 4.0 999999.9 999999.9 999999.9 00000 00098 00098 - 8.6 - 8.5 .1 .0010 56.5 .0 53.8 .0 .0 .0000 1
23154 60 01 02 00 300 2.0 327 2.0 332 2.0 334 3.0 349 3.0 001 4.3 00000 00244 00244 -11.0 - 9.8 1.2 .0049 62.0 .0 63.6 .0 .0 .0000 1
23154 60 01 03 00 190 1.0 218 1.0 220 1.0 231 1.1 265 3.5 288 5.4 - .0060 - .0062 - .0062 - .0066 - .0068 - .0046 49.8 51.9 55.6 58.8 59.0 54.0 NONE 2
23154 60 01 04 00 020 8.0 015 10.0 012 10.0 006 8.0 012 7.4 017 7.0 00000 00096 00096 -11.3 -11.0 .3 .0031 68.4 .0 52.8 .0 .0 .0000 1
23154 60 01 05 00 360 2.0 350 3.0 343 5.0 350 5.0 005 6.8 012 10.1 00000 00484 00484 - 9.8 - 7.1 2.7 .0056 37.8 .0 39.6 .0 .0 .0000 1
23154 60 01 06 00 020 2.0 009 3.0 001 4.0 010 5.0 013 7.3 006 10.1 00000 00338 00338 - 5.5 - 2.5 3.0 .0089 55.9 .0 55.5 .0 .0 .0000 1
23154 60 01 07 00 180 1.0 187 1.0 197 1.0 300 6.8 295 5.5 305 9.3 00000 00111 00111 4.6 4.7 .1 .0009 59.5 .0 56.0 .0 .0 .0000 1
23154 60 01 08 00 090 4.0 160 4.0 206 3.0 225 7.0 246 8.8 263 10.5 00000 00102 00102 1.7 5.3 3.6 .0333 34.0 .0 38.0 .0 .0 .0000 1
23154 60 01 09 00 180 9.0 174 13.0 171 15.0 187 12.0 211 13.8 232 16.2 00000 00101 00101 1.6 5.0 3.4 .0337 55.8 .0 50.7 .0 .0 .0000 1
23154 60 01 10 00 180 7.0 173 10.0 167 12.0 170 10.0 195 8.2 217 9.0 - .0057 - .0054 - .0054 - .0055 - .0053 - .0049 75.8 76.2 76.6 77.4 78.7 80.4 NONE 2
23154 60 01 11 00 180 8.0 173 9.0 168 10.0 169 10.0 183 10.6 202 10.6 00000 00101 00101 1.1 3.0 1.9 .0188 60.4 .0 59.5 .0 .0 .0000 1
23154 60 01 12 00 200 5.0 182 7.0 174 8.0 183 7.1 201 9.9 212 11.2 00000 00101 00101 - 1.7 - 1.0 .7 .0069 70.0 .0 65.6 .0 .0 .0000 1
23154 60 01 13 00 360 3.0 358 4.0 360 5.0 007 4.0 311 3.3 218 3.7 - .0053 - .0053 - .0054 - .0071 - .0071 - .0072 79.8 79.3 78.5 77.7 77.3 76.6 NONE 2
23154 60 01 14 00 270 3.0 318 3.0 355 4.0 016 5.9 050 3.3 095 1.2 00000 00019 00019 - 7.5 - 7.4 .1 .0053 70.5 .0 71.2 .0 .0 .0000 1
23154 60 01 15 00 180 10.0 176 11.0 174 11.0 182 9.0 192 8.4 209 8.6 01270 01753 00483 -13.9 -13.9 .0 .0000 82.0 75.2 .0 - 5.3 - 8.6 - .0068 1
23154 60 01 16 00 020 8.0 015 7.0 010 6.0 004 4.0 008 2.7 009 2.2 00000 00098 00098 - 6.7 - 6.7 .0 .0000 69.7 .0 68.7 .0 .0 .0000 1
23154 60 01 17 00 360 4.0 360 4.0 359 4.0 333 4.1 349 7.9 360 11.8 00000 00097 00097 - 9.2 - 8.8 .4 .0041 54.6 .0 54.7 .0 .0 .0000 1
23154 60 01 18 00 270 2.0 293 2.0 310 2.0 289 6.1 307 9.1 318 13.0 - .0044 - .0034 - .0034 - .0030 - .0072 - .0073 79.9 79.1 77.3 76.7 77.7 77.0 NONE 2
23154 60 01 19 00 360 2.0 342 1.0 290 1.0 233 3.1 266 6.7 292 10.1 00250 01102 00852 -12.4 - 9.6 2.8 .0033 76.6 76.3 .0 -11.0 - 1.4 - .0056 1
23154 60 01 20 00 330 4.0 316 3.0 283 1.0 132 1.0 218 2.8 272 5.9 00834 00963 00129 - 9.9 - 7.5 2.4 .0186 75.5 65.2 .0 - 3.4 - 6.5 - .0078 1
23154 60 01 21 00 140 2.0 158 3.0 170 4.0 171 6.0 192 5.4 217 5.0 01345 01460 00115 - 6.8 - 5.4 1.4 .0122 23.5 41.2 .0 .4 - 7.2 - .0054 1
23154 60 01 22 00 180 8.0 177 11.0 175 13.0 188 11.0 202 12.2 212 13.5 00000 00616 00616 - .4 .3 .7 .0011 35.6 .0 21.5 .0 .0 .0000 1
23154 60 01 23 00 090 2.0 163 2.0 258 2.0 316 3.0 321 3.0 278 4.0 00000 00100 00100 2.7 2.7 .0 .0000 52.5 .0 48.9 .0 .0 .0000 1
23154 60 01 24 00 090 1.0 148 1.0 177 1.0 180 3.2 189 3.4 210 3.0 01972 02221 00249 - 8.4 - 7.5 .9 .0038 36.5 48.0 .0 5.2 -13.8 - .0069 1
23154 60 01 25 00 220 4.0 207 4.0 192 4.0 178 7.0 168 8.2 169 8.1 - .0048 - .0040 - .0040 - .0040 - .0057 - .0062 70.5 64.3 54.3 42.0 39.4 47.0 NONE 2
23154 60 01 26 00 130 2.0 164 3.0 204 3.0 249 6.1 270 8.5 286 11.0 - .0030 - .0032 - .0032 - .0037 - .0071 - .0062 87.9 84.6 79.6 72.5 60.4 39.1 NONE 2
23154 60 01 27 00 170 4.0 174 4.0 176 5.0 164 6.0 170 4.8 189 4.6 - .0044 - .0073 - .0073 - .0073 - .0073 - .0072 70.0 66.4 67.1 68.2 70.0 71.8 NONE 2
23154 60 01 28 00 250 4.0 257 4.0 263 3.0 281 4.0 274 5.2 269 7.3 - .0090 - .0077 - .0077 - .0089 - .0101 - .0095 36.0 36.3 37.1 38.0 39.4 39.8 NONE 2
23154 60 01 29 00 160 3.0 149 3.0 143 2.0 125 1.0 037 1.5 321 3.8 00000 00100 00100 4.1 5.0 .9 .0090 48.5 .0 43.8 .0 .0 .0000 1
23154 60 01 30 00 150 2.0 164 3.0 173 5.0 167 9.0 175 7.4 191 6.0 00000 00152 00152 3.8 6.0 2.2 .0145 40.1 .0 28.9 .0 .0 .0000 1
23154 60 01 31 00 310 6.0 313 6.0 320 7.0 315 7.4 315 9.2 312 10.0 00000 00110 00110 3.2 4.0 .8 .0073 39.6 .0 50.6 .0 .0 .0000 1
23154 60 02 01 00 360 1.0 347 1.0 335 1.0 082 1.0 185 2.2 253 3.3 - .0050 - .0077 - .0077 - .0078 - .0078 - .0083 60.0 56.7 57.8 60.3 63.8 73.4 NONE 2
23154 60 02 02 00 180 13.0 172 15.0 163 18.0 173 15.0 196 14.3 212 15.8 01833 02057 00224 - 8.1 - 7.1 1.0 .0048 89.5 83.7 .0 - .1 - 8.0 - .0044 1
23154 60 02 03 00 320 8.0 323 8.0 327 9.0 328 10.0 327 11.9 328 13.4 00000 00100 00100 - 1.6 - .7 .9 .0090 48.8 .0 43.7 .0 .0 .0000 1
23154 60 02 04 00 200 4.0 194 4.0 187 6.0 179 8.0 197 8.0 212 8.6 - .0026 - .0053 - .0053 - .0055 - .0042 - .0030 49.3 42.9 37.0 30.0 25.0 26.8 NONE 2
23154 60 02 05 00 010 3.0 360 3.0 353 3.0 330 3.0 322 3.6 330 4.0 01107 01371 00464 - 7.5 - 7.5 .0 .0000 61.5 63.0 .0 3.0 -10.5 - .0095 1
23154 60 02 06 00 320 5.0 314 5.0 304 6.0 306 7.0 309 7.6 302 9.1 00000 00101 00101 2.7 5.0 2.3 .0228 53.0 .0 43.3 .0 .0 .0000 1
23154 60 02 07 00 100 2.0 110 2.0 128 2.0 292 3.0 308 4.7 327 5.1 01103 01309 00206 - 1.3 - .5 1.3 .0063 32.1 38.7 .0 6.4 - 8.2 - .0074 1
23154 60 02 08 00 180 5.0 186 6.0 194 7.0 212 9.4 224 11.8 235 13.2 00000 00103 00103 6.7 8.0 1.3 .0126 54.7 .0 50.1 .0 .0 .0000 1
23154 60 02 09 00 200 8.0 200 12.0 204 15.0 212 17.1 229 21.5 237 23.4 00000 00104 00104 3.8 5.0 1.2 .0115 81.5 .0 78.3 .0 .0 .0000 1
23154 60 02 10 00 220 5.0 225 5.0 233 4.0 247 8.1 255 10.3 261 13.2 - .0167 - .0091 - .0089 - .0084 - .0084 - .0071 62.6 59.7 64.4 70.0 75.6 78.0 NONE 2
23154 60 02 11 00 030 7.0 028 7.0 027 8.0 027 8.1 348 10.0 334 10.6 - .0030 - .0084 - .0084 - .0086 - .0086 - .0081 63.6 59.1 62.1 65.8 69.5 73.8 NONE 2
23154 60 02 12 00 020 7.0 019 7.0 016 8.0 015 7.0 013 8.1 018 10.2 01687 02019 00332 -13.0 -13.0 .0 .0000 16.9 46.0 .0 .5 -13.8 - .0080 1
23154 60 02 13 00 300 2.0 276 3.0 250 3.0 217 3.0 231 4.5 250 6.0 01550 01859 00309 - 5.2 - 4.5 .7 .0023 31.8 15.7 .0 6.8 -12.0 - .0077 1
23154 60 02 14 00 360 9.0 352 11.0 336 12.0 336 10.0 331 10.6 326 11.1 - .0011 - .0096 - .0096 - .0095 - .0095 - .0076 53.5 53.0 58.0 64.6 71.3 79.7 NONE 2
23154 60 02 15 00 020 5.0 005 5.0 348 4.0 354 4.0 005 6.8 011 10.0 - .0074 - .0076 - .0078 - .0076 - .0074 - .0045 34.3 32.8 31.2 29.2 27.2 38.8 NONE 2
23154 60 02 16 00 260 4.0 263 5.0 266 5.0 269 6.1 275 8.1 233 9.0 - .0238 - .0088 - .0094 - .0096 - .0100 - .0099 31.0 32.7 35.7 39.6 43.3 48.6 NONE 2
23154 60 02 17 00 010 7.0 005 8.0 358 10.0 348 10.0 338 8.3 333 7.1 - .0094 - .0088 - .0086 - .0086 - .0086 - .0089 47.8 49.4 51.4 53.9 56.7 61.1 NONE 2
23154 60 02 18 00 310 4.0 310 4.0 310 4.0 295 4.0 294 5.8 295 8.4 01798 02065 00267 -12.0 -10.6 1.4 .0032 43.0 37.6 .0 4.0 -16.0 - .0089 1
```

TABLE A-2. EXAMPLES OF THE THREE FORMATS USED TO STORE PROCESSED RAWINSONDE DATA ON MAGNETIC TAPE. ON A PAGE OF ACTUAL PRINTOUT THE HEADING (LINE 1) IS NOT REPEATED (LINES 4 & 7) AND ALL THE DATA FOR A SOUNDING ARE ON ONE LINE. SEE TEXT FOR DETAILS.

SURFACE INVERSION

```
STA   YR MO DA HR SFC  SPD 150  SPD 300  SPD 600  SPD 900  SPD1200  SPD
23066 60 02 18 12 120  8.0 128 10.0 135 11.0 151  9.4 175  7.0 199  6.3
00000 00109 00109  - 7.8  - 7.0   .8  .0073  53.2   .0  49.4   .0   .0  .0000   1
```

ELEVATED INVERSION

```
STA   YR MO DA HR SFC  SPD 150  SPD 300  SPD 600  SPD 900  SPD1200  SPD
23066 60 10 20 12 115  4.0 119  2.0 110  1.0 028  1.0 341  1.7 315  3.4
01943 02169 00226  - 3.7  - 2.2  1.5  .0066  55.0  72.8   .0  7.9 -11.6 - .0060   1
```

NO INVERSION

```
STA   YR MO DA HR SFC  SPD 150  SPD 300  SPD 600  SPD 900  SPD1200  SPD
23066 60 02 19 12 105  5.0 118  6.0 143  7.0 168  7.5 175  9.8 184 11.2
- .0033 - .0034 - .0034 - .0036 - .0073 - .0079 52.5 51.3 49.4 47.4 46.7 53.5   NONE 2
```

TABLE A-3. PHOTOCOPY OF HARD-COPY SUMMARY OF TEMPERATURE STRUCTURE CHARACTERISTICS, BASED ON PROCESSED SOUNDING DATA. SEE TEXT FOR DETAILS.

STATION 94823 TIME 00 SEASON 09-11 PER CENT TEMPERATURE FREQUENCY OF OCCURRENCE 4

| DELTA HEIGHT | | SURFACE | 1- 100 | 101- 250 | 251- 500 | 501- 750 | 751-1000 | 1001-1500 | 1501-2000 | 2001-2500 | 2501-3000 | TOTAL | NONE | GRAND TOT | MISSING |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | BASE OF INVERSION | | | | | | | | | | | | | |
| 1- 100 | A | .2 | | .9 | | .7 | | | | | .2 | 2.0 | | | |
| | B | .4 | | | | | | | | | | .4 | | | |
| | C | 1.3 | | .2 | | | | | | | | 1.5 | | | |
| | D | | | | | | .2 | .2 | .2 | | .2 | .9 | | | |
| | E | | | | | | | | | .2 | | .2 | | | |
| 101- 250 | A | 8.2 | | .2 | | .4 | .4 | 2.0 | 1.8 | 1.1 | .9 | 15.0 | | | |
| | B | 8.2 | | | .2 | .7 | .9 | 2.4 | 2.0 | 2.0 | .7 | 17.0 | | | |
| | C | 4.2 | | | .7 | .2 | 1.1 | 1.3 | 1.8 | .9 | .4 | 10.6 | | | |
| | D | | | | | | | | .2 | | | .2 | | | |
| | E | | | | | | | | | | | | | | |
| 251- 500 | A | 2.2 | | | .7 | .7 | .9 | 1.8 | 2.6 | 1.3 | 1.3 | 11.7 | | | |
| | B | .4 | | .2 | .7 | .2 | .7 | 1.3 | .7 | .2 | .7 | 5.3 | | | |
| | C | | | | | | .4 | 1.1 | .7 | | | 2.2 | | | |
| | D | | | | | | | | | | | | | | |
| | E | | | | | | | | | | | | | | |
| 501- 750 | A | | | .2 | | | | .4 | .4 | .2 | .4 | 1.8 | | | |
| | B | | | | .2 | | .2 | .9 | .9 | .2 | | 2.4 | | | |
| | C | | | | | | | | | | | | | | |
| | D | | | | | | | | | | | | | | |
| | E | | | | | | | | | | | | | | |
| 751-1000 | A | .7 | | | | .4 | .2 | .4 | .4 | | | 2.2 | | | |
| | B | | | | | | .2 | | .2 | .2 | | .7 | | | |
| | C | | | | | | | | | | | | | | |
| | D | | | | | | | | | | | | | | |
| | E | | | | | | | | | | | | | | |
| 1001-1500 | A | .4 | | | | .2 | .2 | .9 | .2 | | | 2.0 | | | |
| | B | | | | | | .2 | | | | | .2 | | | |
| | C | | | | | | | | | | | | | | |
| | D | | | | | | | | | | | | | | |
| | E | | | | | | | | | | | | | | |
| >1500 | A | | | | | .2 | | | | | | .2 | | | |
| | B | | | | | | | | | | | | | | |
| | C | | | | | | | | | | | | | | |
| | D | | | | | | | | | | | | | | |
| | E | | | | | | | | | | | | | | |
| TOTAL | | 26.3 | | 1.8 | 2.4 | 3.8 | 5.7 | 13.0 | 12.1 | 6.4 | 5.1 | 76.6 | | | |
| SFC-BASE OF INVER | A | | | .9 | .4 | .4 | | | | | | 1.8 | | | |
| | B | | | .2 | 1.5 | 2.0 | 3.1 | 6.6 | 6.0 | 3.3 | 4.2 | 28.9 | | | |
| | C | | | .4 | .4 | 1.3 | 2.6 | 6.4 | 6.2 | 1.1 | .9 | 19.4 | | | |
| | D | | | .2 | | | | | | | | .2 | | | |
| | E | | | | | | | | | | | | | | |
| NONE | A | | 3.3 | 2.6 | .7 | .7 | 1.3 | 2.0 | | | | | | | |
| | B | | 12.8 | 13.3 | 13.7 | 14.6 | 13.0 | 18.3 | | | | | | | |
| | C | | 6.2 | 7.1 | 9.1 | 8.2 | 7.1 | 3.1 | | | | | | | |
| | D | | .7 | | | | | | | | | | | | |
| | E | | .4 | .2 | | | | | | | | | 23.4 | | |
| GRAND TOTAL | | | | | | | | | | | | | | 100.0 | |
| MISSING | | | | | | | | | | | | | | | .4 |

DELTA T/H INVERSION LAYER
A 0.0000 - 0.0047 C/M D 0.0283 - 0.0600
B 0.0048 - 0.0114 C/M E > 0.0600
C 0.0115 - 0.0282 C/M

DELTA T/H NO INVERSION
A <0.0000 TO -0.0040 D -0.0121 TO -0.0160
B -0.0041 TO -0.0080 E < -0.0160
C -0.0081 TO -0.0120

TABLE A-4. PHOTOCOPY OF HARD-COPY SUMMARY OF RELATIVE HUMIDITY CHARACTERISTICS, BASED ON PROCESSED SOUNDING DATA. PERCENTAGE FREQUENCIES ARE IN TENTHS. SEE TEXT FOR DETAILS.

STATION 94823 TIME 00 SEASON 09-11 PER CENT RELATIVE HUMIDITY FREQUENCY OF OCCURRENCE 9

| | | DELTA HEIGHT | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1-100 RH | | | | 101-250 RH | | | | 251-500 RH | | | | 501-750 RH | | | | 751-1000 RH | | | | 1001-1500 AND >1500 RH | | | | LINE | |
| | | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | TOTAL | MISS |
| SURFACE | I | 2 | 18 | | | 38 | 124 | 20 | 4 | | 22 | 4 | | | | | | 2 | 4 | | | 2 | 2 | | | 263 | |
| | A | 7 | 13 | | | 84 | 102 | 15 | 4 | 2 | 20 | 4 | | | | | | 7 | | | | 4 | | | | 263 | |
| 1- 100 | I | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | B | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 101- 250 | I | 2 | 7 | 2 | | | 2 | | | | | 2 | | | | 2 | | | | | | | | | | 18 | |
| | B | 2 | 7 | 2 | | | 2 | | | | | 2 | | | | 2 | | | | | | | | | | 18 | |
| 251- 500 | I | | | | | 2 | 4 | 2 | | 4 | 2 | 2 | 4 | | | | 2 | | | | | | | | | 24 | |
| | B | | | | | | 7 | | 2 | 2 | 4 | 2 | 4 | | | | 2 | | | | | | | | | 24 | |
| 501- 750 | I | | 2 | 2 | 2 | 2 | 11 | | | 7 | | 2 | | | | | | | 2 | | 2 | | 4 | | | 38 | |
| | B | | 2 | 2 | 2 | | 9 | 4 | | | 7 | 2 | | | | | | | | 4 | | | | 4 | | 38 | |
| 751-1000 | I | | 2 | | | 7 | 11 | 4 | 2 | 9 | 4 | 4 | 2 | 2 | | | | 4 | | | | 4 | | | | 58 | |
| | B | | 2 | | | | 18 | 4 | 2 | | 13 | 7 | | | | | 2 | | 4 | | | | 2 | 2 | | 58 | |
| 1001-1500 | I | 2 | | | | 29 | 24 | 2 | 2 | 13 | 22 | 4 | 2 | 7 | 4 | 2 | | 4 | | | | 7 | | 2 | | 131 | |
| | B | | 2 | | | 2 | 51 | 2 | 2 | 2 | 22 | 18 | 2 | | 9 | 4 | | | 4 | | | | 2 | 7 | | 131 | |
| 1501-2000 | I | | | | 2 | 7 | 38 | 11 | 2 | 4 | 24 | 11 | | 4 | 9 | | | 2 | 4 | | | 2 | | | | 122 | |
| | B | | | | 2 | 2 | 29 | 27 | | | 20 | 20 | | | 11 | 2 | | | 7 | | | | 2 | | | 122 | |
| 2001-2500 | I | | 2 | | | 7 | 15 | 11 | 7 | 7 | 7 | 2 | | | 4 | | | 2 | | | | | | | | 64 | |
| | B | | 2 | | | | 20 | 13 | 7 | 2 | 11 | 2 | | | 2 | 2 | | | 2 | | | | | | | 64 | |
| 2501-3000 | I | | 2 | | 2 | 7 | 9 | 4 | | 7 | 11 | 4 | | | 2 | 2 | | | | | | | | | | 51 | |
| | B | | 2 | | 2 | 2 | 4 | 13 | | | 9 | 13 | | | | 2 | 2 | | | | | | | | | 51 | |
| TOTAL | I | 7 | 33 | 4 | 7 | 117 | 239 | 55 | 18 | 53 | 93 | 38 | 9 | 13 | 20 | 7 | 2 | 13 | 11 | | 2 | 15 | 7 | 2 | | 768 | |
| | B | 2 | 18 | 4 | 7 | 7 | 139 | 64 | 13 | 7 | 86 | 66 | 7 | | 22 | 13 | 7 | | 18 | 4 | | | 7 | 13 | | 504 | |
| NONE | | 20 | 102 | 80 | 31 | 22 | 95 | 95 | 20 | 20 | 86 | 104 | 22 | 9 | 86 | 113 | 24 | 9 | 73 | 126 | 24 | 11 | 62 | 133 | 27 | 232 | |
| GRAND TOT | | | | | | | | | | | | | | | | | | | | | | | | | | 1000 | |
| MISSING | | | | | | | | | | | | | | | | | | | | | | | | | | | 7 |

RELATIVE HUMIDITY
1 < 40% I = IN INVERSION LAYER
2 40% TO 69% A = ABOVE INVERSION LAYER
3 70% TO 89% B = BELOW INVERSION LAYER
4 > 89%

TABLE A-5. PHOTOCOPY OF PART OF HARD-COPY SUMMARY OF WINDS BY TEMPERATURE STRUCTURE, BASED ON PROCESSED SOUNDING DATA. SEE TEXT FOR DETAILS.

STATION 94823 TIME 00 SEASON 09-11 PER CENT WIND FREQUENCY OF OCCURRENCE 62

NO INVERSION

| HEIGHT | SURFACE | | | | | 150M | | | | | 300M | | | | | 600M | | | | | 900M | | | | | 1200M | | | | | LINE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C | 1 | 2 | 3 | 4 | C | 1 | 2 | 3 | 4 | C | 1 | 2 | 3 | 4 | C | 1 | 2 | 3 | 4 | C | 1 | 2 | 3 | 4 | C | 1 | 2 | 3 | 4 | TOTAL |
| N | | 9 | 18 | 7 | | | 5 | 30 | 7 | | | 5 | 18 | 16 | 8 | | 3 | 11 | 21 | 7 | | 5 | 5 | 23 | 7 | | 2 | 7 | 14 | 11 | 39 |
| E | | 13 | 29 | | | | 9 | 16 | 7 | | | 5 | 7 | 14 | 2 | | 2 | 2 | 11 | 2 | | 2 | | 7 | 2 | | | 2 | 2 | | 33 |
| S | | 7 | 35 | 2 | | | 7 | 16 | 34 | | | 2 | 14 | 30 | 16 | | 2 | 9 | 21 | 23 | | 5 | 2 | 18 | 28 | | 9 | 2 | 18 | 23 | 54 |
| W | | 18 | 73 | 24 | | | 2 | 34 | 35 | 9 | | | 14 | 50 | 34 | | | 18 | 41 | 35 | | 5 | 18 | 32 | 73 | | 5 | 20 | 30 | 91 | 117 |
| C | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| NO INVERSION TOTAL | | 47 | 155 | 33 | | | 23 | 96 | 105 | 9 | | 11 | 53 | 110 | 97 | | 9 | 41 | 94 | 87 | | 16 | 29 | 80 | 110 | | 16 | 32 | 64 | 125 | 233 |

ALL INVERSIONS

| HEIGHT | SURFACE | | | | | 150M | | | | | 300M | | | | | 600M | | | | | 900M | | | | | 1200M | | | | | LINE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C | 1 | 2 | 3 | 4 | C | 1 | 2 | 3 | 4 | C | 1 | 2 | 3 | 4 | C | 1 | 2 | 3 | 4 | C | 1 | 2 | 3 | 4 | C | 1 | 2 | 3 | 4 | TOTAL |
| N | | 60 | 106 | 16 | | | 28 | 96 | 55 | | | 18 | 76 | 53 | 23 | | 23 | 57 | 48 | 32 | | 18 | 50 | 55 | 32 | | 14 | 39 | 52 | 39 | 168 |
| E | | 58 | 64 | | | | 28 | 69 | 23 | | | 18 | 53 | 39 | | | 11 | 23 | 30 | 7 | | 7 | 25 | 23 | 9 | | 11 | 21 | 18 | 7 | 91 |
| S | | 47 | 124 | 11 | | | 21 | 87 | 85 | 2 | | 21 | 55 | 62 | 62 | | 21 | 53 | 46 | 67 | | 21 | 46 | 48 | 46 | | 9 | 36 | 48 | 36 | 175 |
| W | | 78 | 157 | 29 | | | 18 | 126 | 106 | 21 | | 7 | 71 | 151 | 60 | | 16 | 73 | 144 | 117 | | 9 | 67 | 147 | 165 | | 27 | 61 | 173 | 170 | 332 |
| C | 18 | | | | | 5 | | | | | | | | | | | | | | | | | | | | | | | | | 5 |
| ALL INVERSIONS TOTL | 18 | 242 | 452 | 55 | | 5 | 94 | 378 | 268 | 23 | | 64 | 255 | 303 | 144 | | 71 | 206 | 268 | 222 | | 55 | 188 | 273 | 252 | | 61 | 159 | 291 | 252 | 767 |
| GRAND TOTAL | | | | | 1000 | | | | | 1000 | | | | | 1000 | | | | | 1000 | | | | | 1000 | | | | | 1000 | 1000 |
| MISSING TOTAL | | | | | 9 | | | | | 44 | | | | | 44 | | | | | 44 | | | | | 44 | | | | | 34 | 36 |

| SPEED | | DIRECTION |
|---|---|---|
| C | < 00.1 M/SEC | N 316-045 |
| 1 | 00.1 - 02.5 M/SEC | E 046-135 |
| 2 | 02.6 - 05.0 M/SEC | S 136-225 |
| 3 | 05.1 - 10.0 M/SEC | W 226-315 |
| 4 | > 10.0 M/SEC | C CALM |

THE SURFACE, 150M, AND 300M WINDS ARE OBSERVED WINDS
THE 600M, 900M, AND 1200M WINDS ARE INTERPOLATED FROM OBSERVED WINDS

TABLE A-6. NATIONAL WEATHER SERVICE STATIONS FOR WHICH RAWINSONDE OBSERVATIONS AT SCHEDULED SYNOPTIC TIMES OF 0000 AND 1200 GMT HAVE BEEN PROCESSED AND SUMMARIZED. SUPERSCRIPT LETTERS ON WBAN NUMBERS REFER TO FOOTNOTES AT END OF TABLE.

| CITY | WBAN NO. | PERIOD SUMMARIZED | CITY | WBAN NO. | PERIOD SUMMARIZED |
|---|---|---|---|---|---|
| Albany, NY | 14735 | 01/60-12/64 | Glasgow, MT | 94008 | 01/60-12/64 |
| Albuquerque, NM | 23050 | 01/60-12/64 | Grand Junction, CO | 23066 | 01/60-12/64 |
| Amarillo, TX | 23047 | 01/60-12/64 | Great Falls, MT | 24143 | 01/60-12/64 |
| Anchorage, AK | 26409 | 01/60-12/64 | Green Bay, WI | 14898 | 01/60-12/64 |
| Annette, AK | 25308 | 01/60-12/64 | Greensboro, NC | 13723 | 01/60-12/64 |
| Athens, GA | 13873 | 01/60-12/64 | Hilo, HI | 21504 | 01/60-12/64 |
| Barter Island, AK | 27401 | 01/60-12/64 | Huntington, WV | 03860 | 01/62-12/64 |
| Bismark, ND | 24011 | 01/60-12/64 | International Falls, MN | 14918 | 01/60-12/64 |
| Boise, ID | 24131 | 01/60-12/64 | Jackson, MS | 13956 | 01/59-12/62 |
| Brownsville, TX | 12919 | 01/60-12/64 | Jacksonville, FL | 13889 | 01/60-12/64 |
| Buffalo, NY | 14733 | 01/61-12/64 | Lake Charles, LA | 03937 | 01/62-12/64 |
| Burwood, LA | 12863 | 01/60-12/64 | Lander, WY | 24021 | 01/60-12/64 |
| Cape Hatteras, NC | 93729 | 01/60-12/64 | Las Vegas, NV | 23169 | 01/60-12/64 |
| Caribou, ME | 14607 | 01/60-12/64 | Lihue, HI | 22536 | 01/60-12/64 |
| Charleston, SC | 13880 | 01/60-12/64 | Little Rock, AR | 13963 | 01/60-12/64 |
| Columbia, MO | 13983 | 01/60-12/64 | Medford, OR | 24225 | 01/60-12/64 |
| Dayton, OH | 13840[a] | 01/60-12/64 | Miami, FL | 12839 | 01/60-12/64 |
| Denver, CO | 23062 | 01/60-12/64 | Midland, TX | 23023 | 01/60-12/64 |
| Denver, CO | 23062 | 07/71-06/72 | Montgomery, AL | 13895 | 01/60-12/64 |
| Dodge City, KS | 13985 | 01/60-12/64 | Nantucket, MA | 14756 | 01/60-12/64 |
| El Paso, TX | 23044 | 01/60-12/64 | Nashville, TN | 13897 | 01/60-12/64 |
| Ely, NV | 23154 | 01/60-12/64 | New York, NY | 94789[c] | 01/60-12/64 |
| Fairbanks, AK | 26411 | 01/60-12/64 | Nome, AK | 26617 | 01/60-12/64 |
| Flint, MI | 14826 | 01/60-12/64 | North Platte, NE | 24023 | 01/60-12/64 |
| Fort Worth, TX | 13911[b] | 01/60-12/64 | Oakland, CA | 23230 | 01/60-12/64 |

TABLE 6. (Continued)

| CITY | WBAN NO. | PERIOD SUMMARIZED |
|---|---|---|
| Oklahoma City, OK | 13967[d] | 01/60-12/64 |
| Omaha, NE | 94918 | 01/60-12/64 |
| Peoria, IL | 14842 | 01/60-12/64 |
| Pittsburgh, PA | 94823 | 01/60-12/64 |
| Pittsburgh, PA | 94823 | 01/72-12/72 |
| Point Barrow, AK | 27502 | 01/60-12/64 |
| Portland, ME | 14764 | 01/60-12/64 |
| Rapid City, SD | 24090 | 01/60-12/64 |
| St. Cloud, MN | 14926 | 01/60-12/64 |
| Salem, OR | 24232 | 01/60-12/64 |
| Salt Lake City, UT | 24127 | 01/60-12/64 |
| San Antonio, TX | 12921 | 01/60-12/64 |
| San Diego, CA | 03131 | 01/60-12/64 |
| San Juan, PR | 11641 | 01/60-12/64 |
| Santa Monica, CA | 93197 | 01/60-12/64 |
| Sault Ste. Marie, MI | 14847 | 01/60-12/64 |
| Seattle, WA | 24233 | 01/59-12/61 |
| Shreveport, LA | 13957 | 01/60-12/64 |
| Spokane, WA | 24157 | 01/60-12/64 |
| Tampa, FL | 12842 | 01/60-12/64 |
| Tatoosh Island, WA | 24240 | 01/60-12/64 |
| Topeka, KS | 13996 | 01/60-12/64 |
| Tucson, AZ | 23160 | 01/60-12/64 |
| Wallops Island, VA | 93739 | 07/70-12/72 |
| Washington, DC | 93734[e] | 01/61-12/64 |
| Washington, DC | 93734[e] | 07/70-06/72 |
| Winnemucca, NV | 24128 | 01/60-12/64 |
| Winslow, AZ | 23194 | 01/62-12/64 |
| Yakutat, AK | 25339 | 01/60-12/64 |

FOOTNOTES

a. WBAN No. 13840 is for the rawinsonde sight at Sulphur Grove. In table A-1 of AP-101 (Holzworth, 1972) WBAN No. 93815 is for Cox-Dayton Airport, about 10 km from Sulphur Grove.

b. Soundings made from Carswell Air Force Base.

c. Soundings made from Kennedy Airport.

d. In table A-1 of AP-101 (Holzworth, 1972) the correct WBAN No. for Oklahoma City should be 13967.

e. *Soundings made from Dulles Airport.*

TABLE A-7. NATIONAL WEATHER SERVICE STATIONS FOR WHICH LOW-LEVEL RADIOSONDE OBSERVATIONS HAVE BEEN PROCESSED AND SUMMARIZED.

| CITY | WBAN NO. | LAT | LONG | ELEV (M) | PERIOD SUMMARIZED | APPROXIMATE TIMES BALLOONS RELEASED | RELEASE SITE |
|---|---|---|---|---|---|---|---|
| Birmingham, AL | L0180 | 33°34' | 086°45' | 0190 | 08/01/72-12/28/73 | sunrise ± 1/2 hr & noon LST | Eastern edge Municipal Airport |
| Boston, MA | L0120 | 42°21' | 071°05' | 0030 | 08/24/71-04/26/73 | sunrise ± 1/2 hr & 1245 LST ± 1/2 hr | International Airport |
| Charleston, WV | L0170 | 38°23' | 081°46' | 0182 | 07/27/72-12/28/73 | 0600-0700 & 1100-1200 EST | West Virginia State College campus |
| Chicago, IL | L0020 | 41°47' | 087°45' | 0188 | 04/14/69-12/31/73 | 0620 & 1000 EST | Midway Airport |
| Cleveland, OH | L0060 | 41°30' | 081°36' | 0217 | 04/01/71-03/27/73 | sunrise ± 1/2 hr & noon LST | Case Western Reserve Univ campus |
| Denver, CO | L0080 | 39°47' | 104°59' | 1576 | 07/01/71-06/30/72 | sunrise ± 1/2 hr & noon LST | Just south of Coliseum |
| Detroit, MI | L0160[a] | 42°19' | 083°13' | 0187 | 07/03/72-02/27/73 | about 0700 & 1200 EST | Univ Michigan (Park lot E) Dearborn |
| El Monte, CA | L0090 | 34°05' | 118°02' | 0091 | 04/01/71-12/28/73 | about 0600 & 1300 PST | Northeast corner El Monte Airport |
| Houston, TX | L0130[b] | 29°46' | 095°22' | 0017 | 08/16/71-12/28/73 | near sunrise & noon LST | 1/2 mi northwest of downtown |
| Los Angeles, CA | L0100[c] | 33°56' | 118°23' | 0034 | 05/01/71-12/31/73 | 0530 & 1230 PST | International Airport |
| Louisville, KY | L0070 | 38°12' | 085°45' | 0141 | 04/29/71-06/15/73 | near sunrise & noon LST | Univ Louisville campus |
| New York, NY | L0040 | 40°46' | 073°54' | 0013 | 07/01/70-06/12/72 | 0600-0700 & 1100-1200 EST | La Guardia Airport |
| Philadelphia, PA | L0050 | 39°53' | 075°11' | 0005 | 06/27/69-12/28/73 | sunrise ± 1/2 hr & noon LST | US Army Quartermaster Depot |
| Pittsburgh, PA | L0150 | 40°25' | 079°59' | 0224 | 01/03/72-12/29/72 | sunrise ± 1/2 hr & 1200 LST | South 6th St & Monongahela Riv |
| Portland, OR | L0190 | 45°32' | 122°41 | 0042 | 10/30/72-06/18/73 | about 0620 & 1240 LST or DST | Roof of Federal Bldg downtown |
| San Jose, CA | L0110[d] | 37°19' | 121°52' | 0032 | 08/30/71-06/08/73 | 0530 & 1130 LT | San Jose State Univ campus |
| Seattle, WA | L0140 | 47°39' | 122°18 | 0008 | 10/18/71-06/29/73 | 0545 & 1115 PST | Just south of Univ of Washington |
| St. Louis, MO | L0010 | 38°37' | 090°11' | 0139 | 04/16/69-04/27/73 | sunrise ± 1/2 hr & noon LST | Gateway Arch |
| Washington, DC | L0030 | 38°51' | 077°02' | 0023 | 07/01/70-06/30/72 | sunrise - 1/2 hr & 1215 LST | National Airport, main terminal |

a. 1200 EST soundings extended through 03/28/73.

b. Noon soundings sparse since 05/08/73.

c. Soundings made <u>every</u> day.

d. 1130 LT soundings ended 03/16/73.

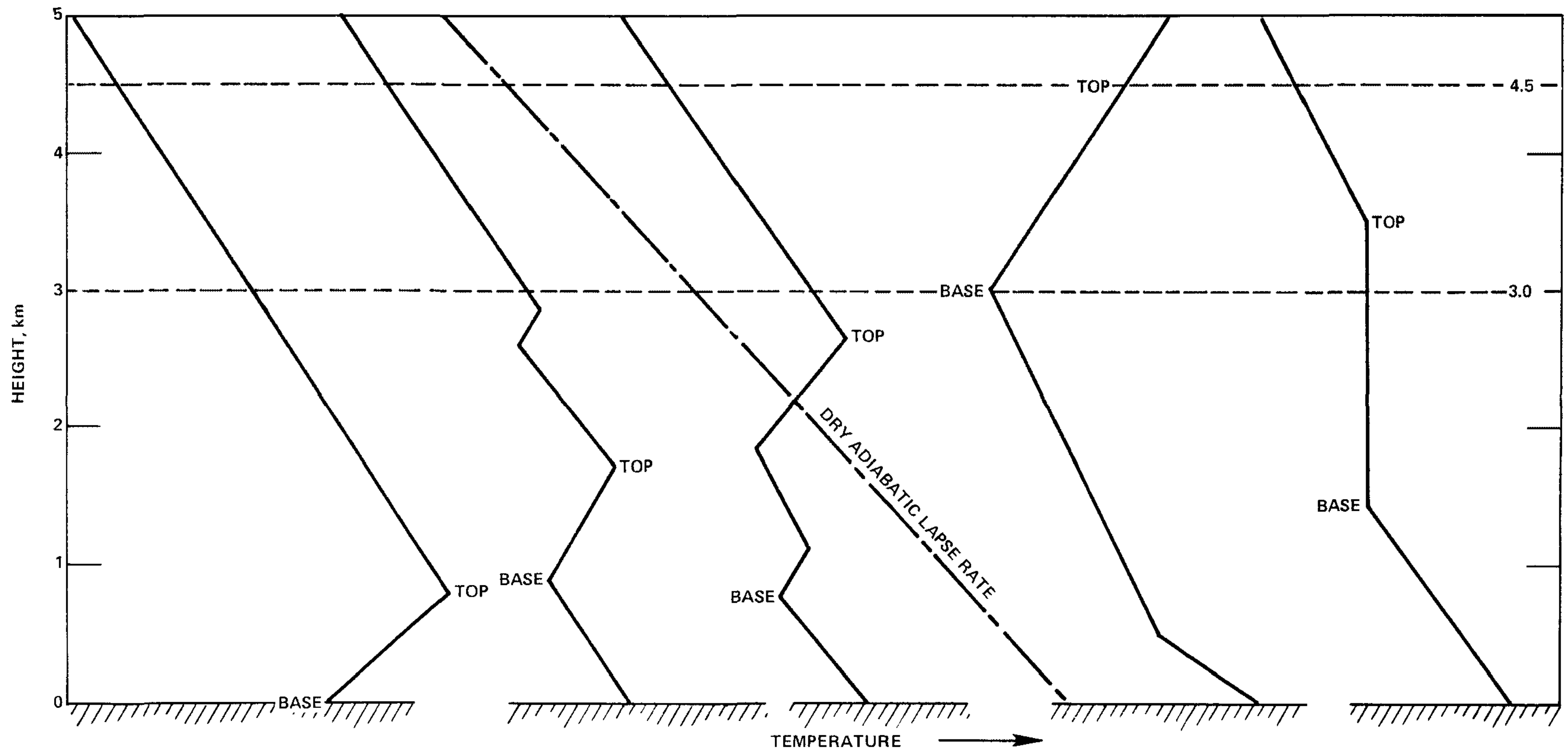


Figure 1 Objective scheme for specifying base and top of inversions for various temperature profile configurations.

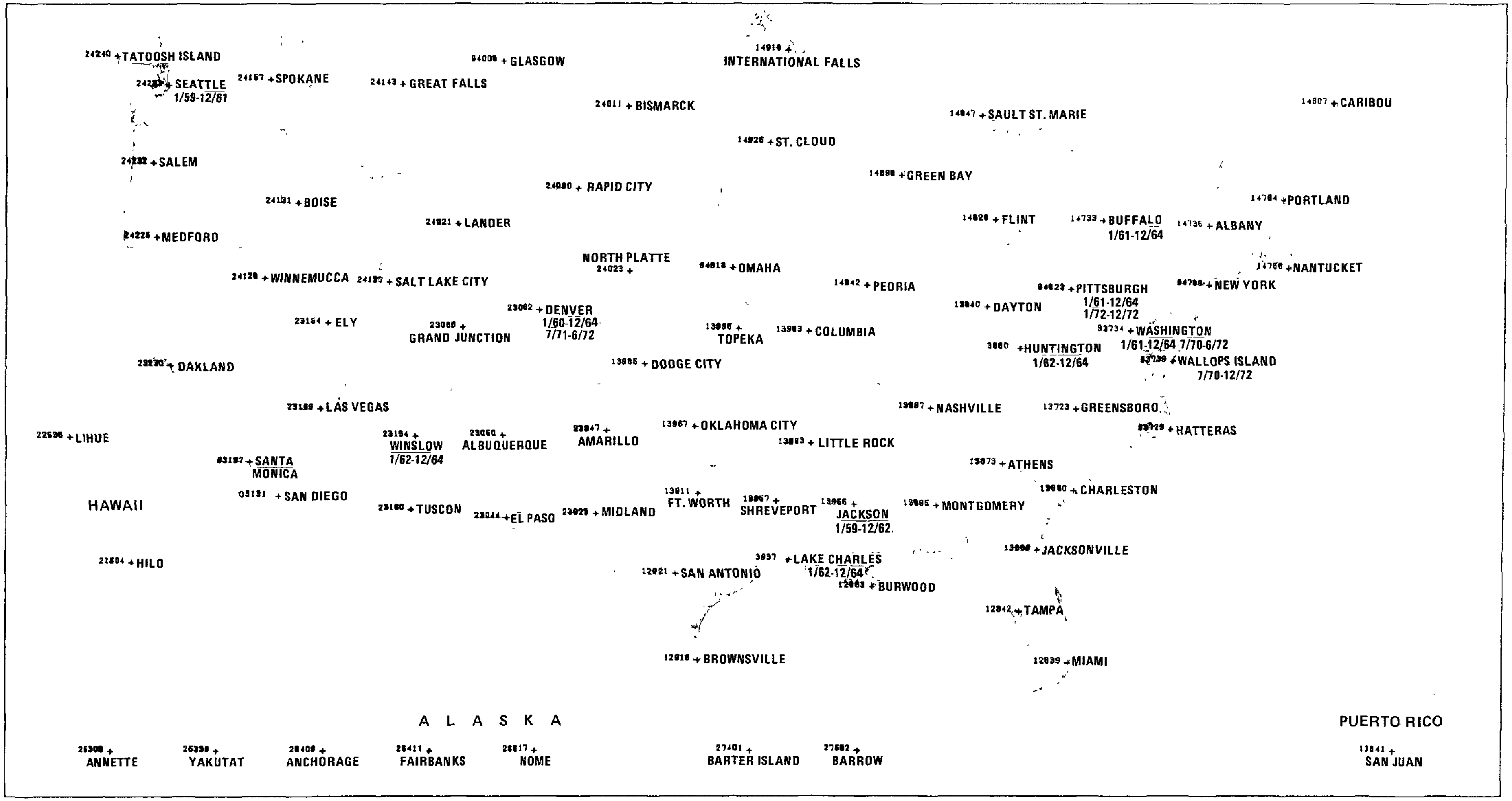


Figure 2. The 76 rawinsonde locations and their WBAN numbers used in this study. Dates indicate observational period(s) at those stations where it was other than 1/60-12/64. San Diego is plotted about 250 km south of its true location to avoid overprinting. Stations outside the contiguous United States are plotted along the periphery.

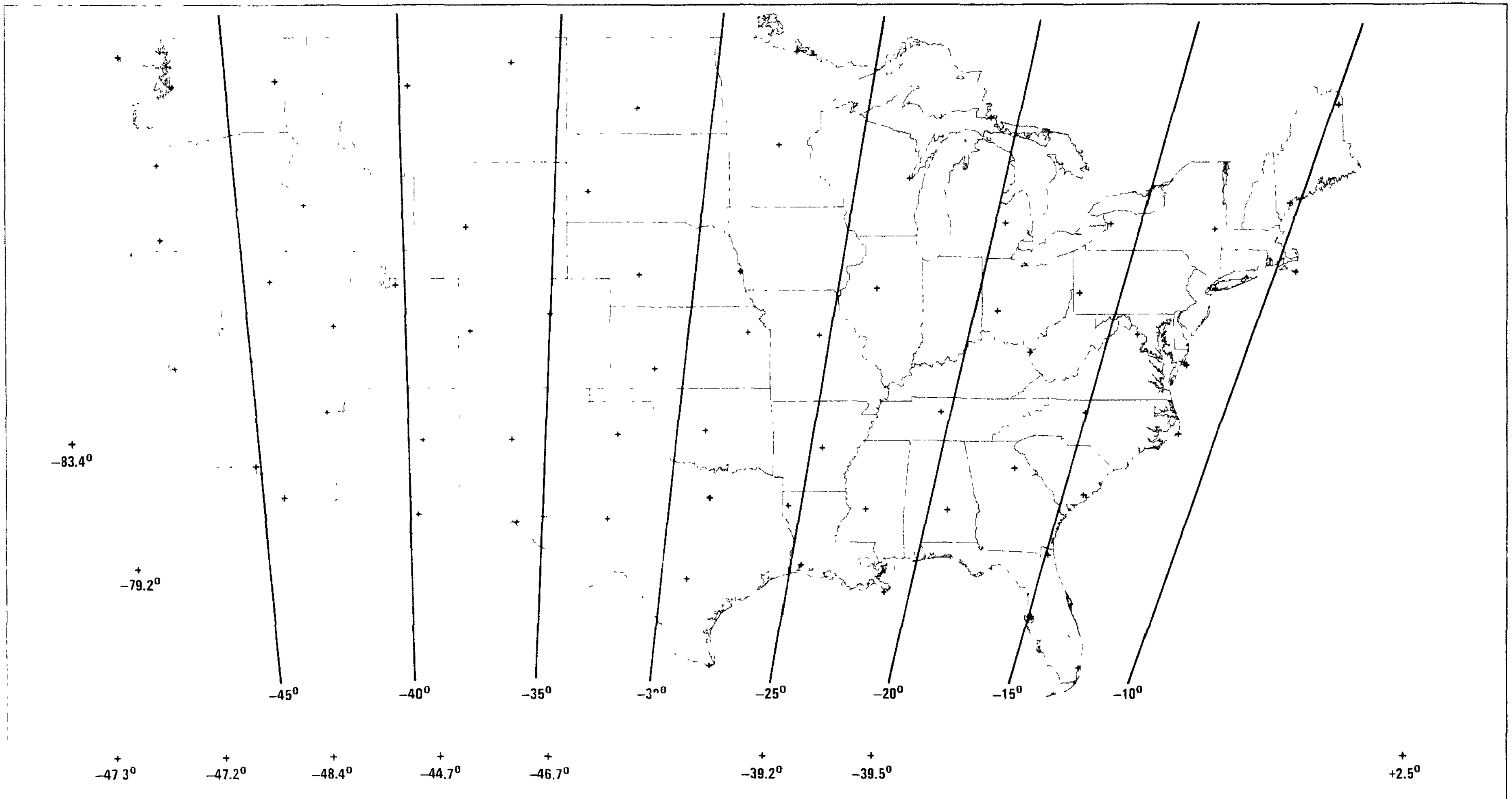


Figure 3 Angles of solar elevation on January 15 at 1115 GMT Negative angles indicate that the sun is below the horizon. See Figure 2 to identify peripheral stations.

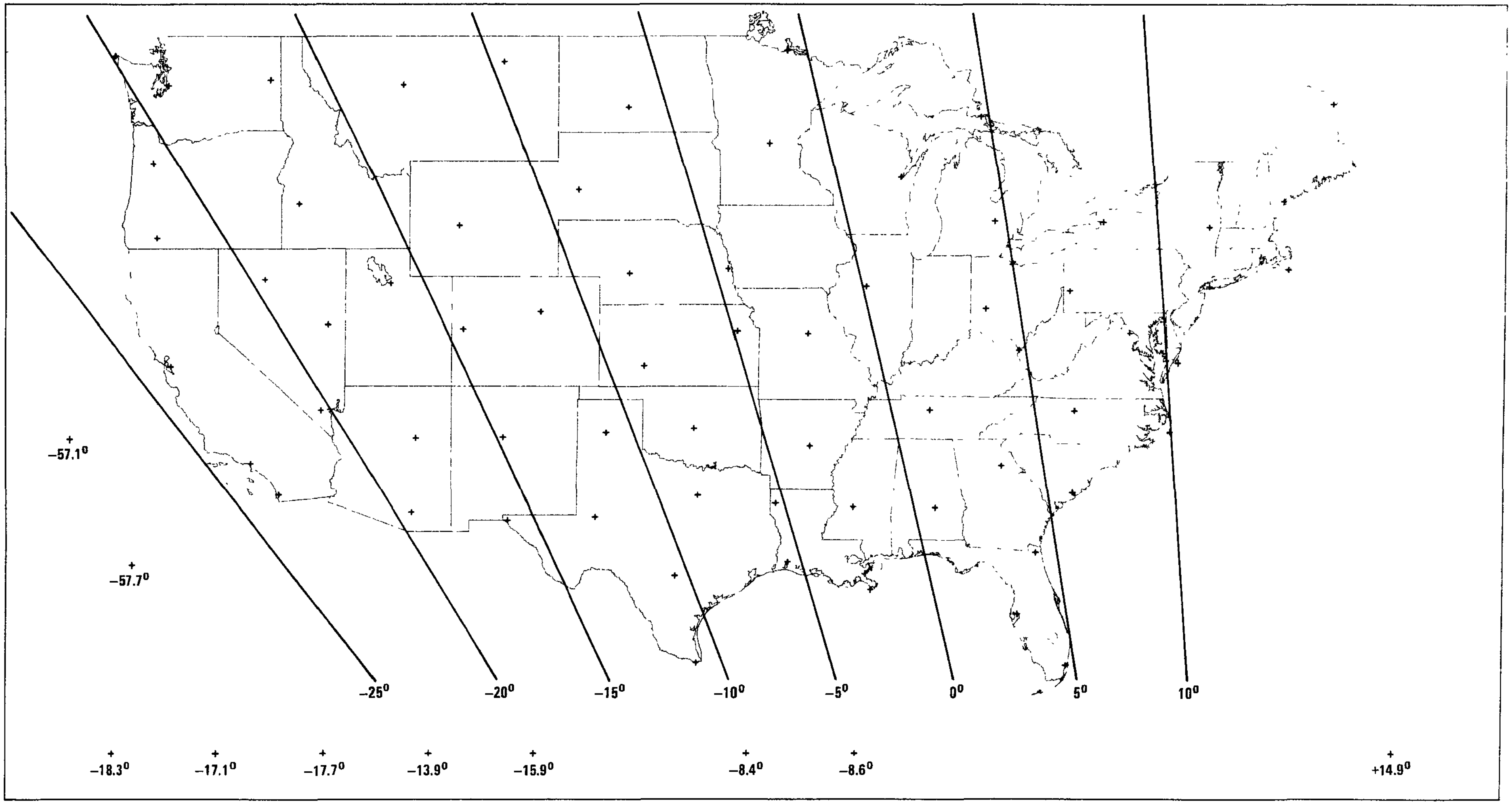


Figure 4. Angles of solar elevation on April 15 at 1115 GMT. Negative angles indicate that the sun is below the horizon. See Figure 2 to identify peripheral stations.

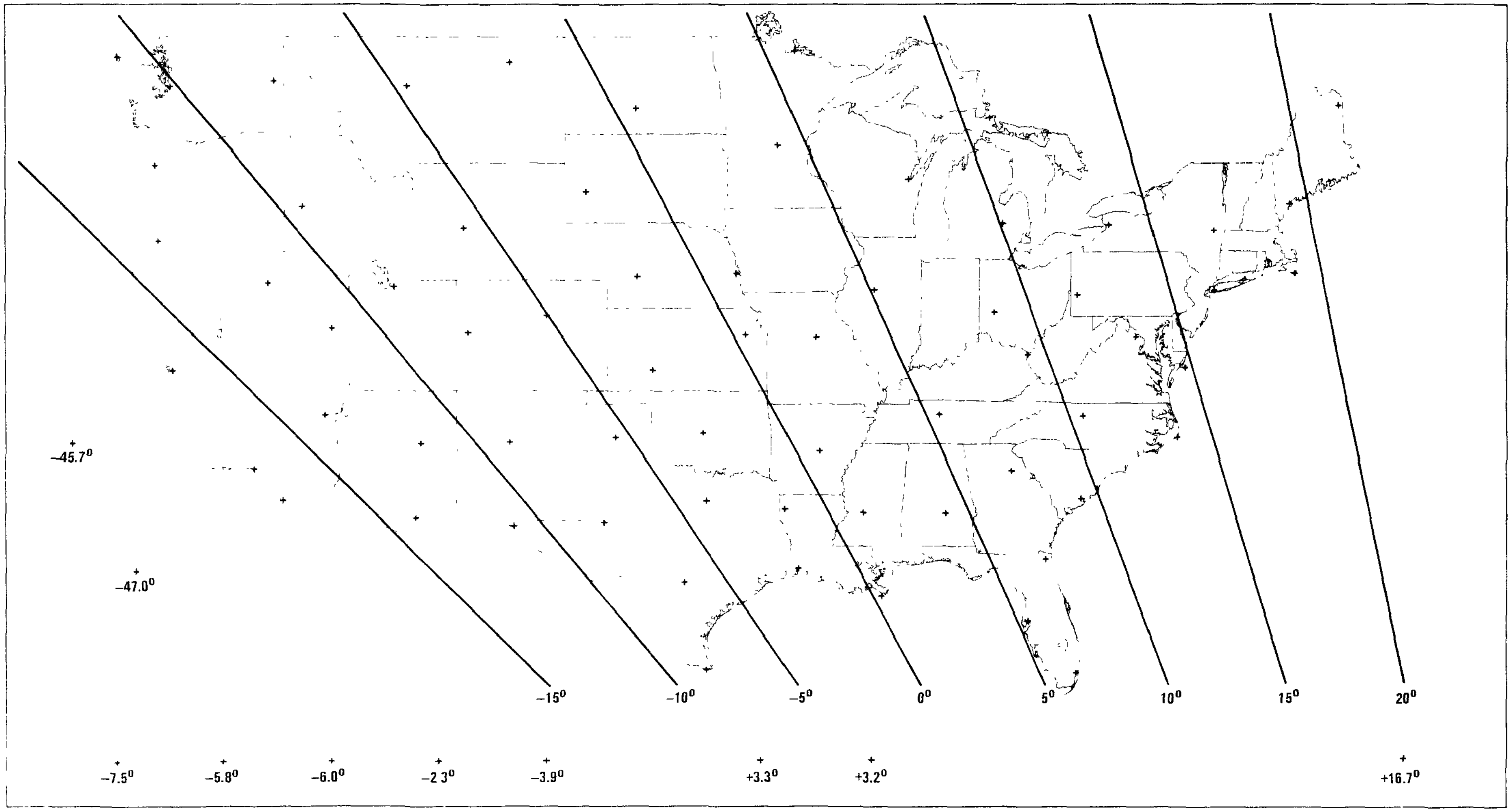


Figure 5 Angles of solar elevation on July 15 at 1115 GMT Negative angles indicate that the sun is below the horizon See Figure 2 to identify peripheral stations

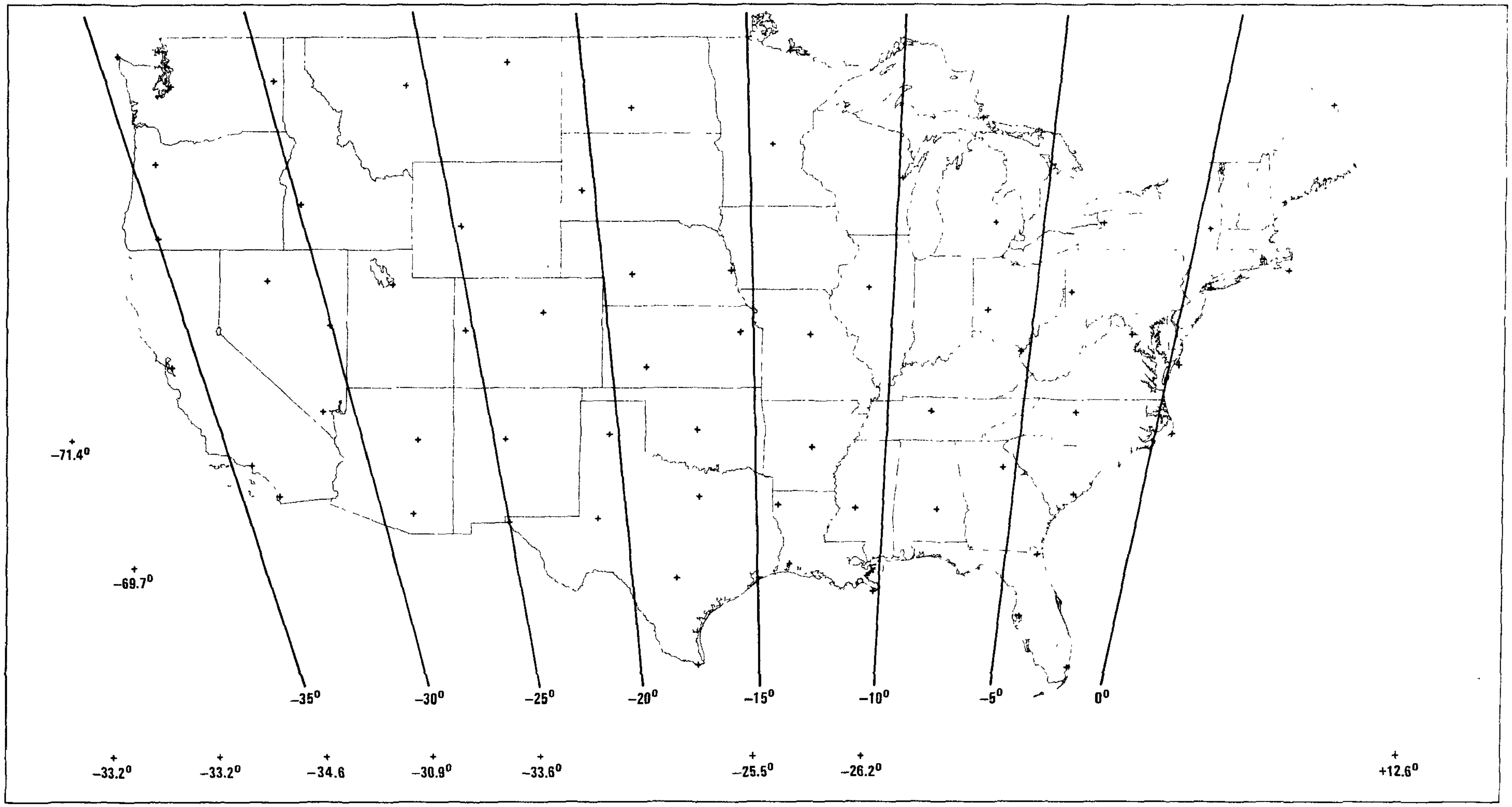


Figure 6. Angles of solar elevation on October 15 at 1115 GMT. Negative angles indicate that the sun is below the horizon. See Figure 2 to identify peripheral stations.

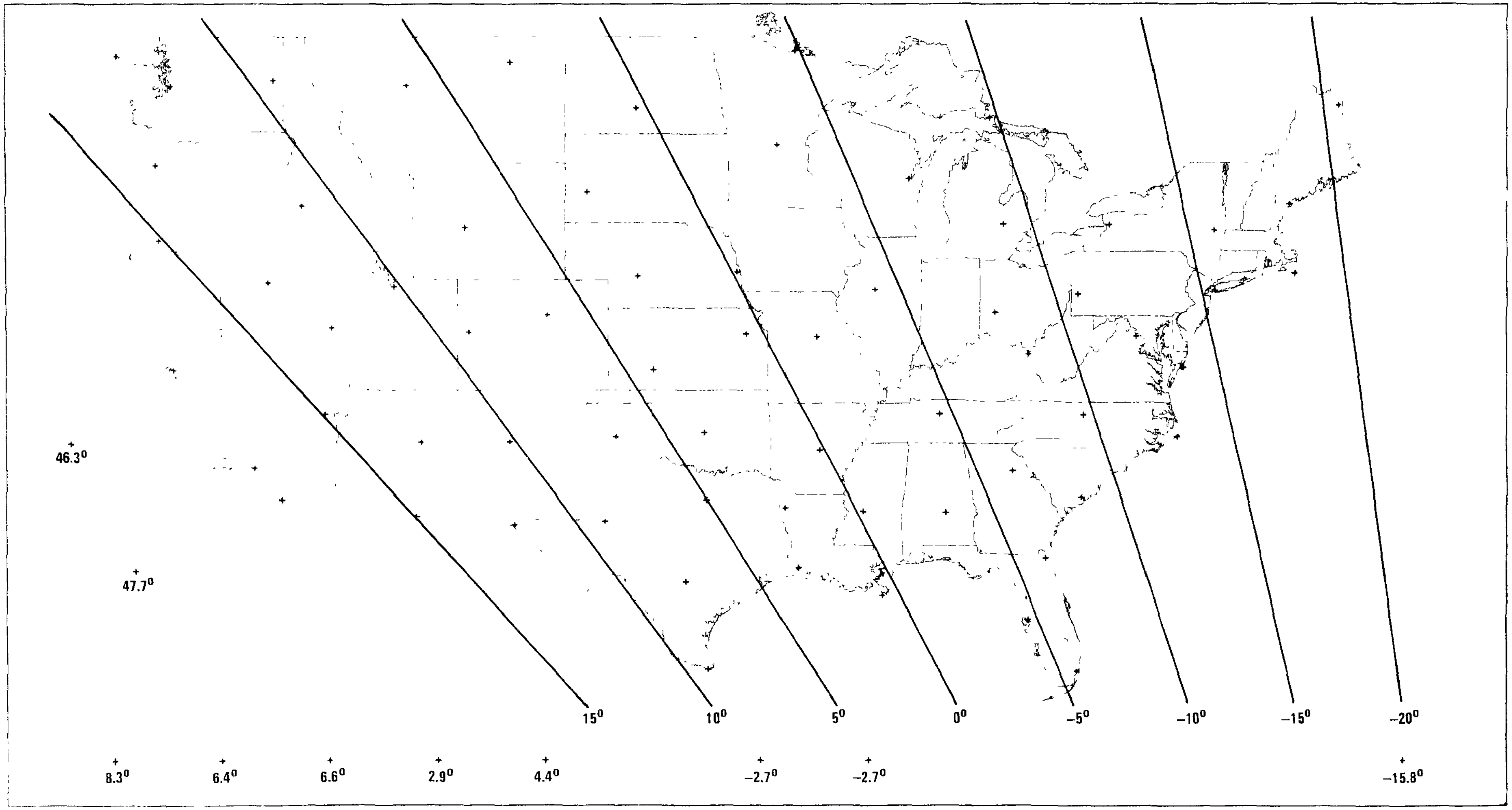


Figure 7 Angles of solar elevation on January 15 at 2315 GMT Negative angles indicate that the sun is below the horizon See Figure 2 to identify peripheral stations.

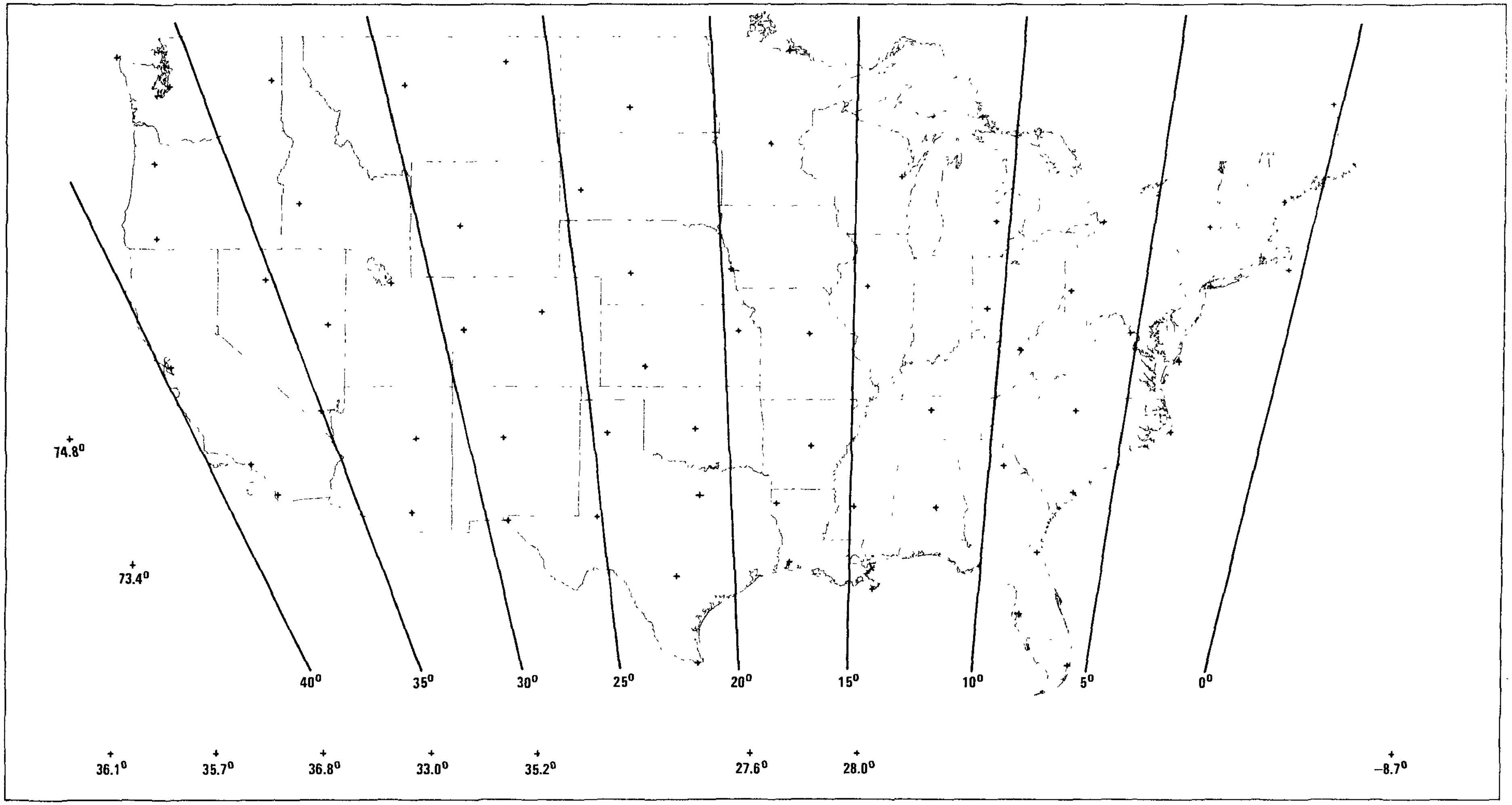


Figure 8 Angles of solar elevation on April 15 at 2315 GMT. Negative angles indicate that the sun is below the horizon. See Figure 2 to identify peripheral stations.

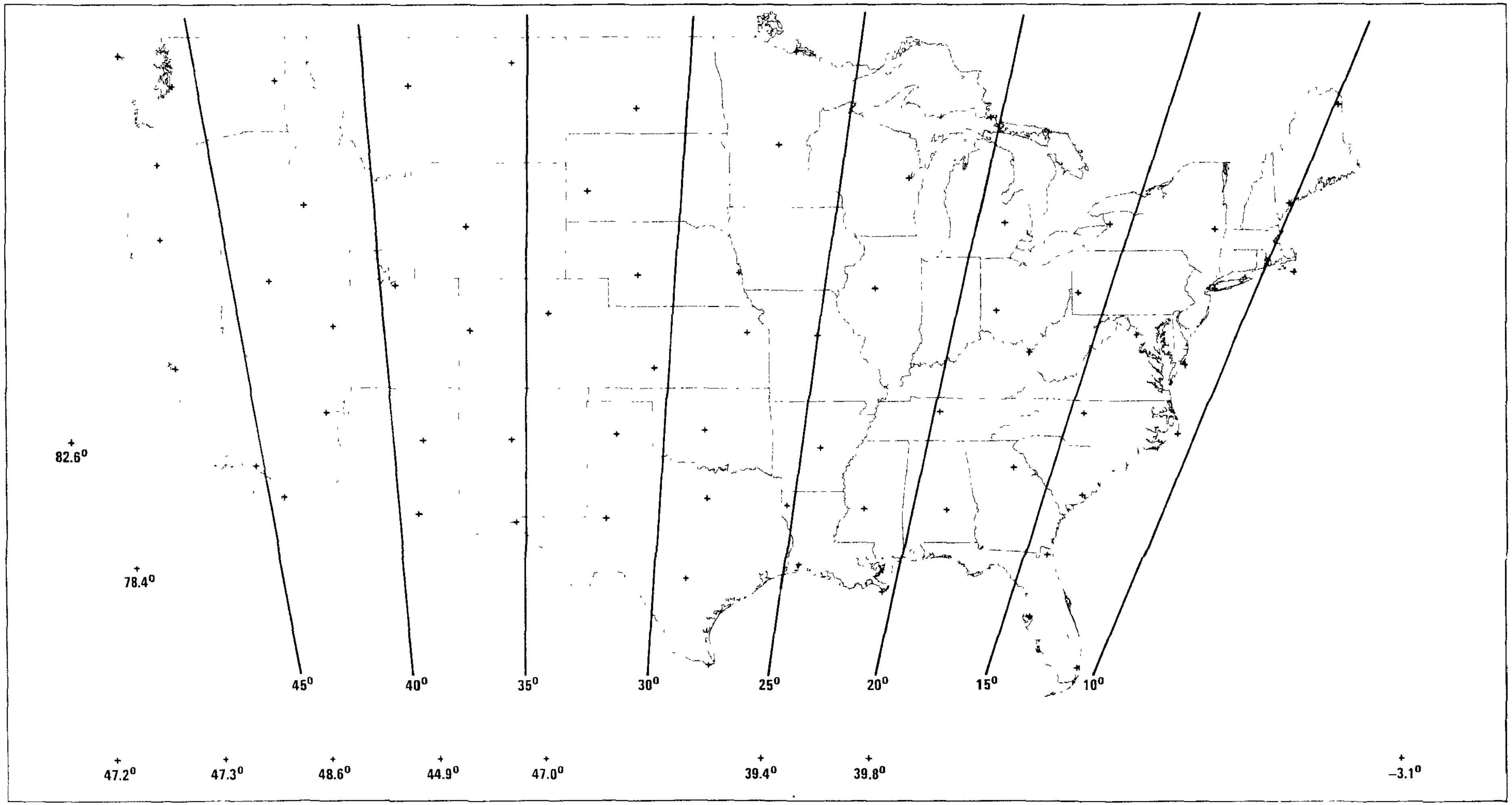


Figure 9 Angles of solar elevation on July 15 at 2315 GMT Negative angles indicate that the sun is below the horizon See Figure 2 to identify peripheral stations.

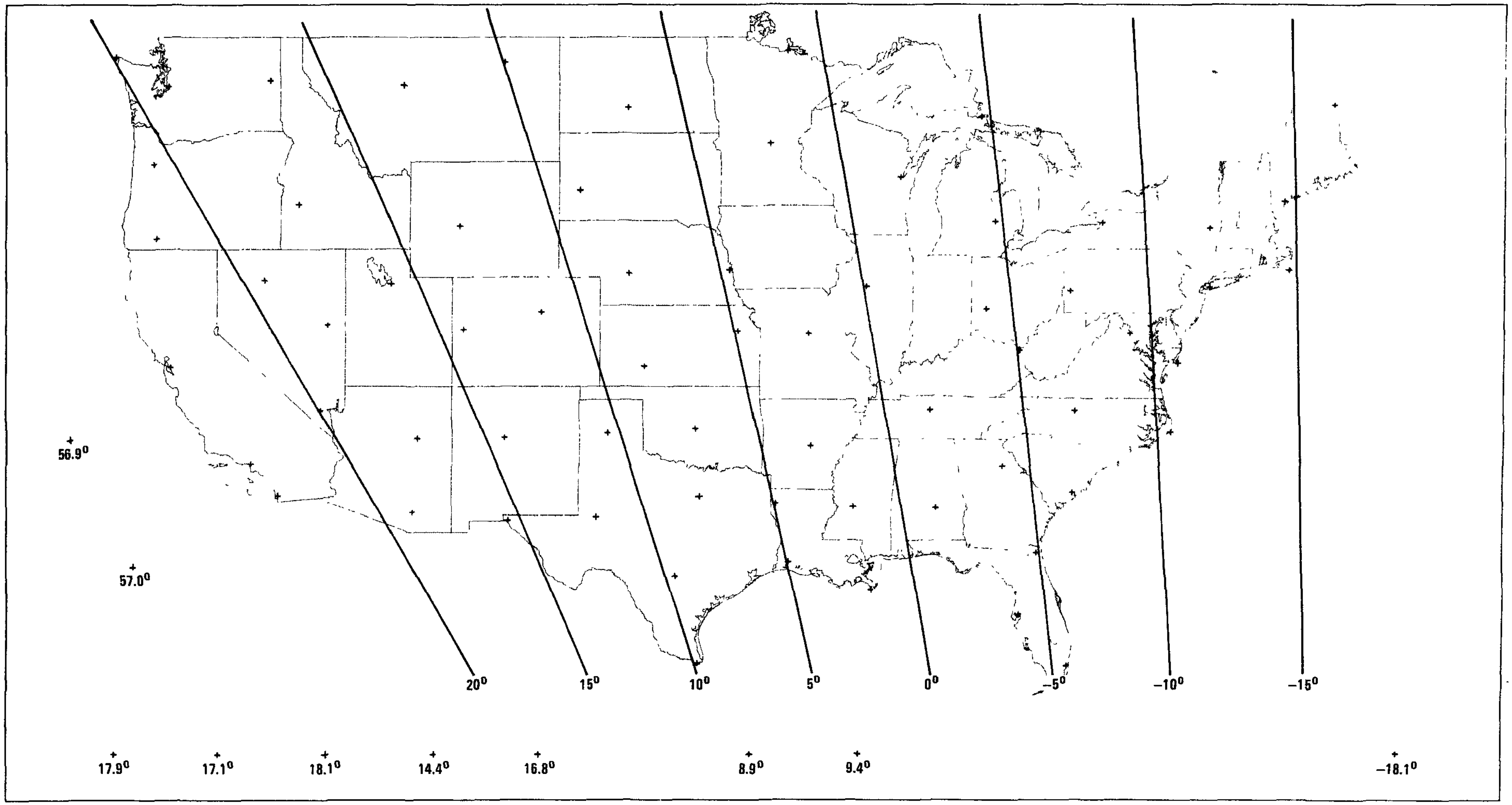


Figure 10. Angles of solar elevation on October 15 at 2315 GMT. Negative angles indicate that the sun is below the horizon. See Figure 2 to identify peripheral stations.

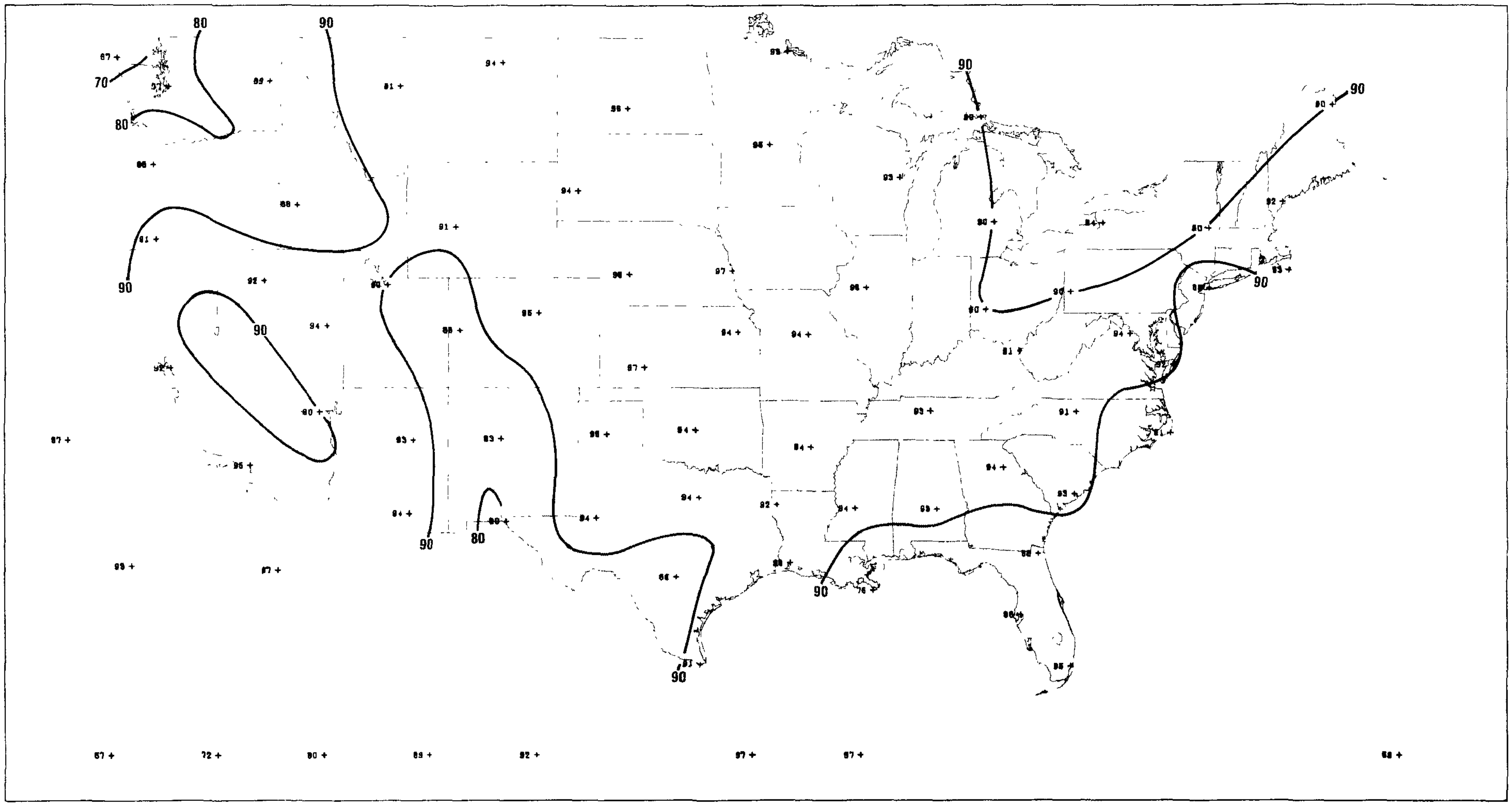


Figure 11. Percentage of all 1115 GMT soundings with a surface-based or elevated inversion below 3000 m AGL. See Figure 2 to identify peripheral stations.

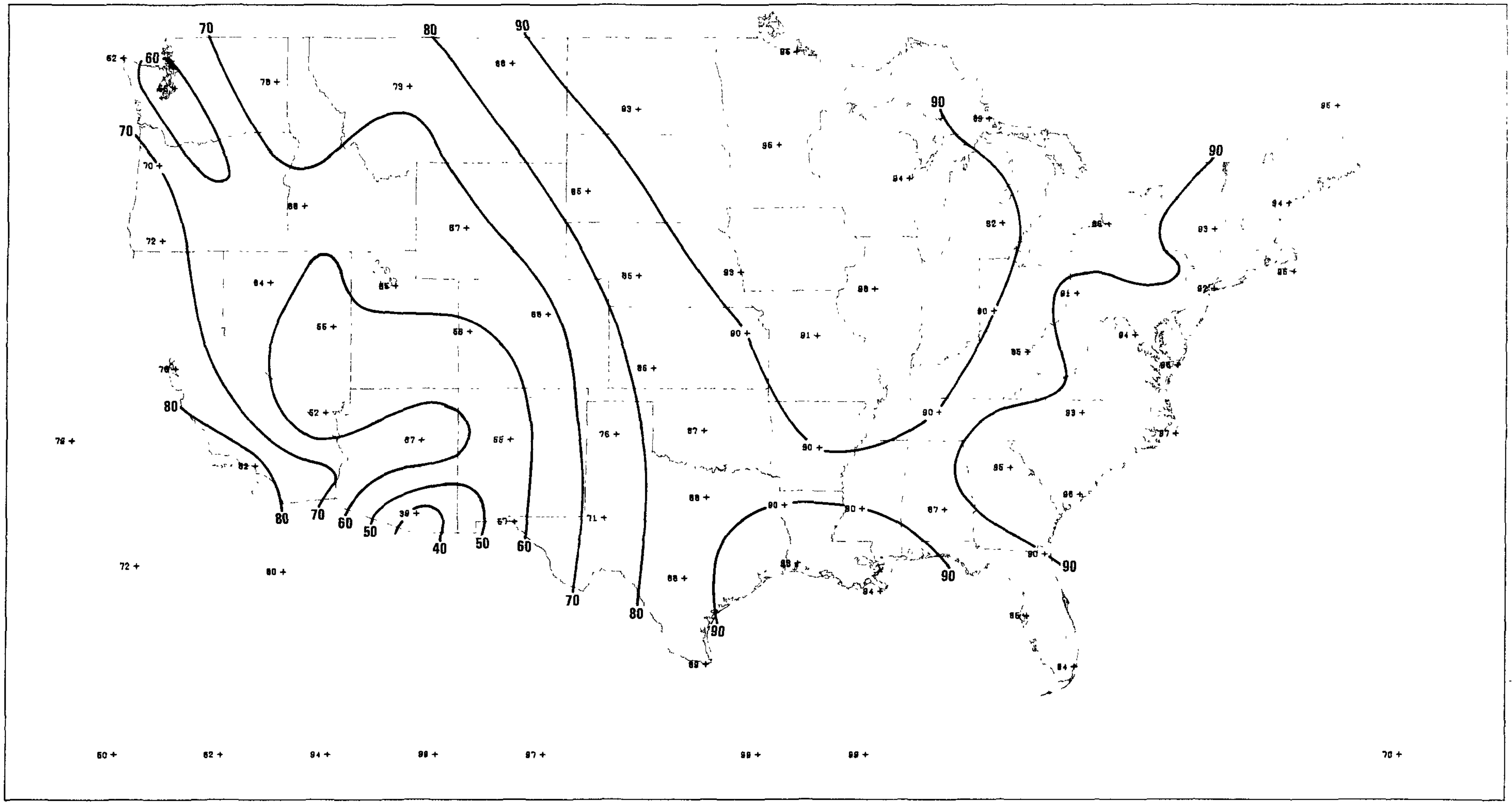


Figure 12. Percentage of winter 2315 GMT soundings with a surface-based or elevated inversion below 3000 m. See Figure 2 to identify peripheral stations.

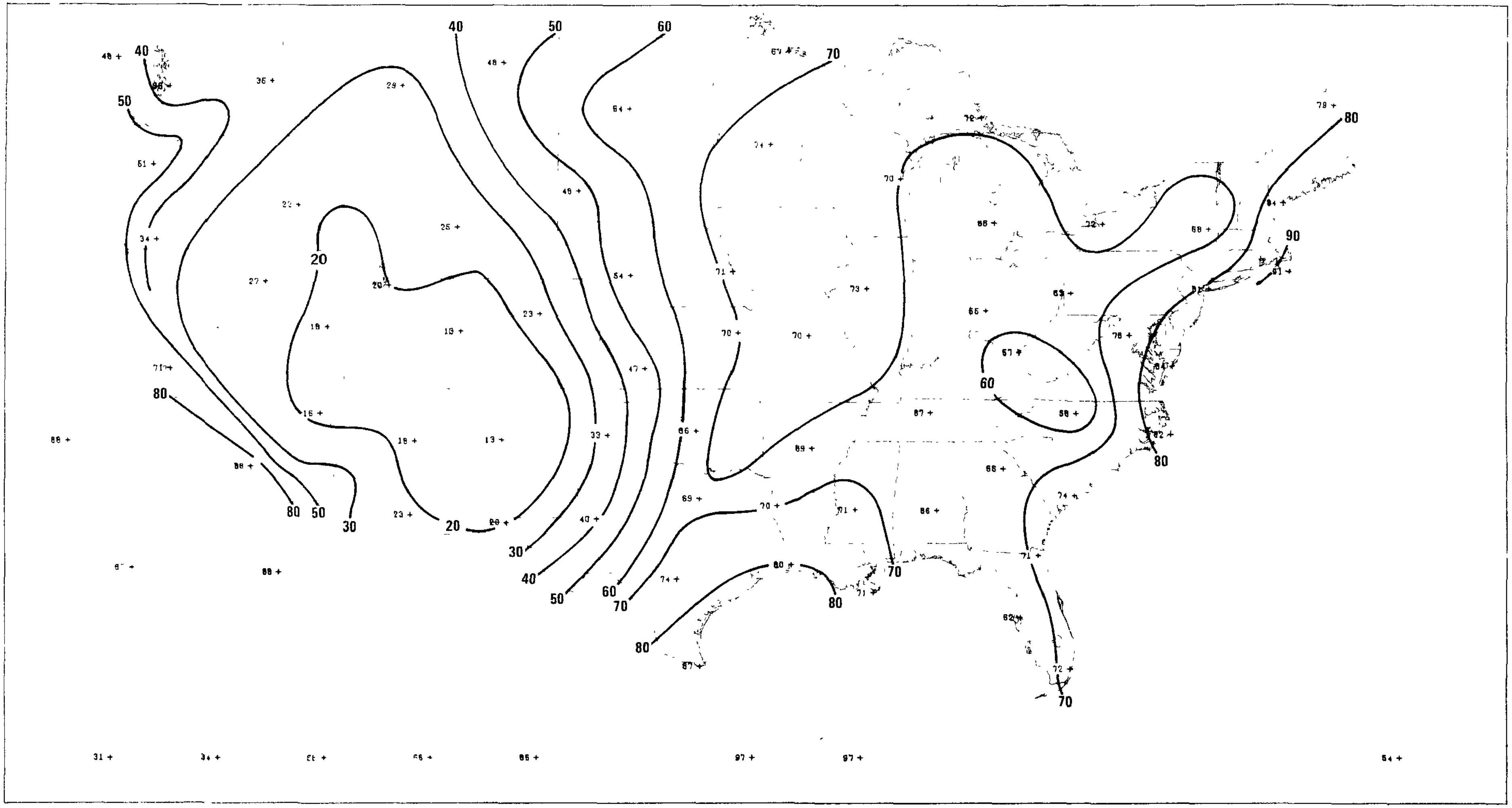

Figure 13. Percentage of spring 2315 GMT soundings with a surface-based or elevated inversion below 3000 m. See Figure 2 to identify peripheral stations.

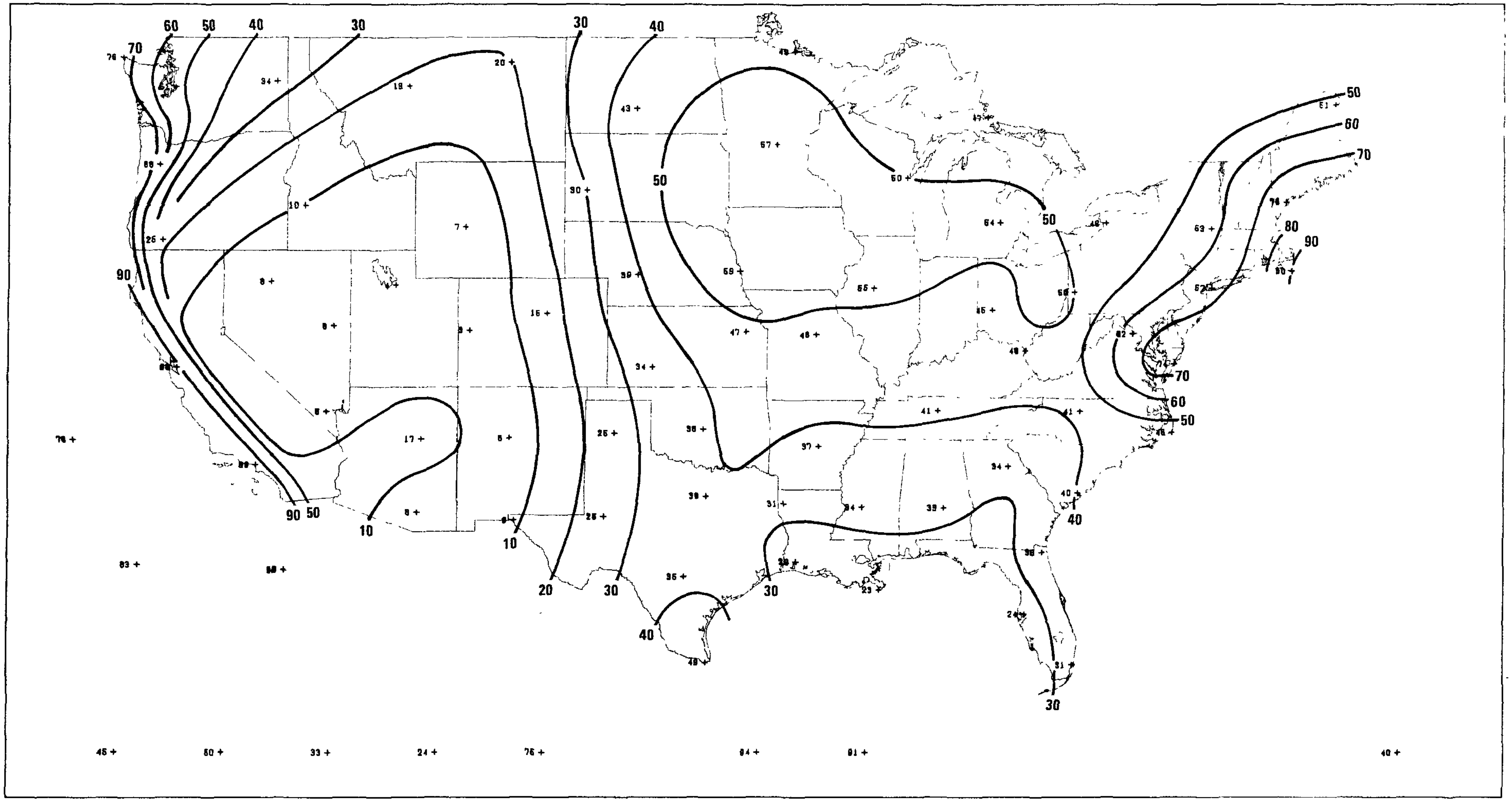

Figure 14. Percentage of summer 2315 GMT soundings with a surface-based or elevated inversion below 3000 m. See Figure 2 to identify peripheral stations.

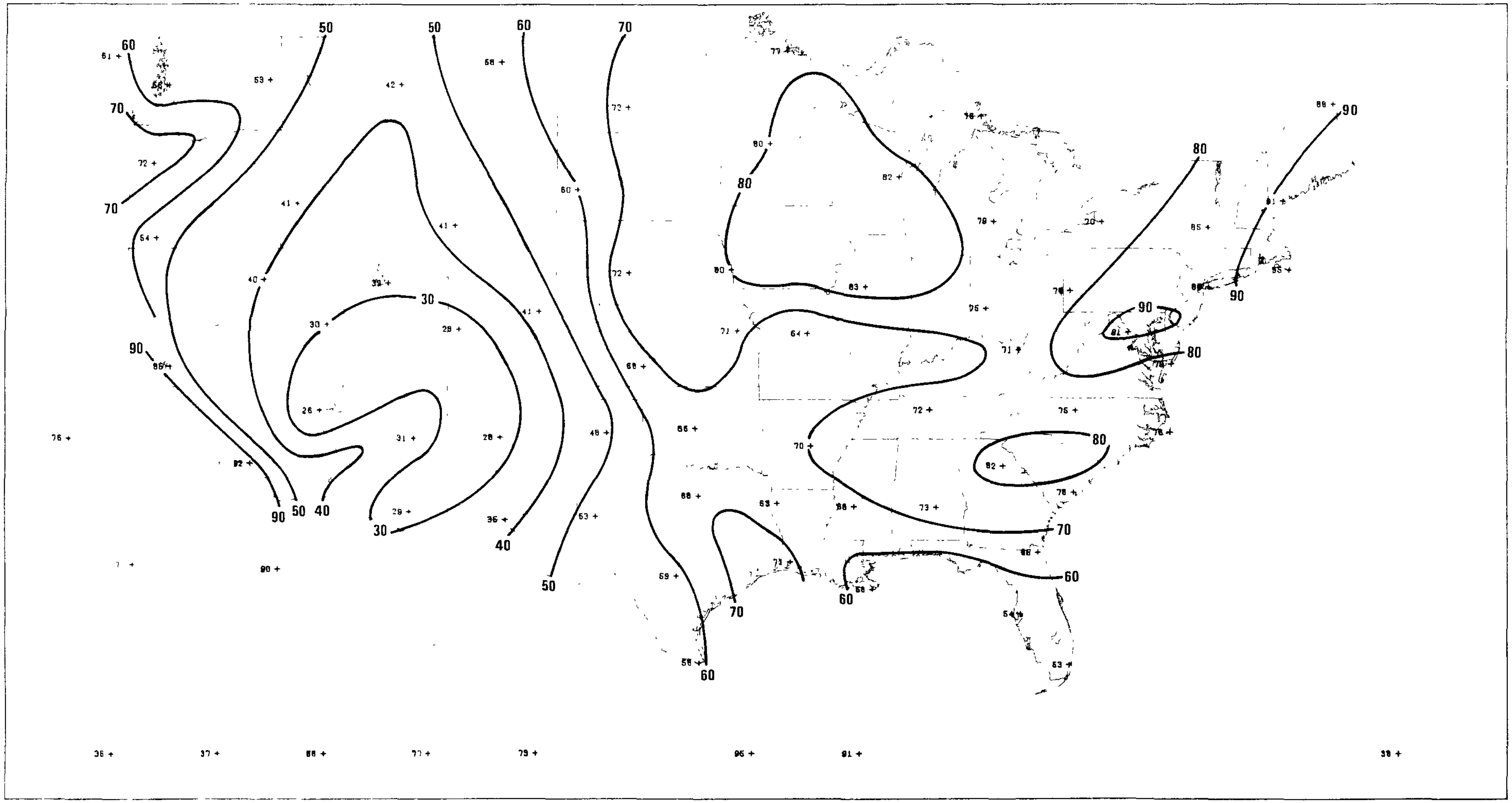

Figure 15  Percentage of autumn 2315 GMT soundings with a surface-based or elevated inversion below 3000 m  See Figure 2 to identify peripheral stations.

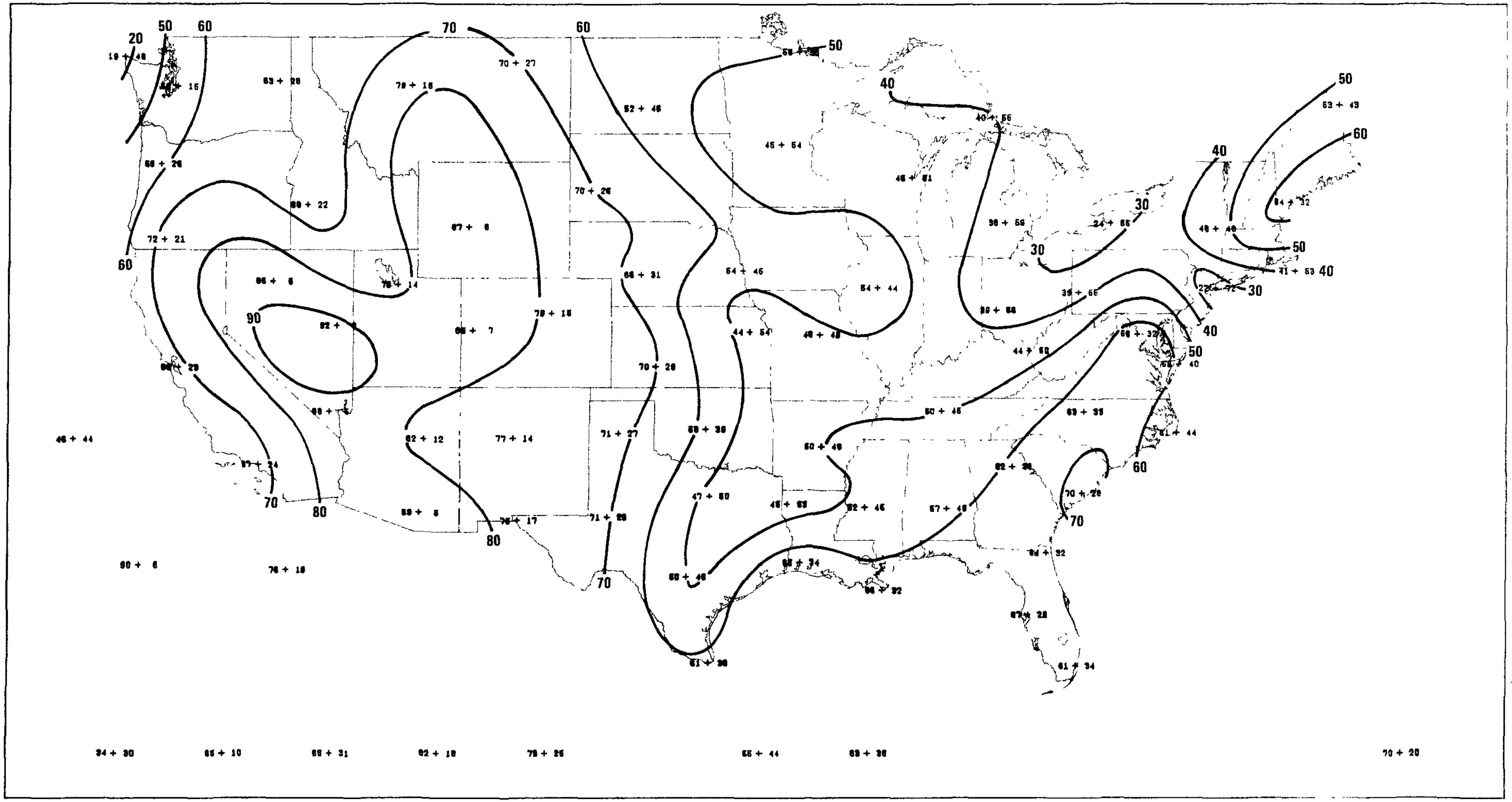


Figure 16. Percentage of winter 1115 GMT soundings with a surface-based inversion. Elevated inversion frequency is at right. See Figure 2 to identify peripheral stations.

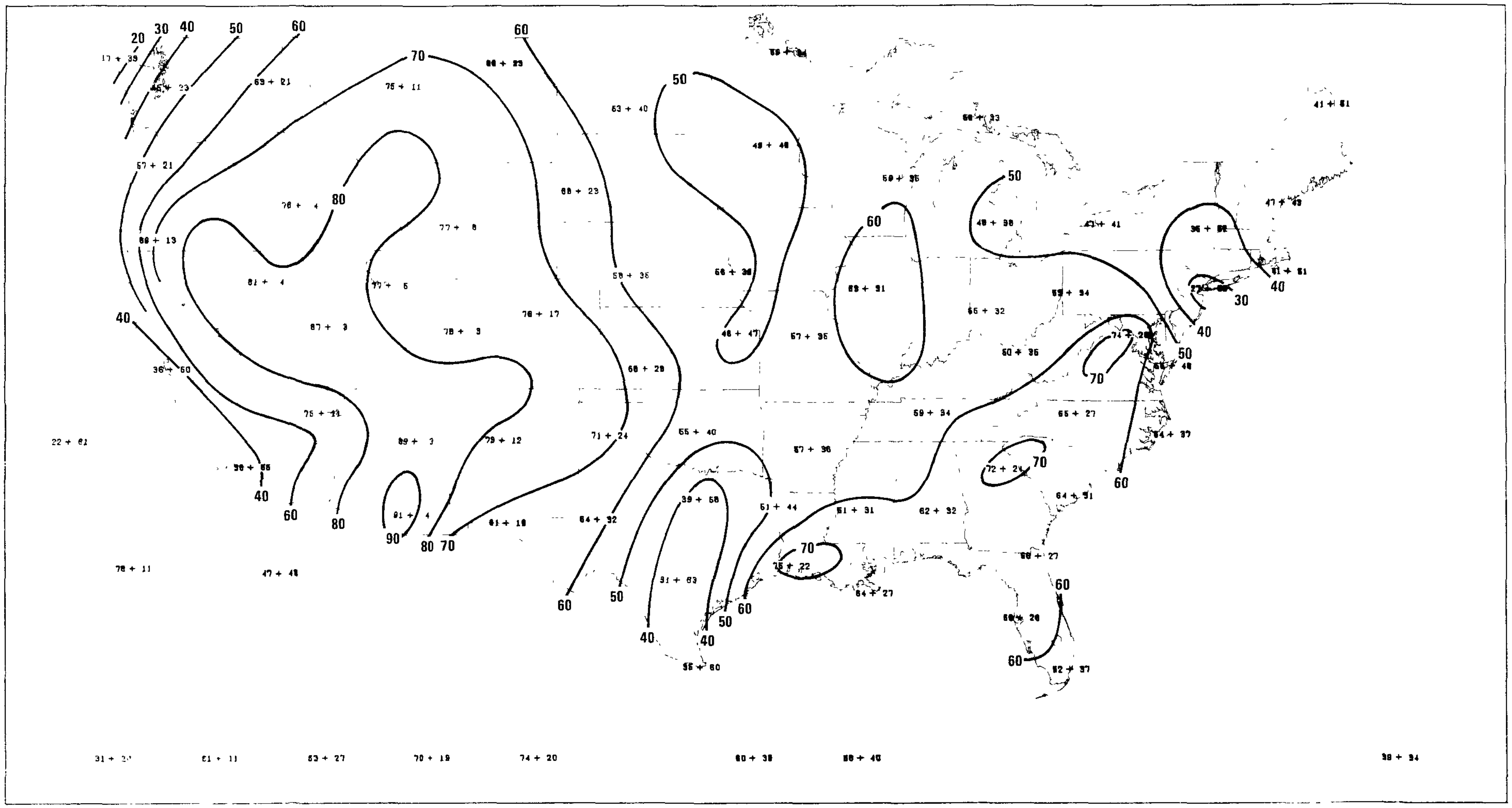

Figure 17 Percentage of spring 1115 GMT soundings with a surface-based inversion. Elevated inversion frequency is at right. See Figure 2 to identify peripheral stations.

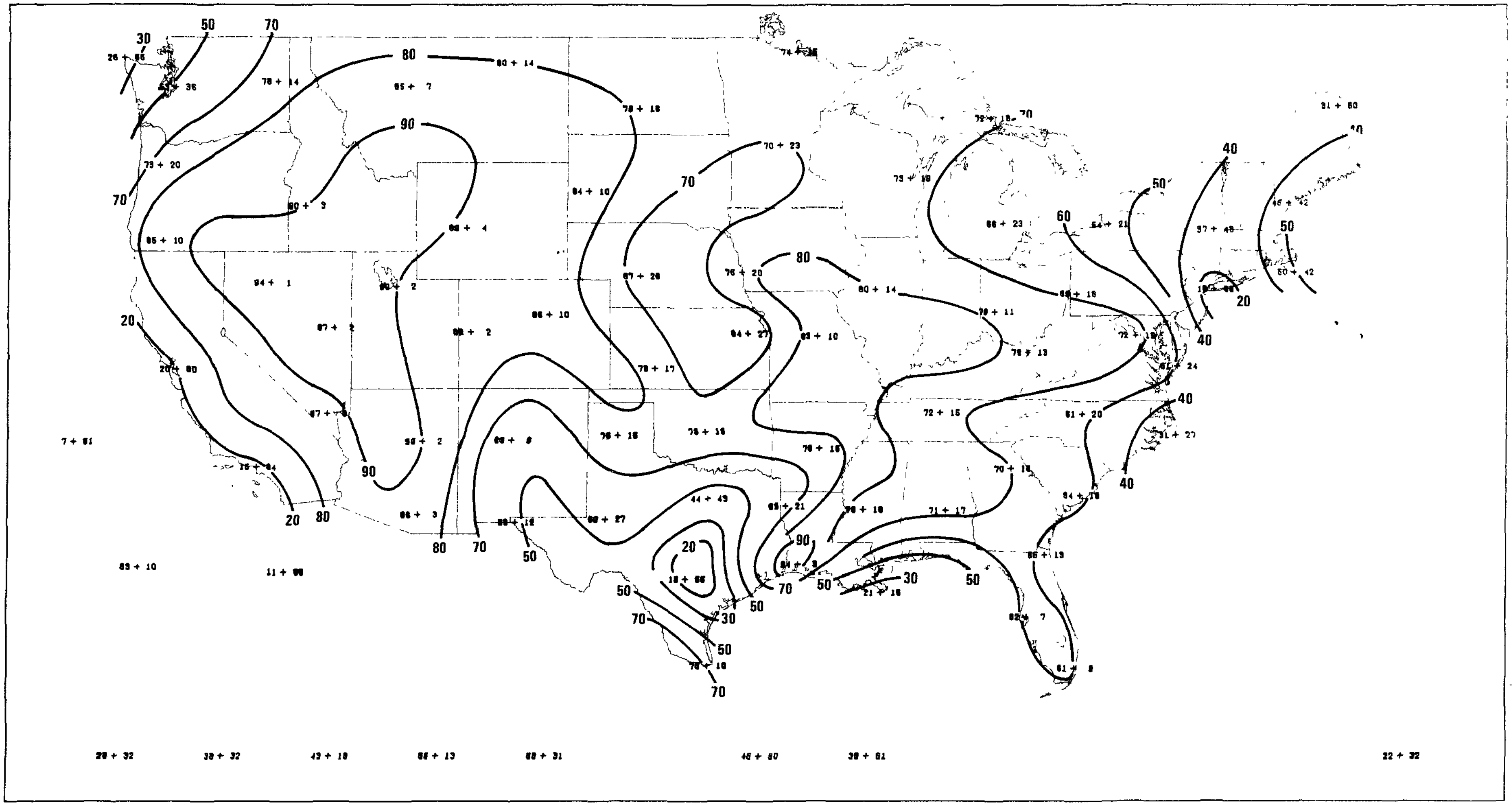

Figure 18. Percentage of summer 1115 GMT soundings with a surface-based inversion. Elevated inversion frequency is at right. See Figure 2 to identify peripheral stations.

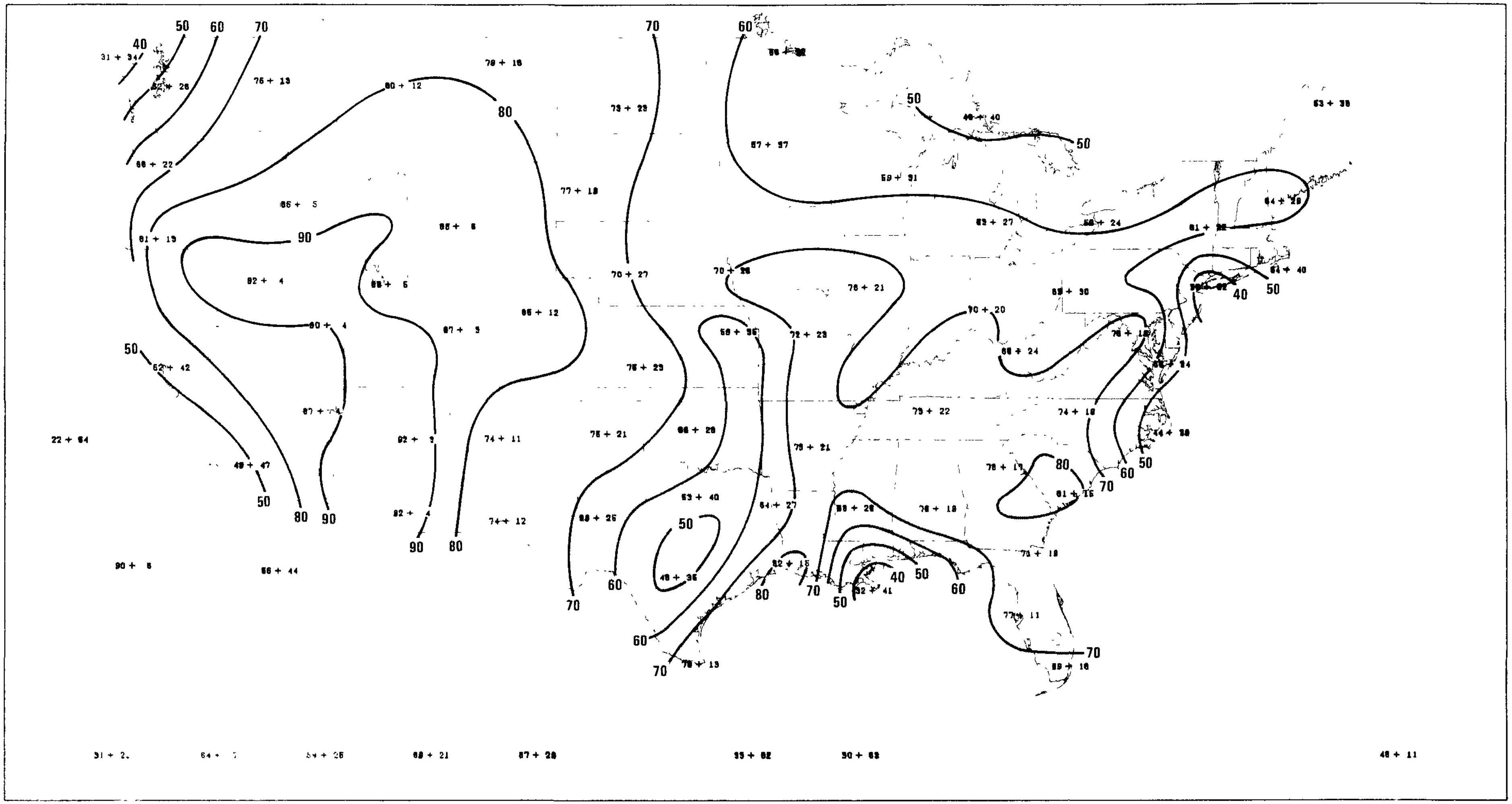

Figure 19. Percentage of autumn 1115 GMT soundings with a surface-based inversion. Elevated inversion frequency is at right
See Figure 2 to identify peripheral stations

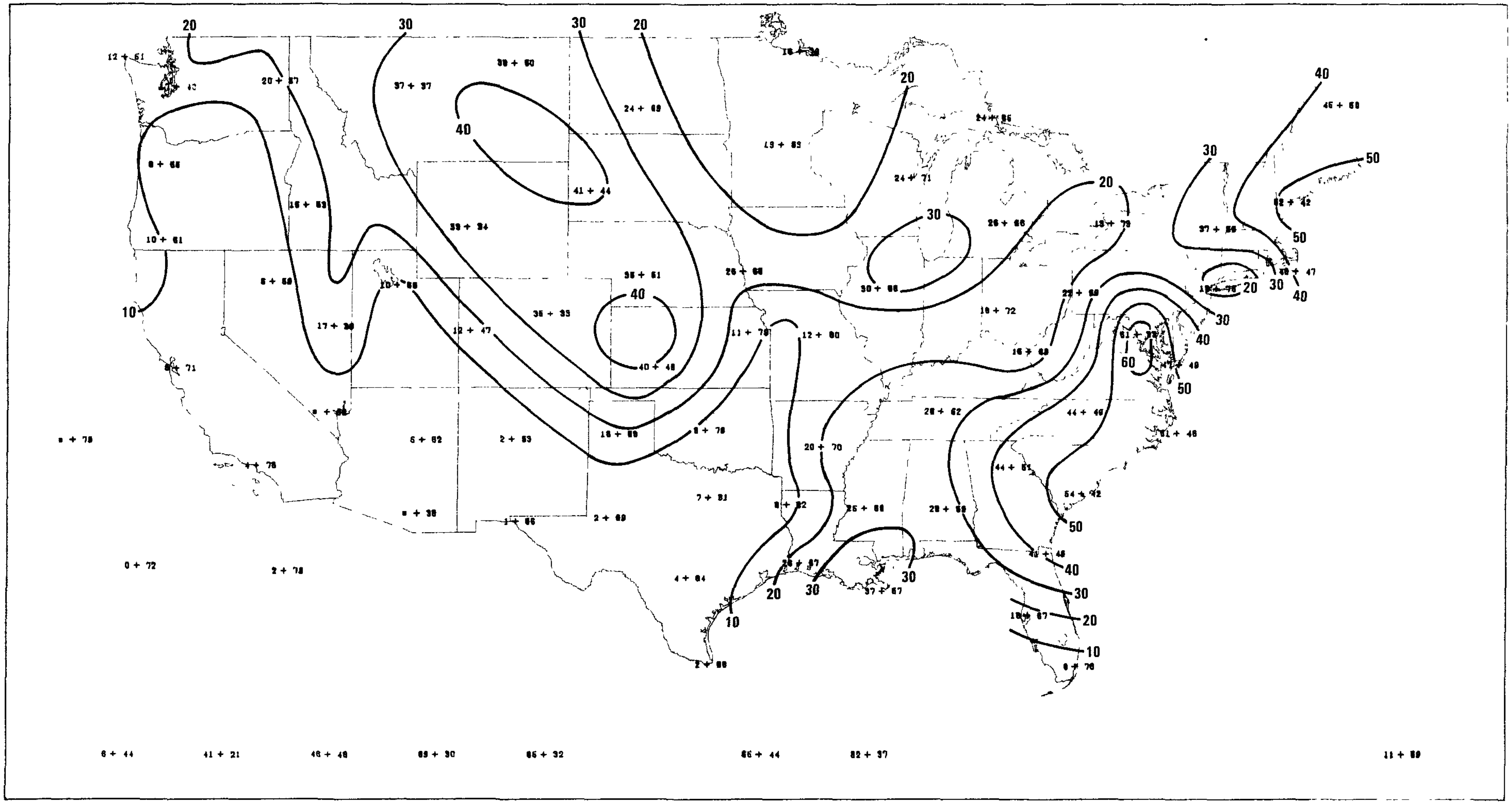

Figure 20. Percentage of winter 2315 GMT soundings with a surface-based inversion. Elevated inversion frequency is at right
See Figure 2 to identify peripheral stations.

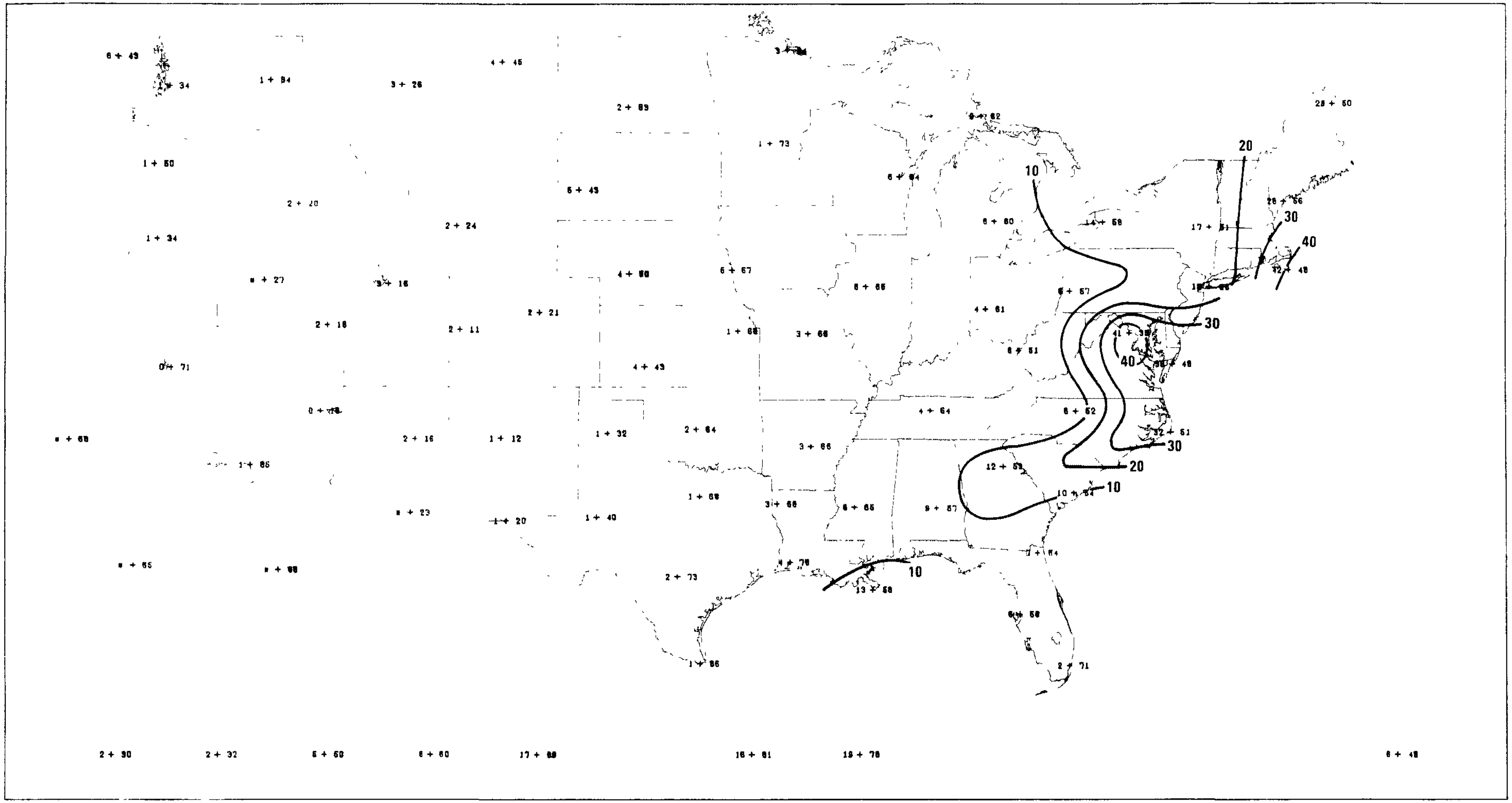


Figure 21 Percentage of spring 2315 GMT soundings with a surface-based inversion. Elevated inversion frequency is at right. See Figure 2 to identify peripheral stations.

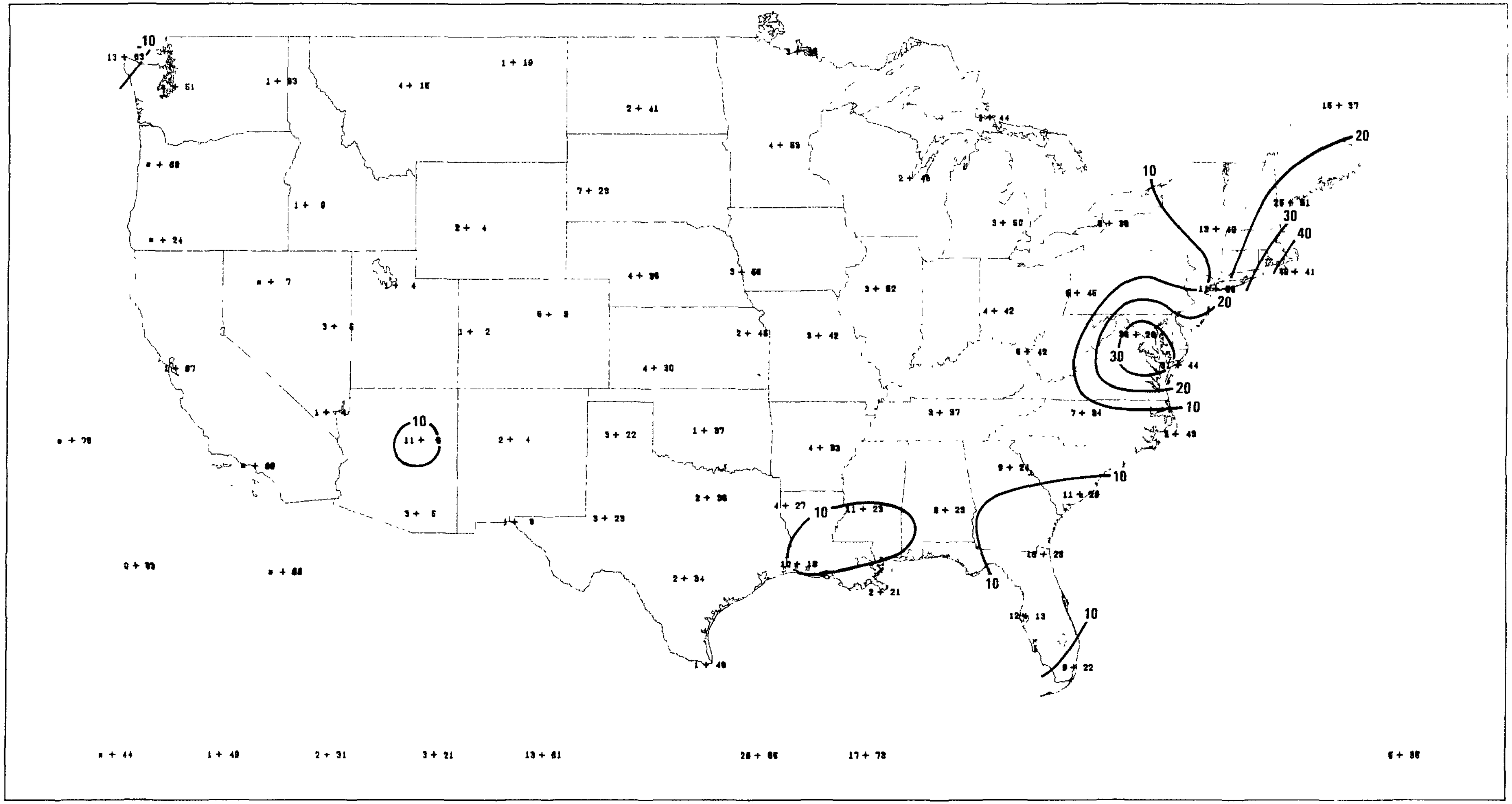


Figure 22. Percentage of summer 2315 GMT soundings with a surface-based inversion. Elevated inversion frequency is at right. See Figure 2 to identify peripheral stations.

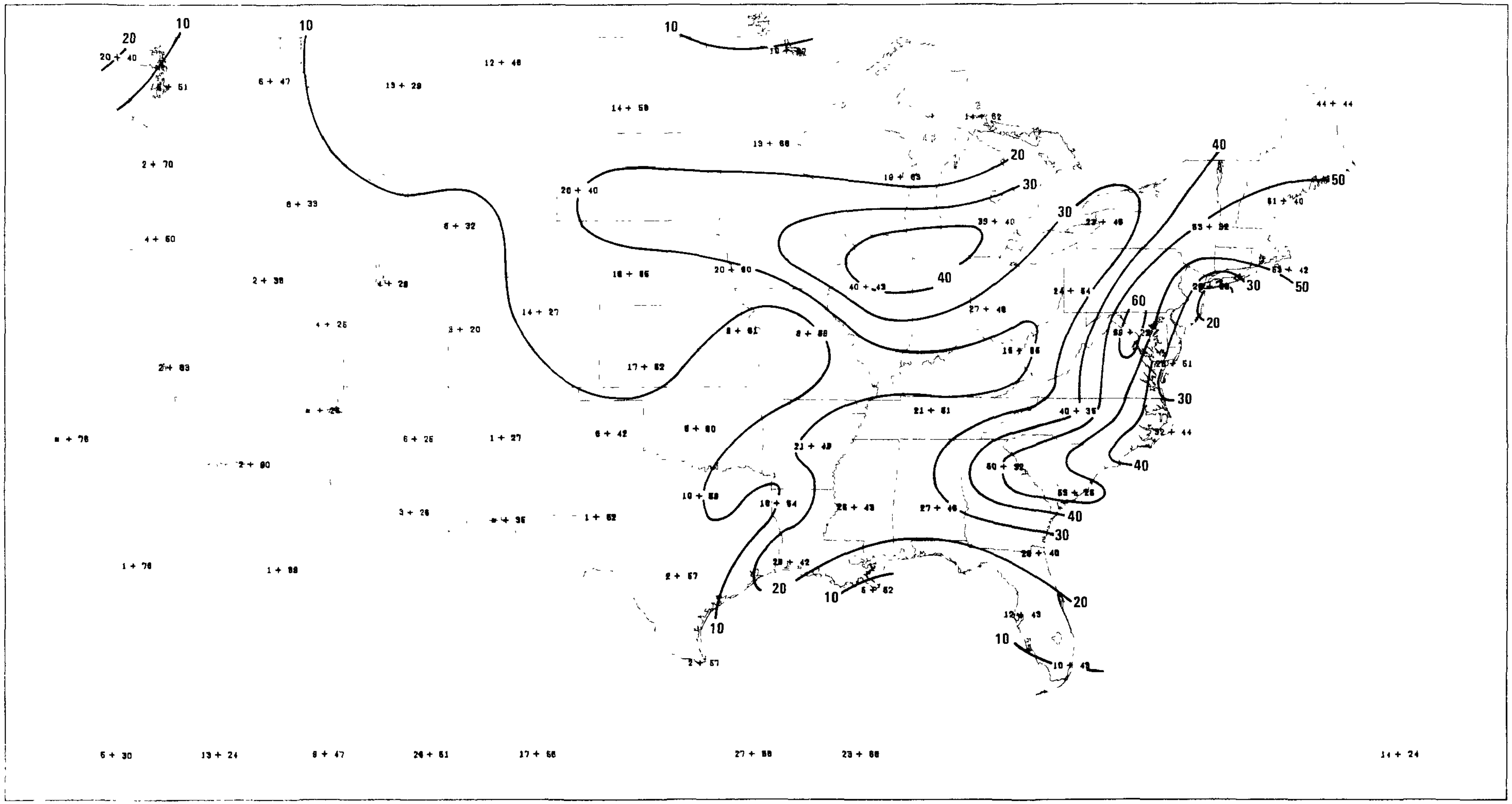

Figure 23. Percentage of autumn 2315 GMT soundings with a surface-based inversion. Elevated inversion frequency is at right.
See Figure 2 to identify peripheral stations.

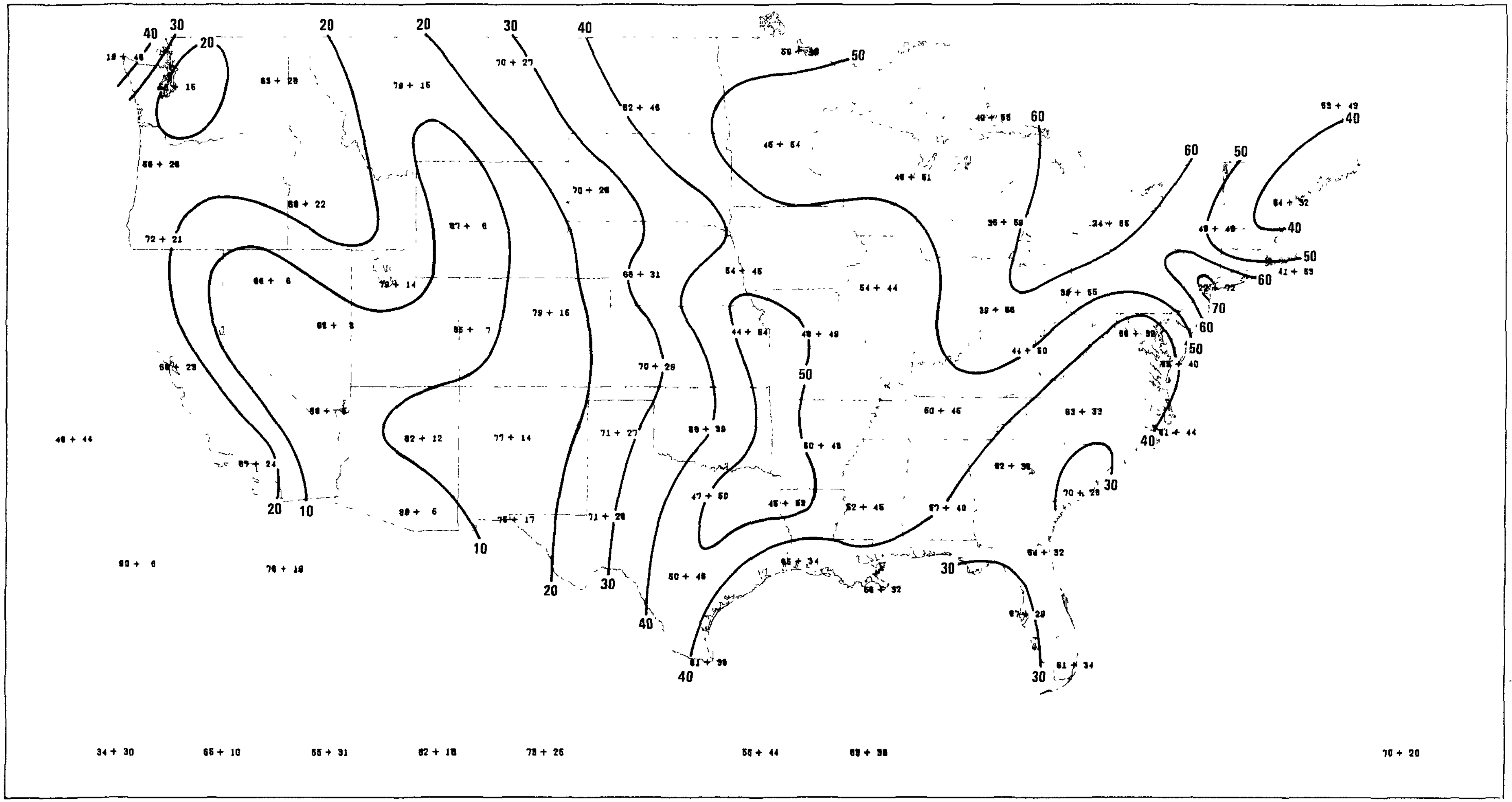

Figure 24. Percentage of winter 1115 GMT soundings with an elevated inversion below 3000 m AGL. Surface-based inversion frequency is at left. See Figure 2 to identify peripheral stations.

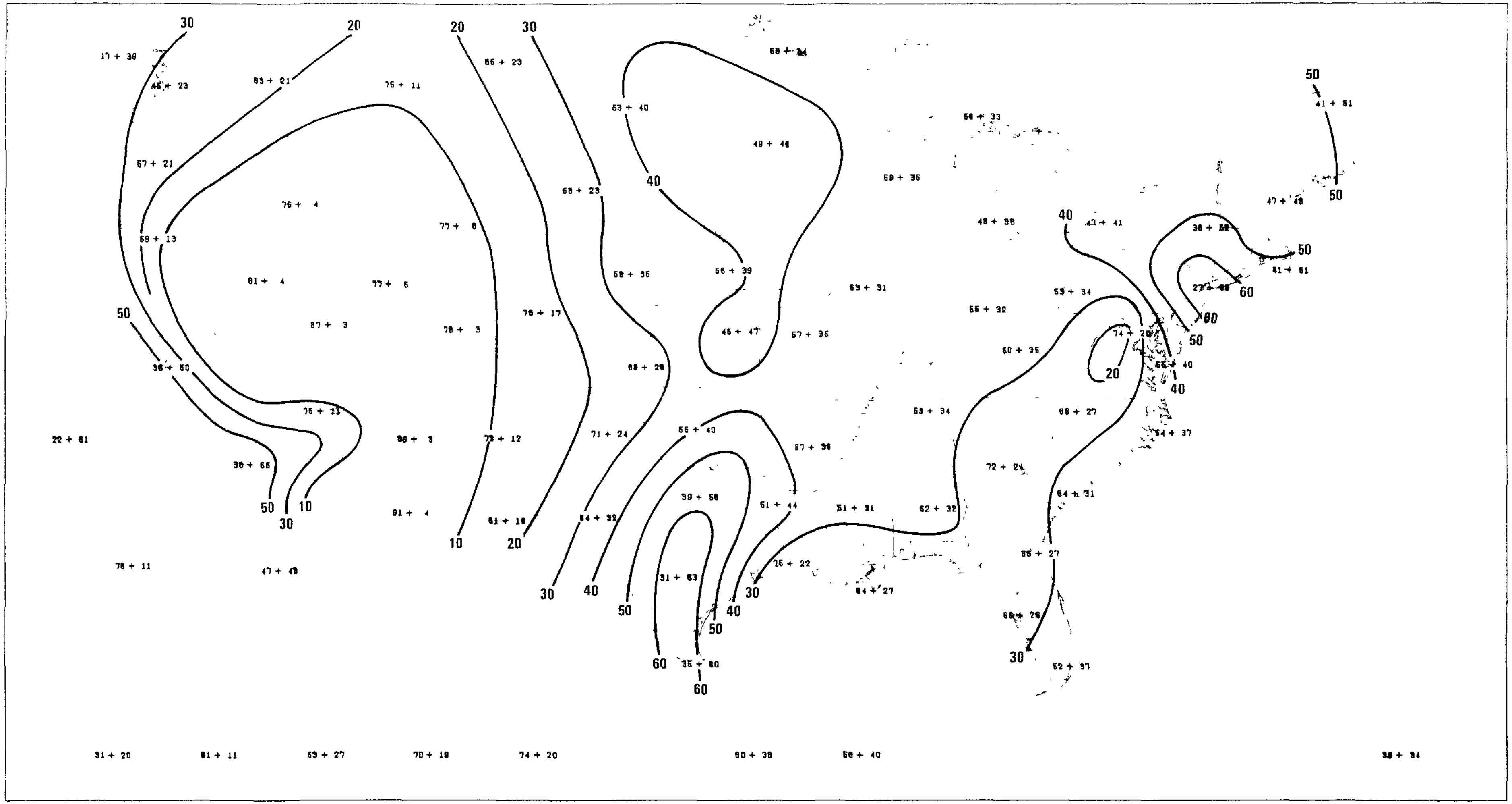

Figure 25 Percentage of spring 1115 GMT soundings with an elevated inversion below 3000 m AGL Surface-based inversion frequency is at left. See Figure 2 to identify peripheral stations

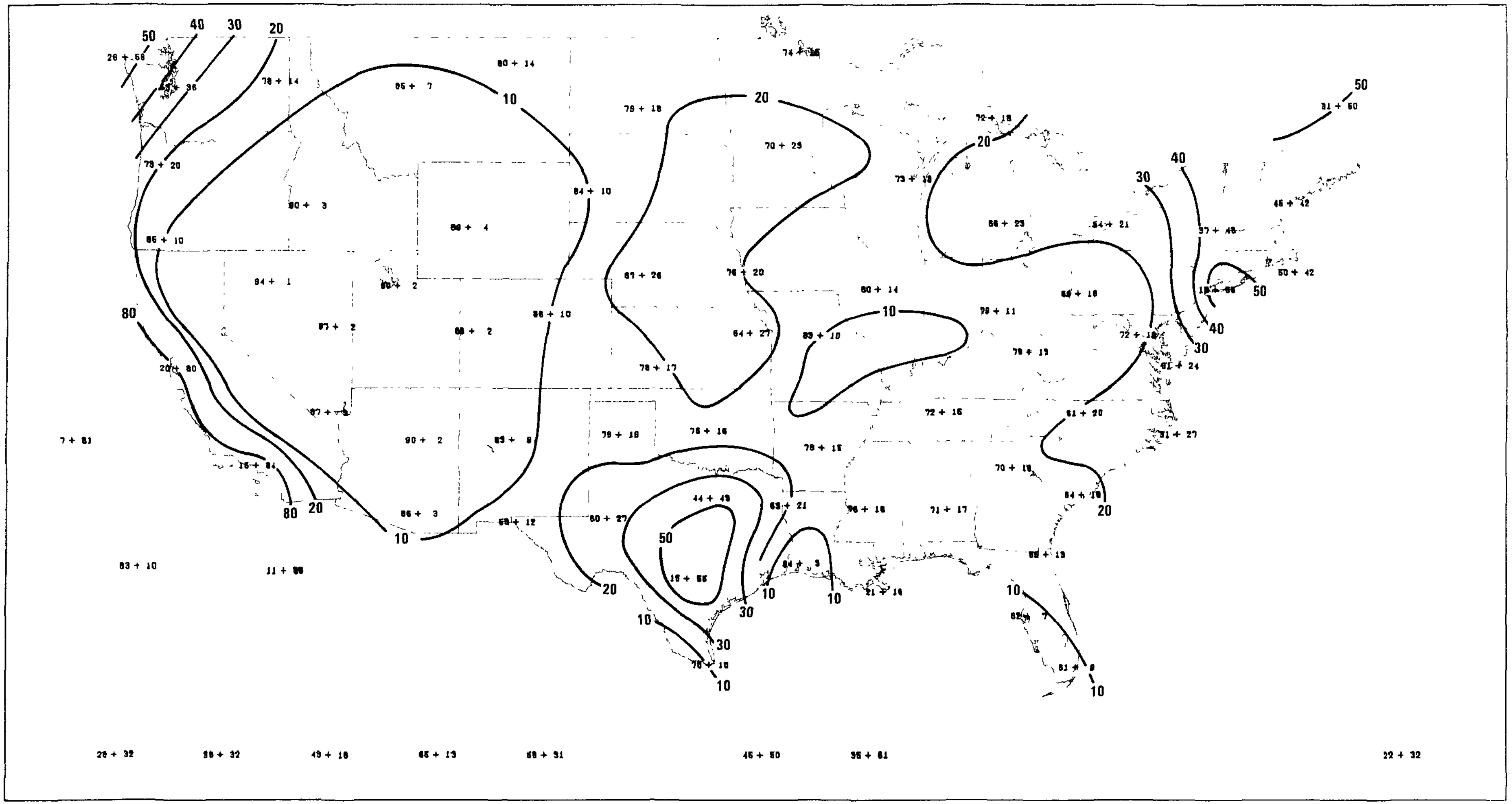

Figure 26. Percentage of summer 1115 GMT soundings with an elevated inversion below 3000 m AGL. Surface-based inversion frequency is at left. See Figure 2 to identify peripheral stations.

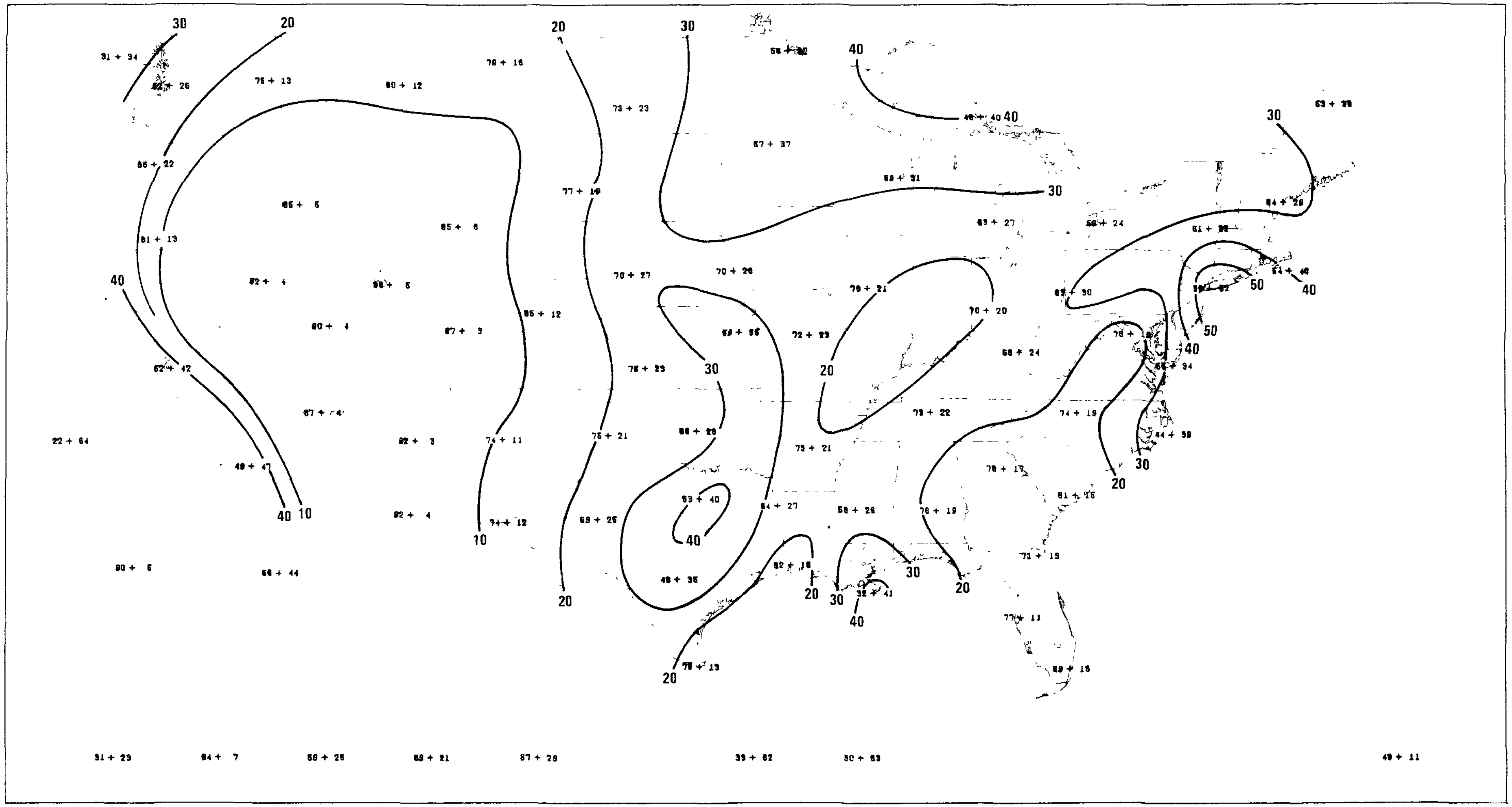

Figure 27 Percentage of autumn 1115 GMT soundings with an elevated inversion below 3000 m AGL. Surface-based inversion frequency is at left. See Figure 2 to identify peripheral stations

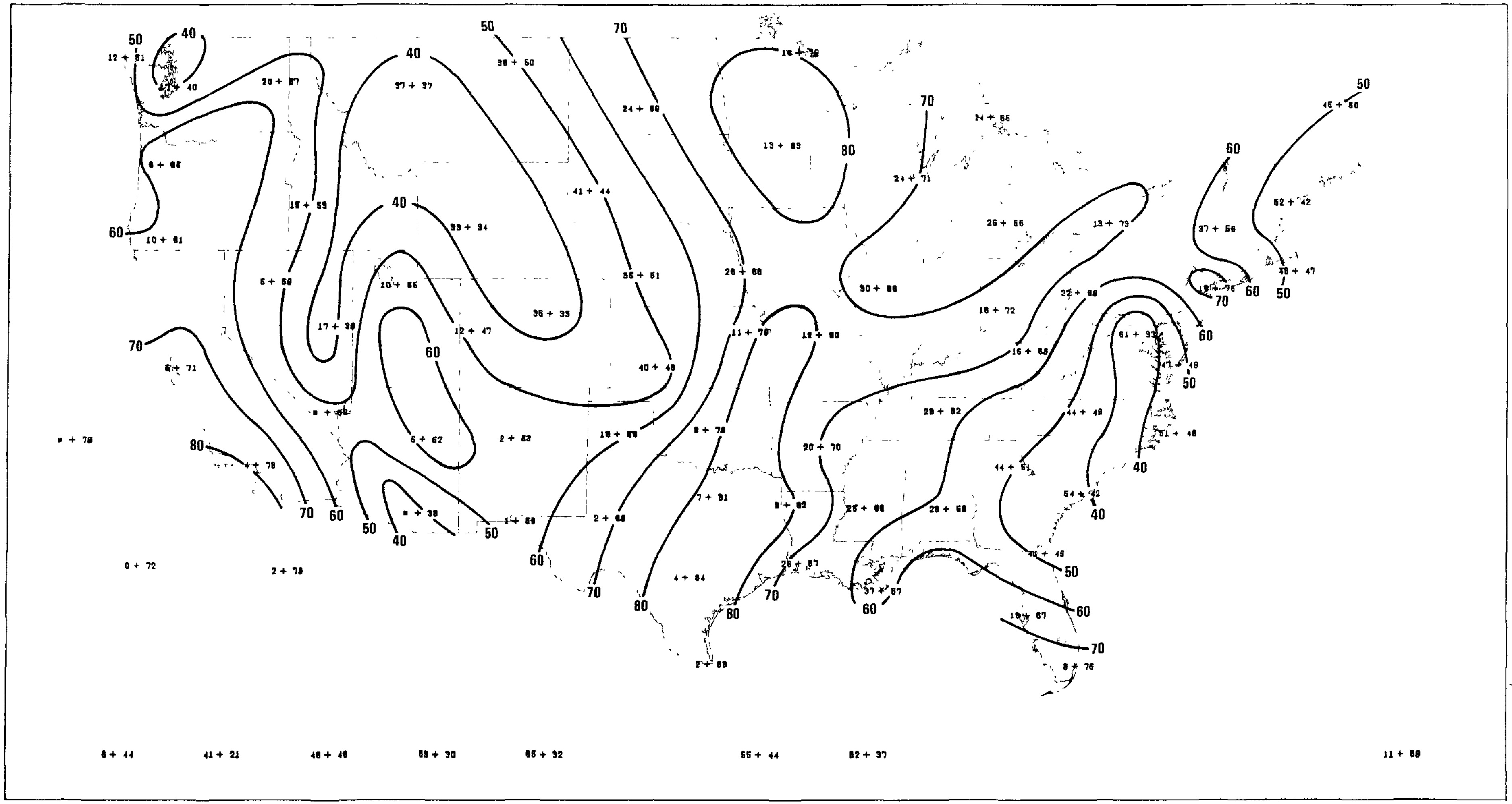

Figure 28. Percentage of winter 2315 GMT soundings with an elevated inversion below 3000 m AGL. Surface-based inversion frequency is at left.
See Figure 2 to identify peripheral stations.

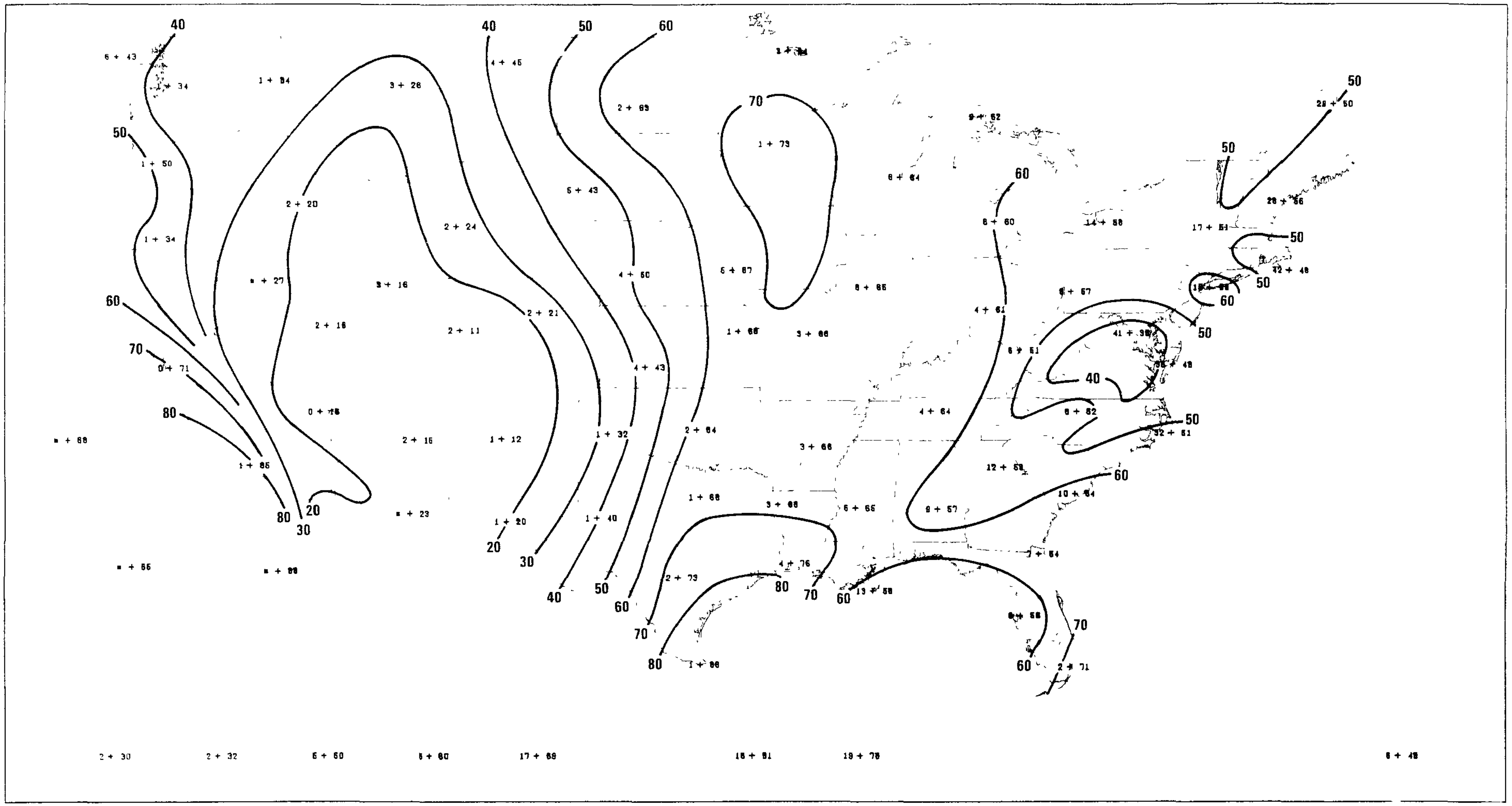

Figure 29 Percentage of spring 2315 GMT soundings with an elevated inversion below 3000 m AGL. Surface-based inversion frequency is at left. See Figure 2 to identify peripheral stations.

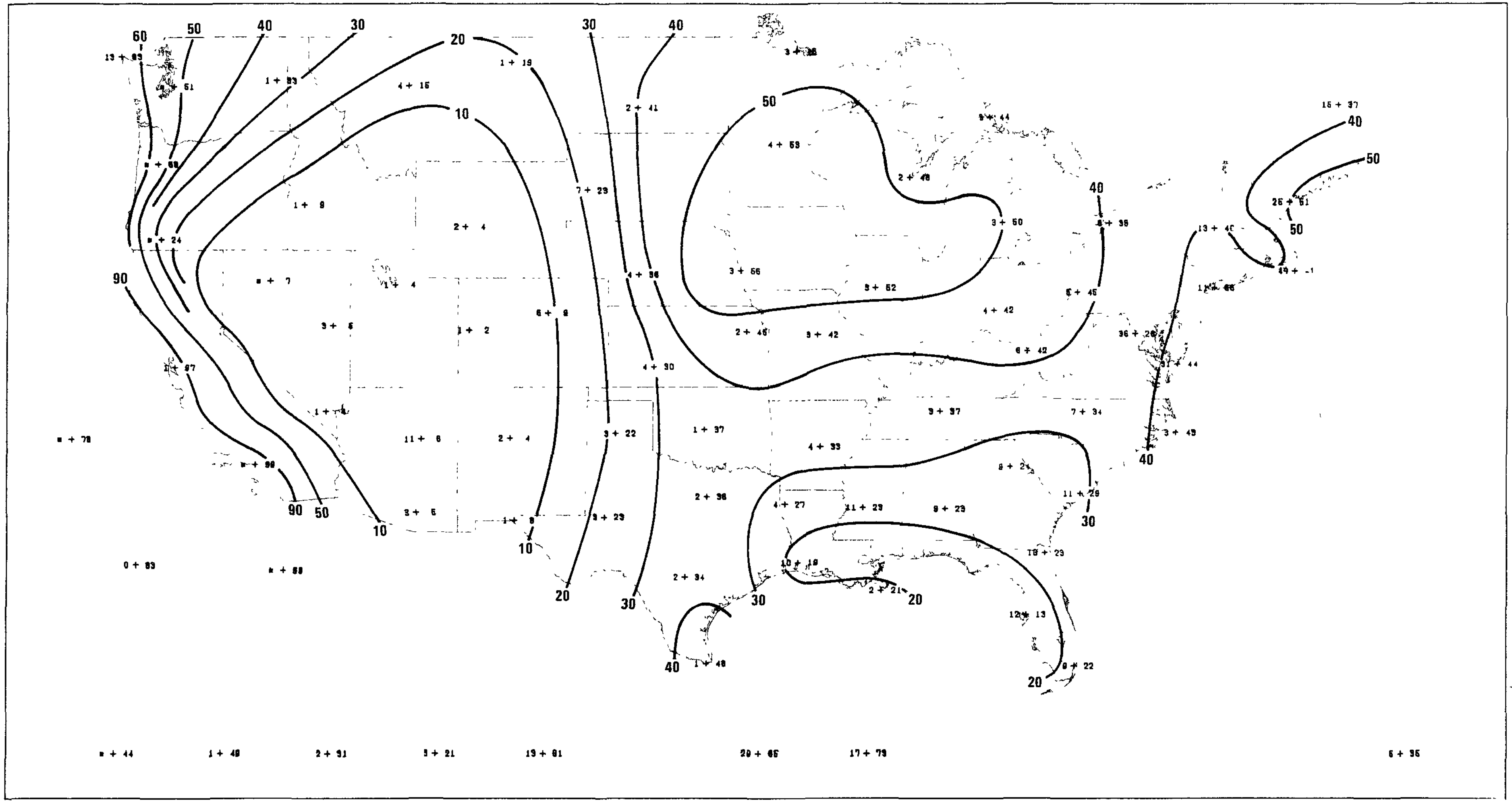

Figure 30. Percentage of summer 2315 GMT soundings with an elevated inversion below 3000 m AGL Surface-based inversion frequency is at left. See Figure 2 to identify peripheral stations.

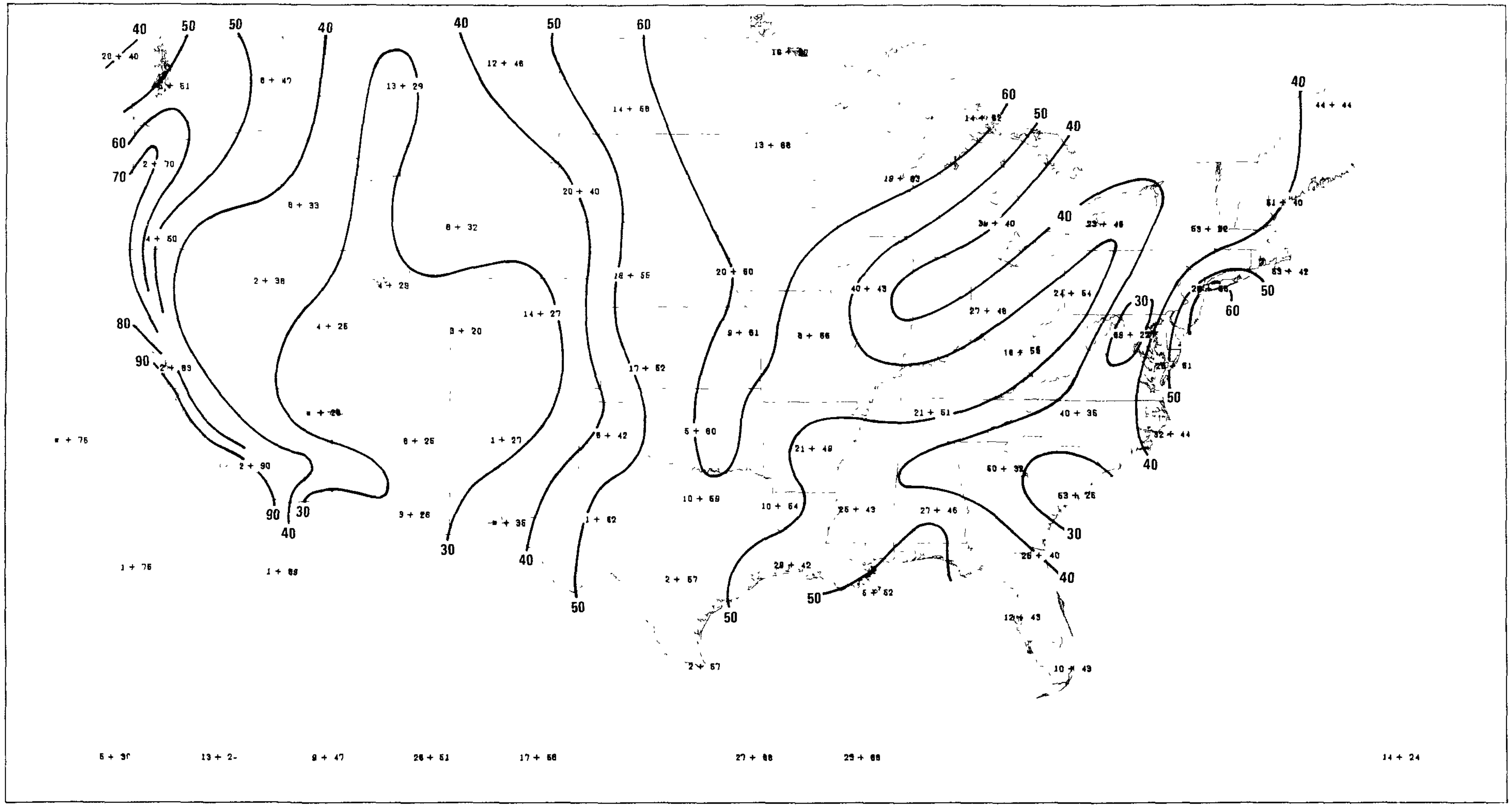

Figure 31. Percentage of autumn 2315 GMT soundings with an elevated inversion below 3000 m AGL. Surface-based inversion frequency is at left. See Figure 2 to identify peripheral stations

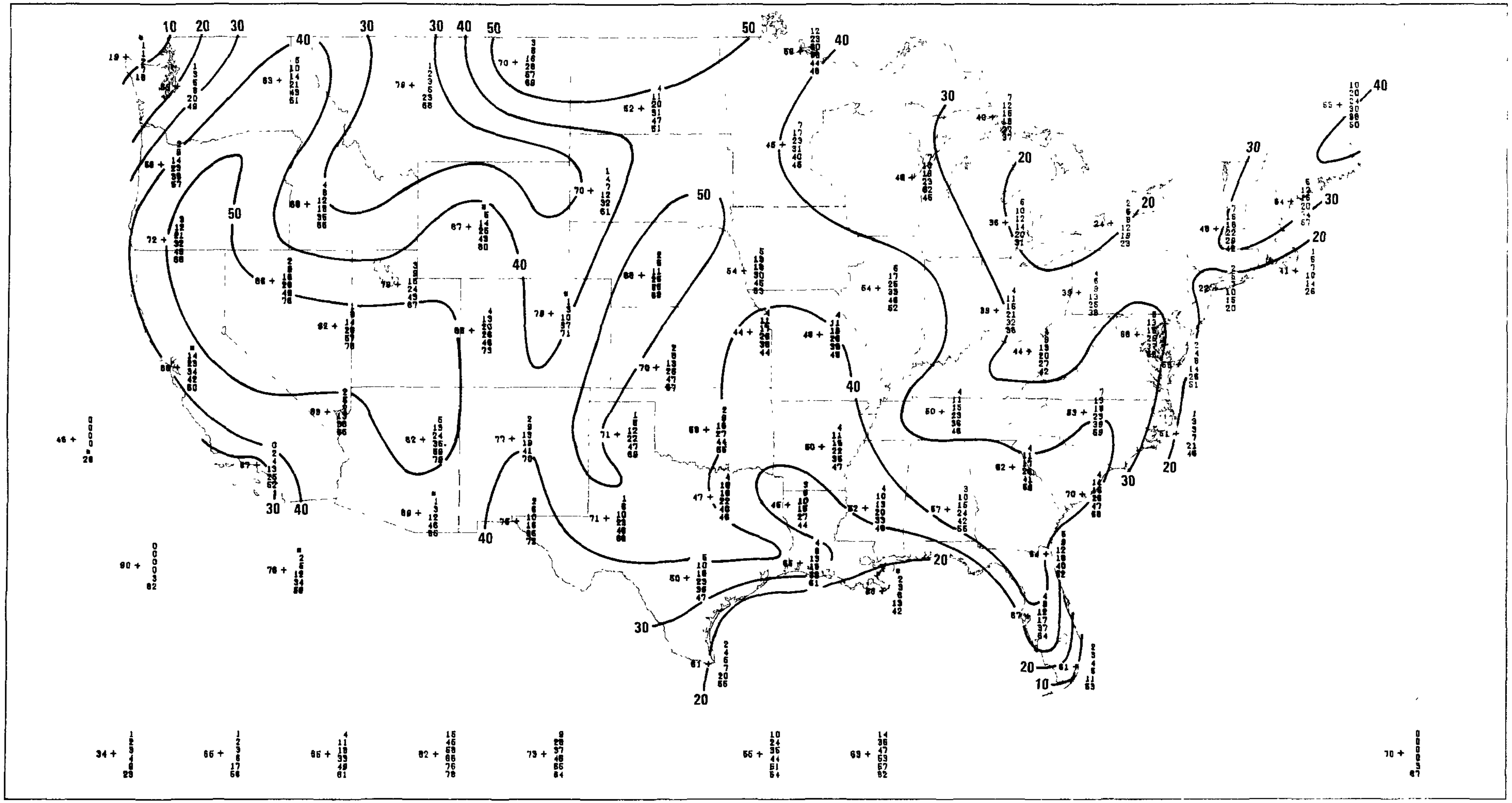

Figure 32. Percentage of winter 1115 GMT soundings with a surface-based inversion (left) whose top exceeds 100, 250, 500, 750, 1000, or 1500 m AGL (right, bottom to top). Isopleths show the percentage with tops that exceed 250 m. See Figure 2 to identify peripheral stations.

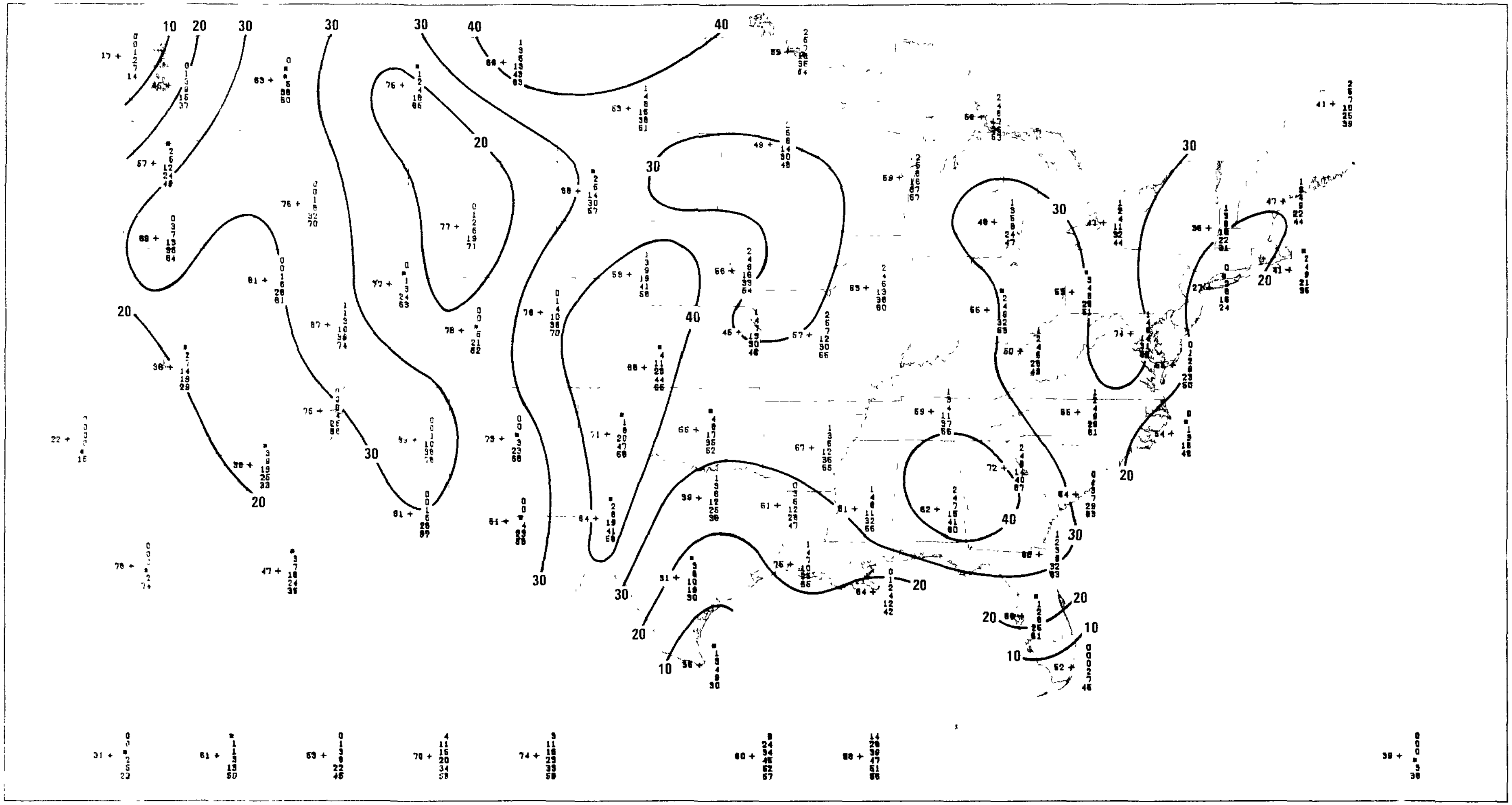

Figure 33 Percentage of spring 1115 GMT soundings with a surface-based inversion (left) whose top exceeds 100, 250, 500, 750, 1000, or 1500 m AGL (right, bottom to top) Isopleths show the percentage with tops that exceed 250 m. See Figure 2 to identify peripheral stations

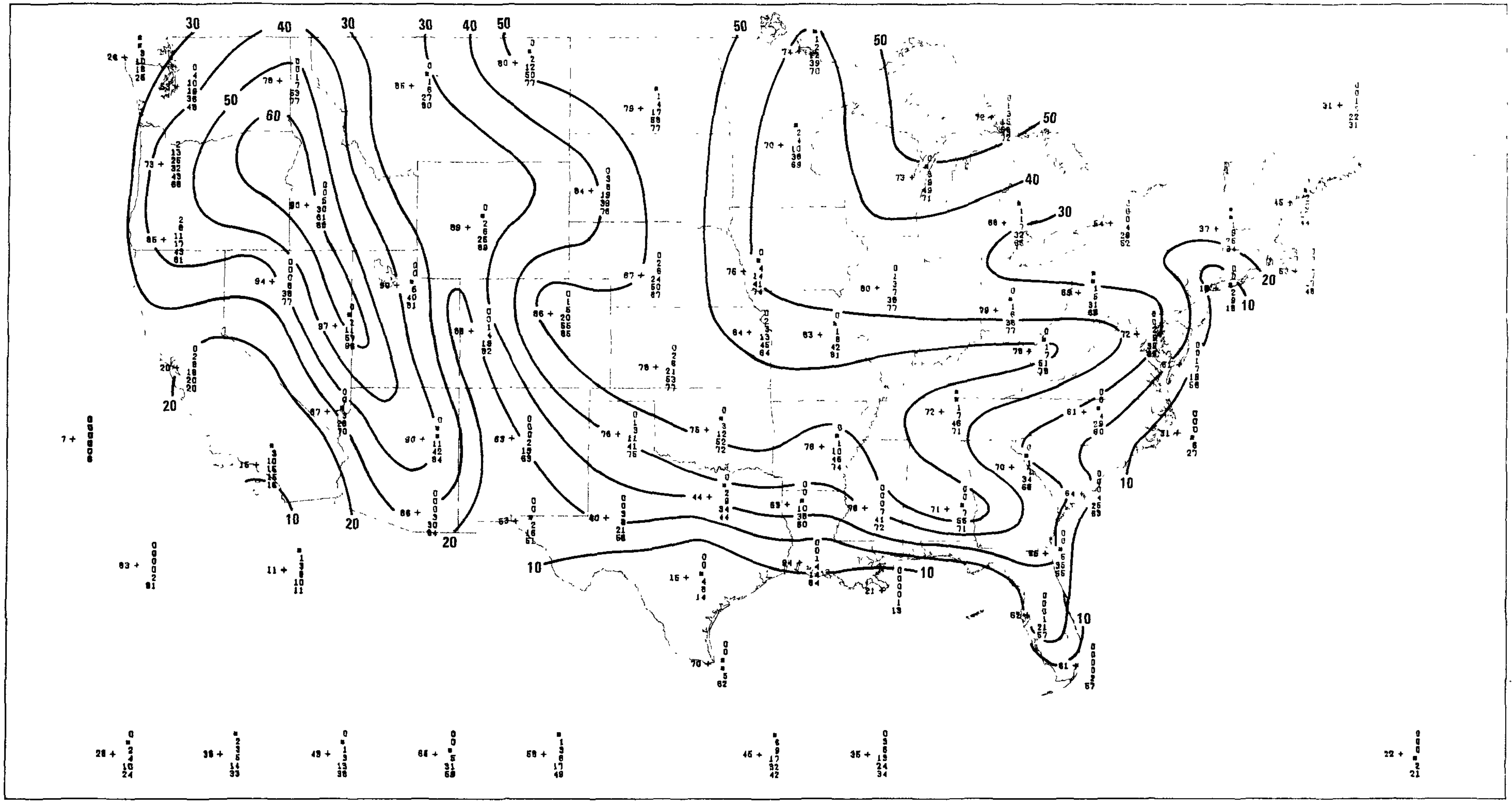

Figure 34. Percentage of summer 1115 GMT soundings with a surface-based inversion (left) whose top exceeds 100, 250, 500, 750, 1000, or 1500 m AGL (right, bottom to top). Isopleths show the percentage with tops that exceed 250 m. See Figure 2 to identify peripheral stations.

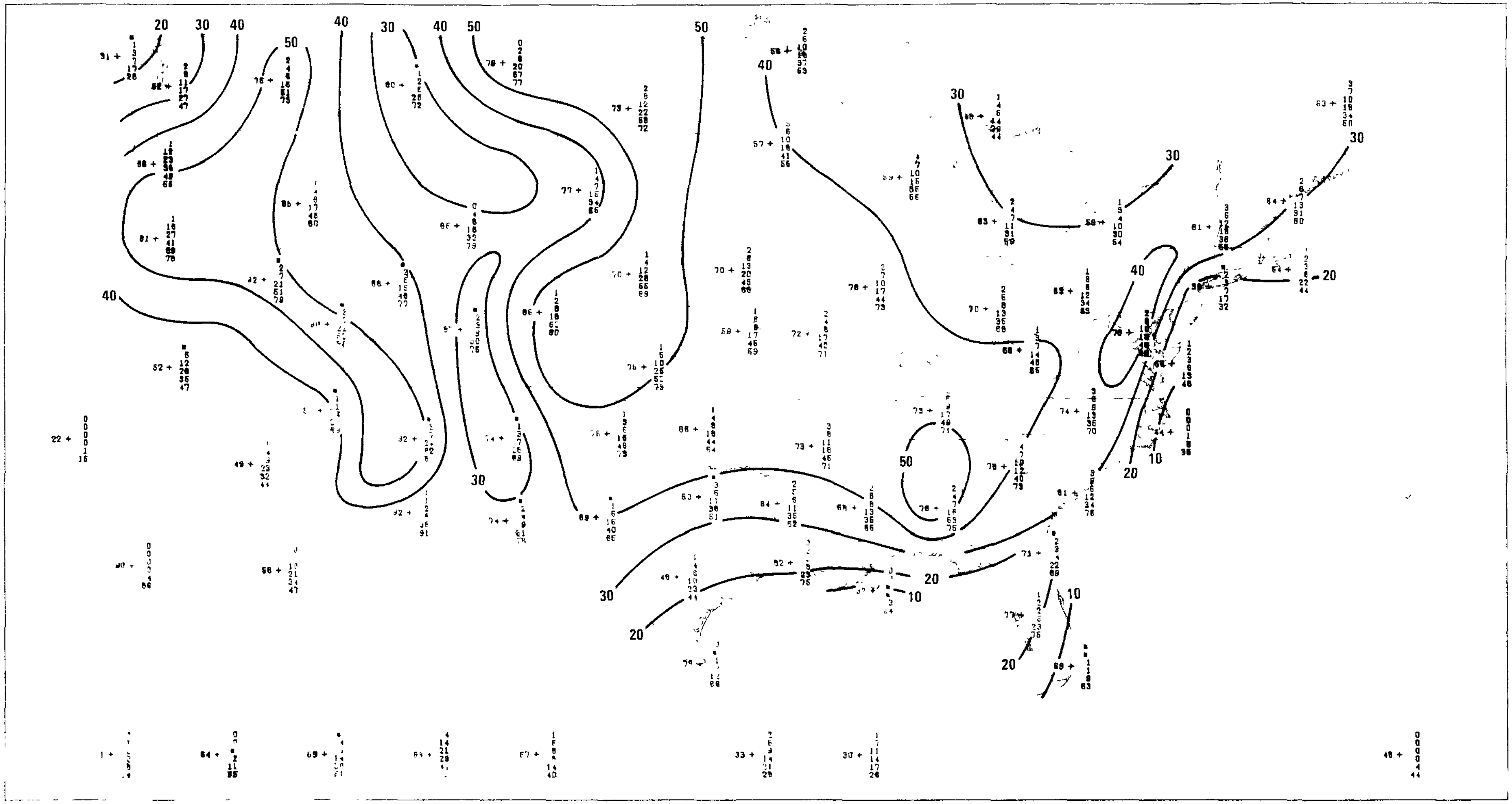

Figure 35  Percentage of autumn 1115 GMT soundings with a surface-based inversion (left) whose top exceeds 100, 250, 500, 750, 1000, or 1500 m AGL (right, bottom to top)  Isopleths show the percentage with tops that exceed 250 m  See Figure 2 to identify peripheral stations.

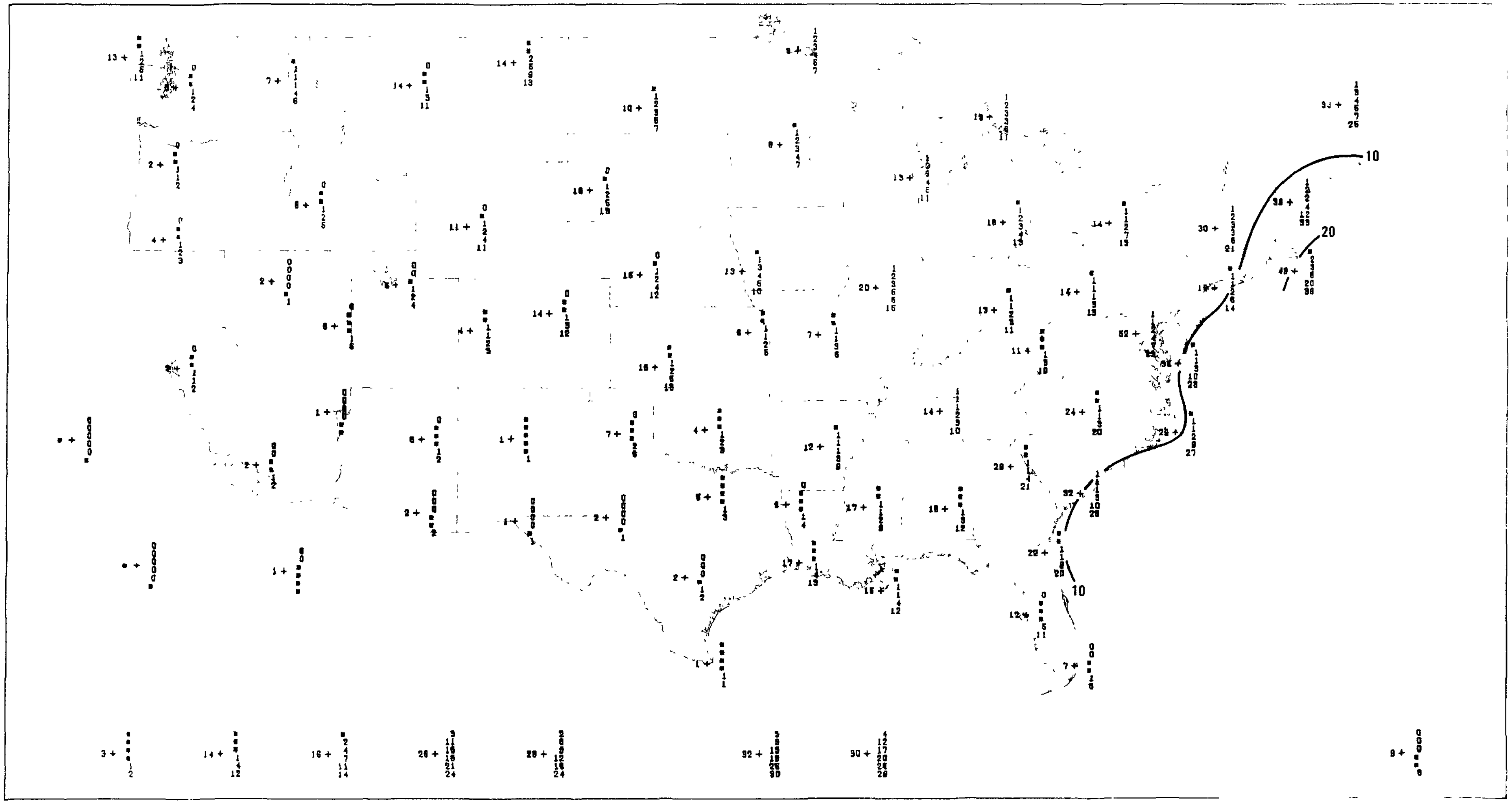


Figure 36 Percentage of all 2315 GMT soundings with a surface-based inversion (left) whose top exceeds 100, 250, 500, 750, 1000, or 1500 m AGL (right, bottom to top). Isopleths show the percentage with tops that exceed 250 m. See Figure 2 to identify peripheral stations

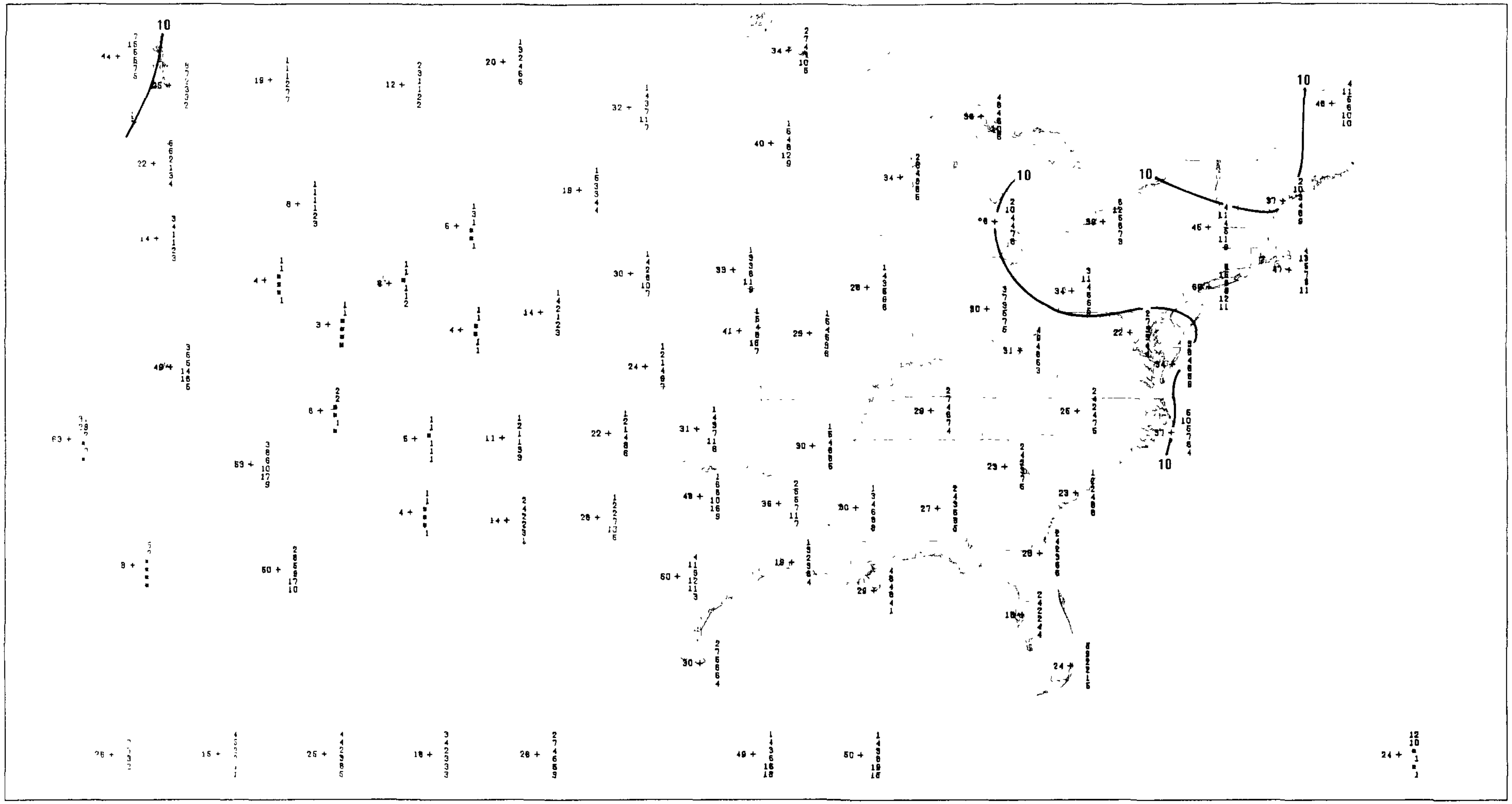

Figure 37 Percentage of all 1115 GMT soundings with an elevated inversion base in the range 1-3000 m AGL (left) and in smaller ranges 1-250, 251-500, 501-750, 751-1000, 1001-2000, or 2001-3000 m AGL (right, bottom to top). Isopleths show the percentage with bases between 1001-2000 m See Figure 2 to identify peripheral stations.

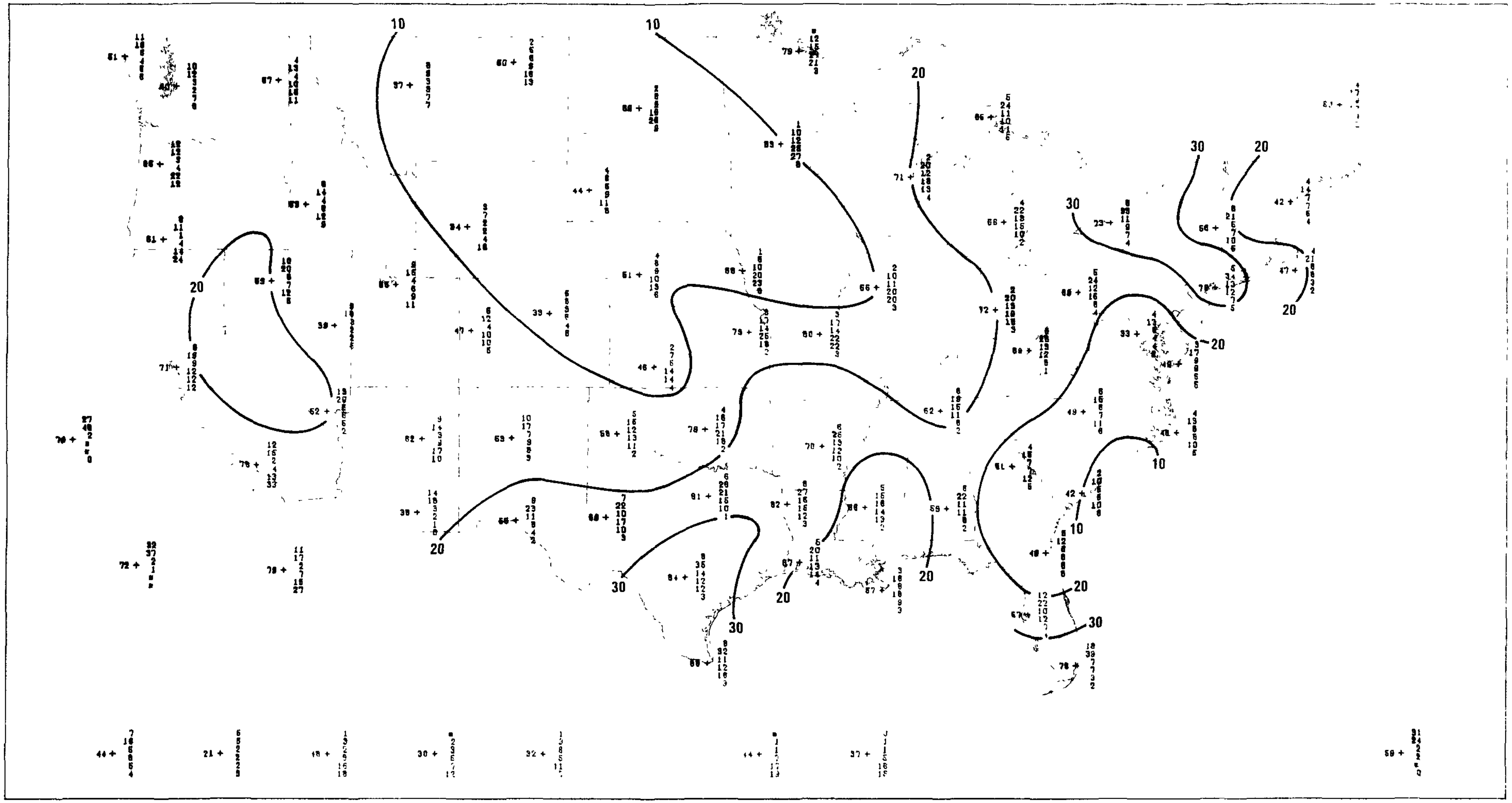

Figure 38  Percentage of winter 2315 GMT soundings with an elevated inversion base in the range 1-3000 m AGL (left) and in smaller ranges 1-250, 251-500, 501-750, 751-1000, 1001-2000, or 2001-3000 m AGL (right, bottom to top). Isopleths show the percentage with bases between 1001-2000 m. See Figure 2 to identify peripheral stations.

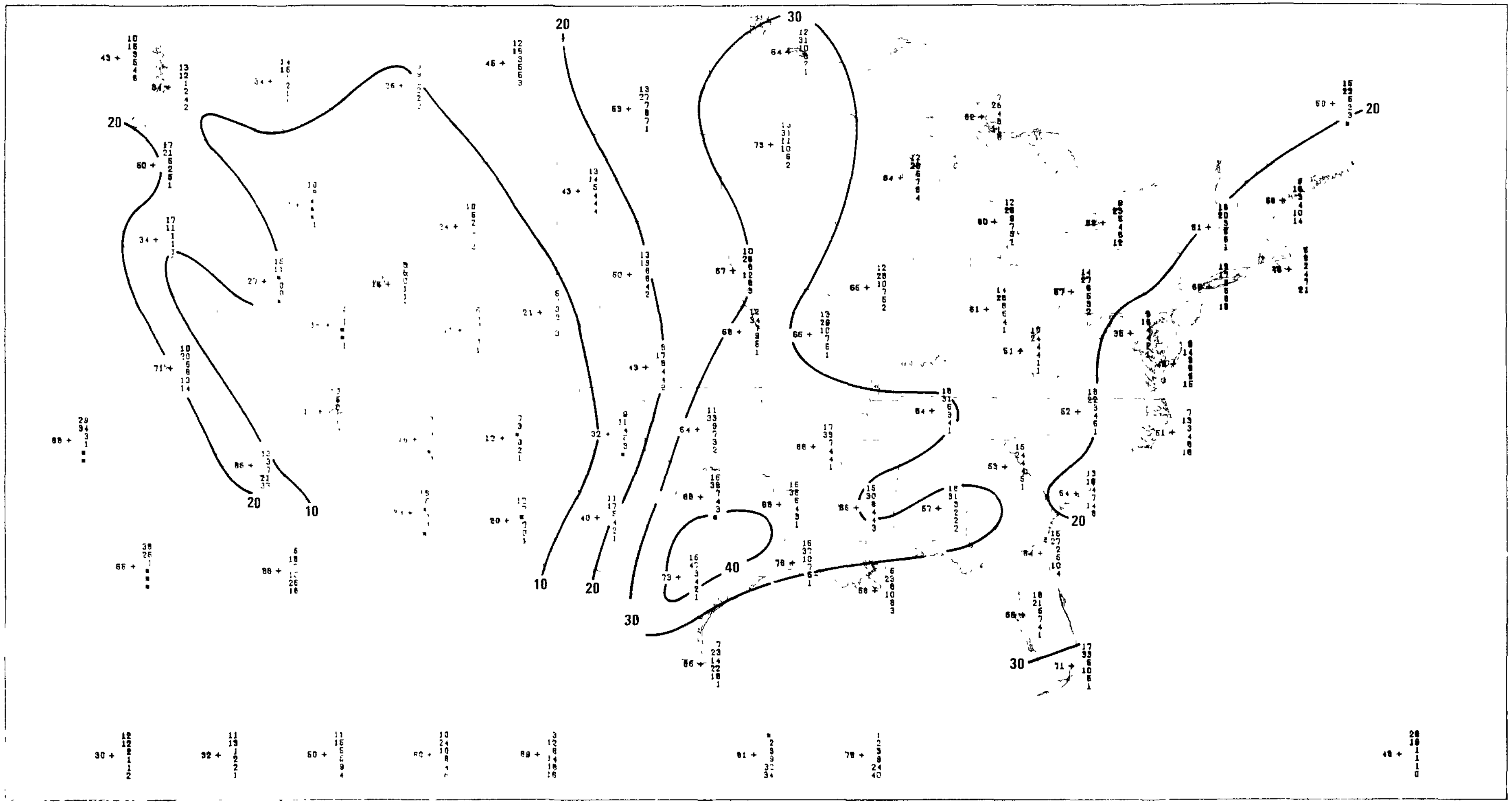


Figure 39 Percentage of spring 2315 GMT soundings with an elevated inversion base in the range 1-3000 m AGL (left) and in smaller ranges 1-250, 251-500, 501-750, 751-1000, 1001-2000, or 2001-3000 m AGL (right, bottom to top). Isopleths show the percentage with bases between 1001-2000 m See Figure 2 to identify peripheral stations

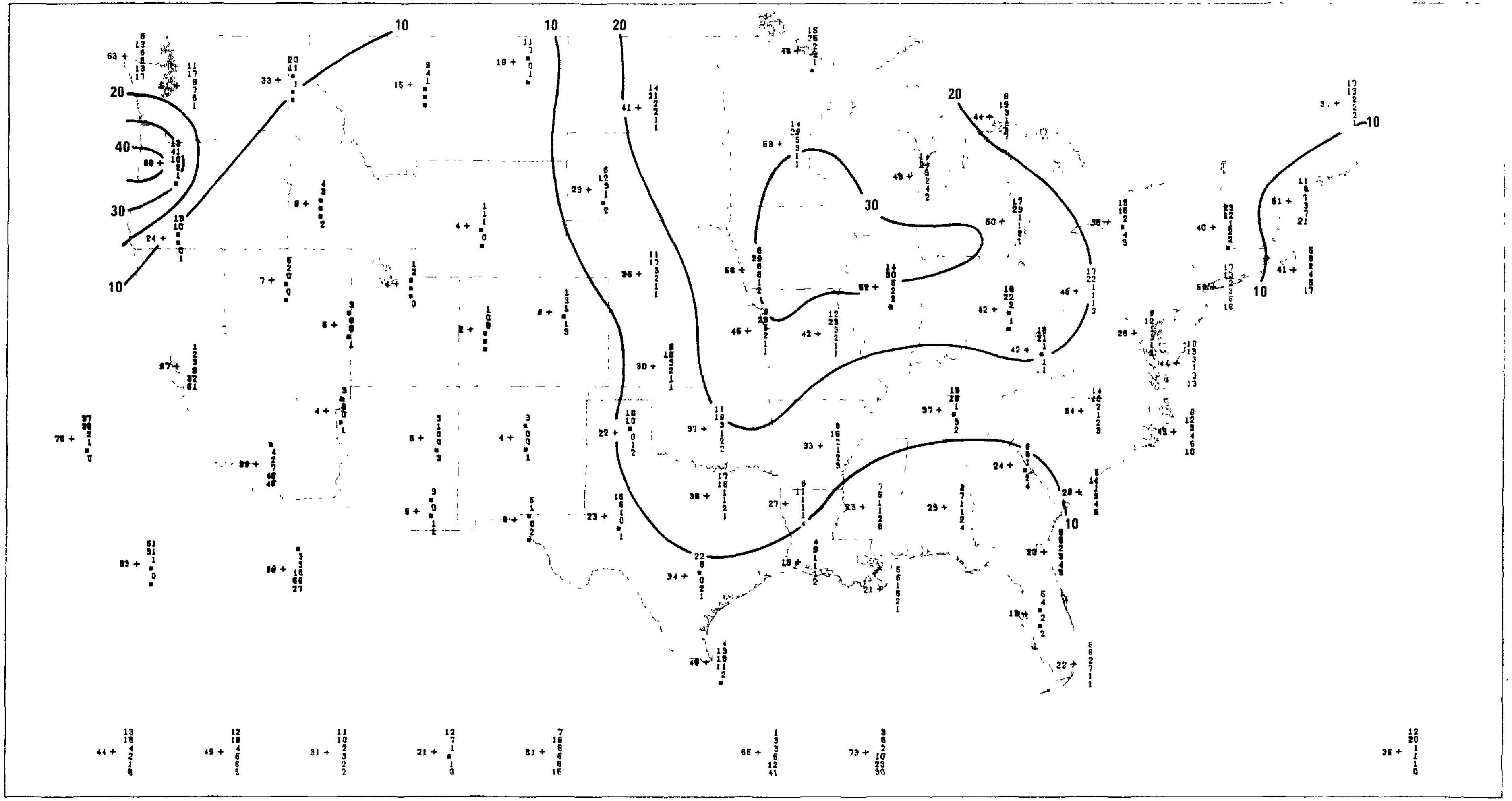


Figure 40. Percentage of summer 2315 GMT soundings with an elevated inversion base in the range 1-3000 m AGL (left) and in smaller ranges 1-250, 251-500, 501-750, 751-1000, 1001-2000, or 2001-3000 m AGL (right, bottom to top) Isopleths show the percentage *with bases between 1001-2000 m. See Figure 2 to identify peripheral stations.*

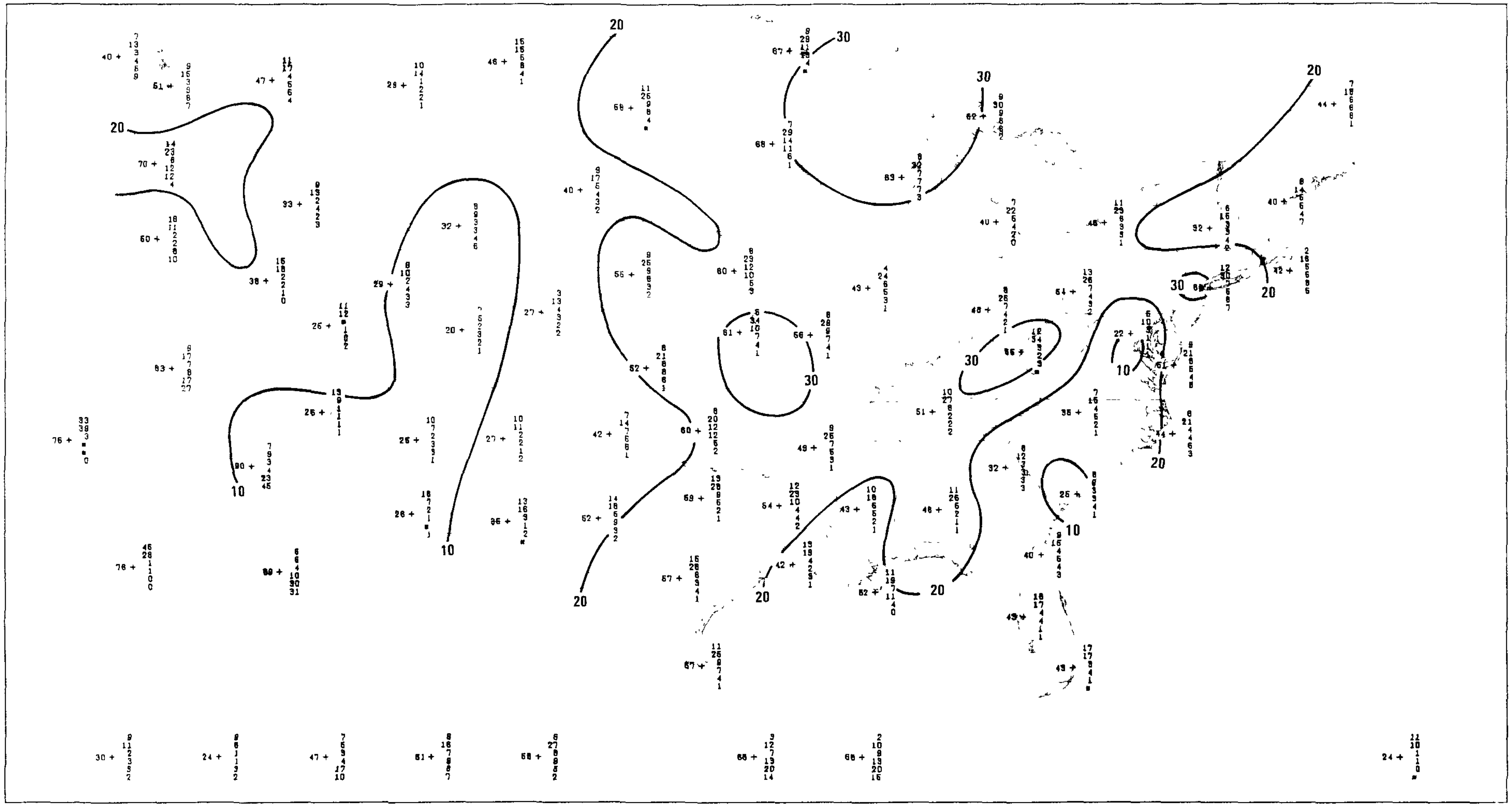

Figure 41. Percentage of autumn 2315 GMT soundings with an elevated inversion base in the range 1-3000 m AGL (left) and in smaller ranges 1-250, 251-500, 501-750, 751-1000, 1001-2000, or 2001-3000 m AGL (right, bottom to top). Isopleths show the percentage with bases between 1001-2000 m. See Figure 2 to identify peripheral stations.

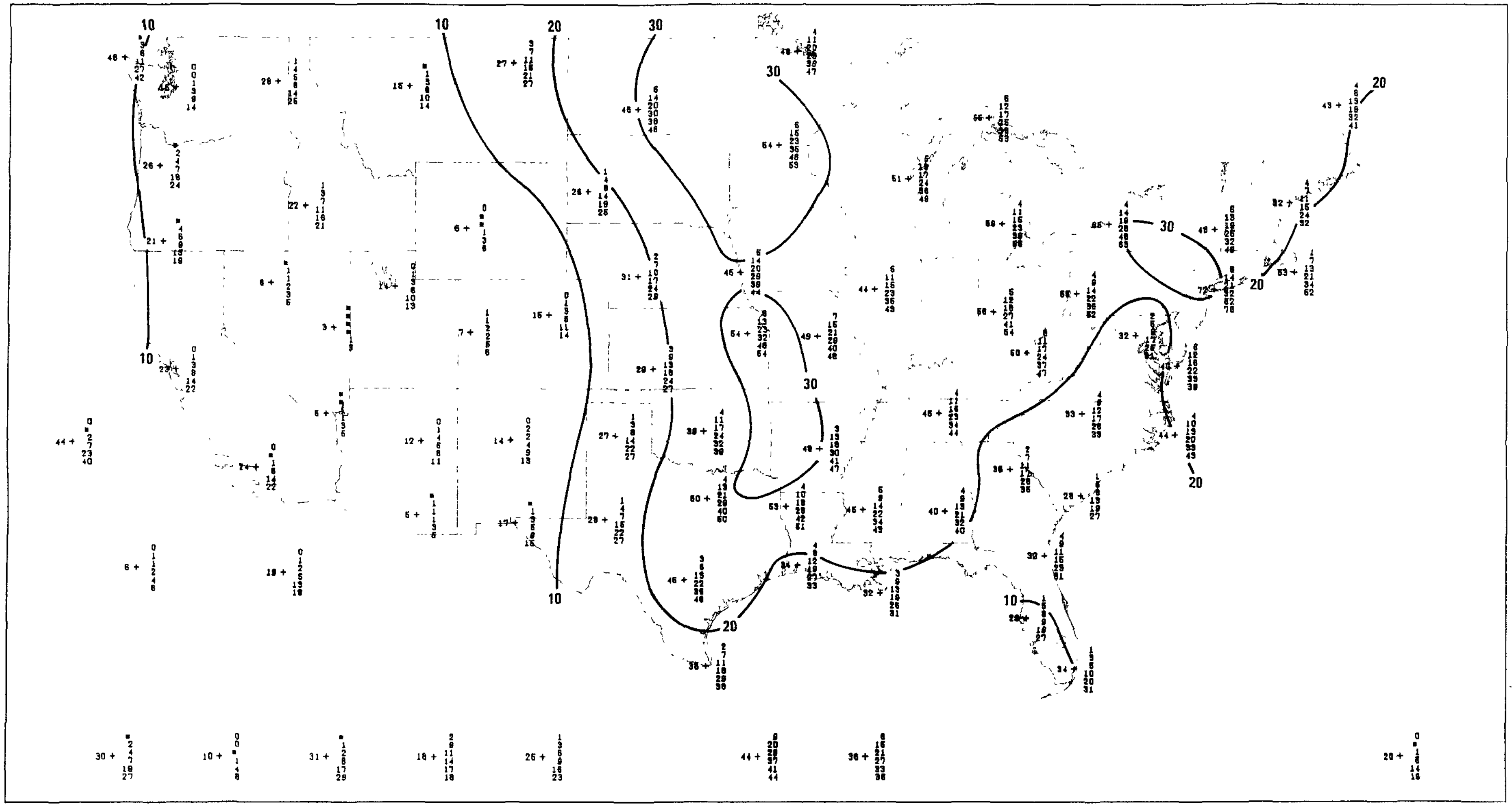

Figure 42 Percentage of winter 1115 GMT soundings with an elevated inversion base within 3000 m AGL (left), and a thickness exceeding 100, 250, 500, 750, 1000, or 1500 m (right, bottom to top). Isopleths show the percentage with thicknesses exceeding 500 m. See Figure 2 to identify peripheral stations.

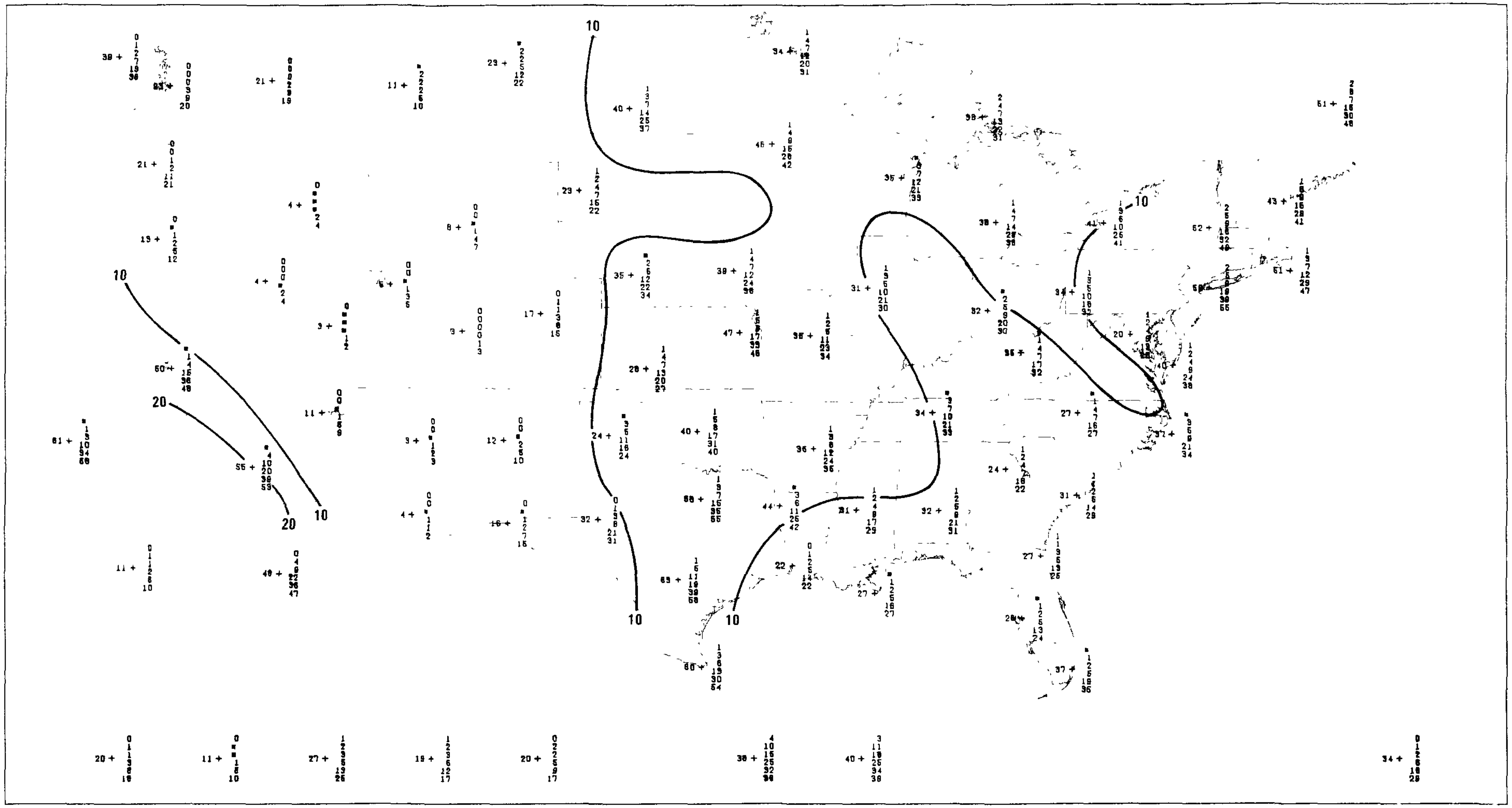


Figure 43 Percentage of spring 1115 GMT soundings with an elevated inversion base within 3000 m AGL (left), and a thickness exceeding 100, 250, 500, 750, 1000, or 1500 m (right, bottom to top). Isopleths show the percentage with thicknesses exceeding 500 m See Figure 2 to identify peripheral stations.

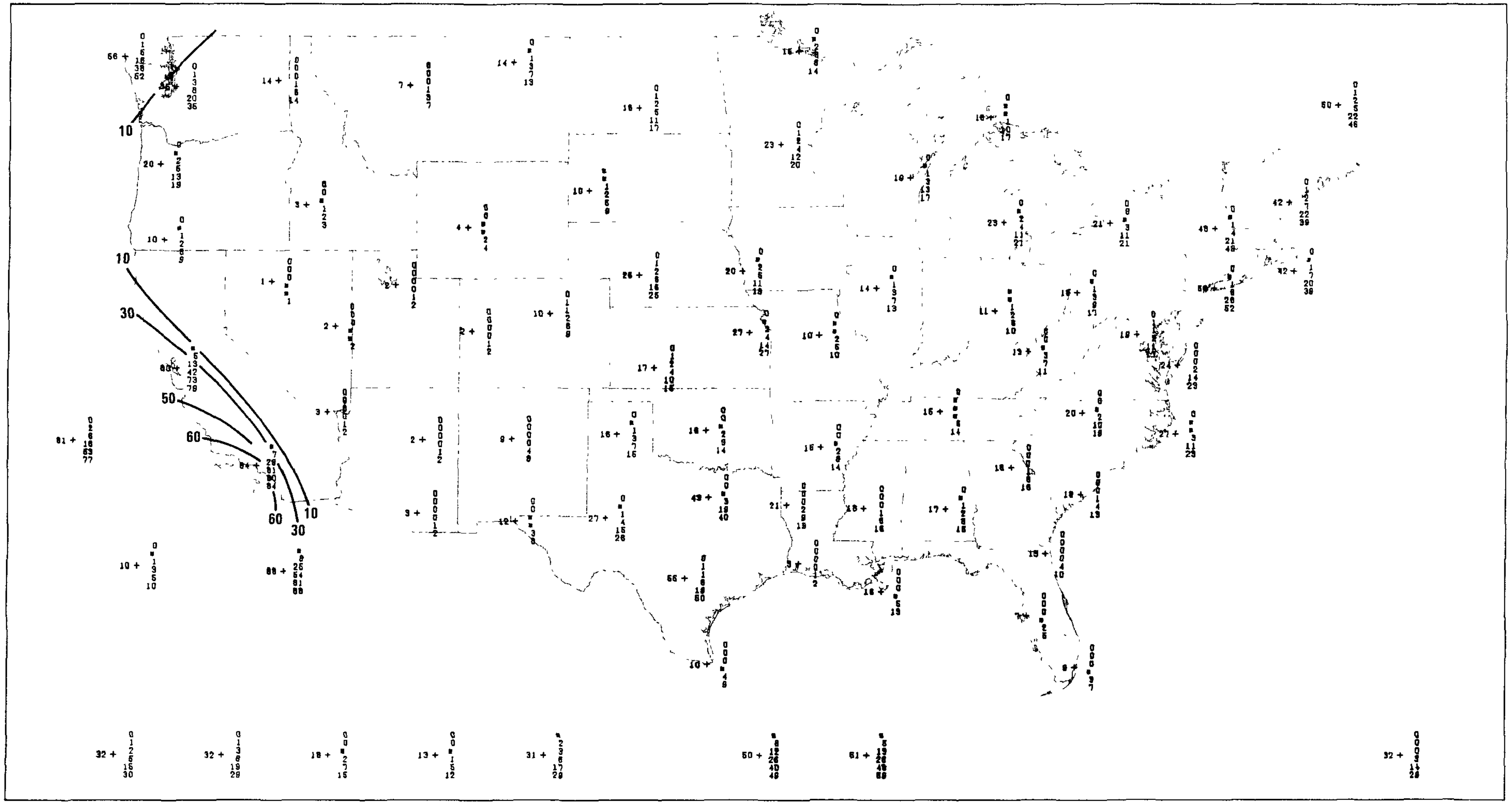

Figure 44 Percentage of summer 1115 GMT soundings with an elevated inversion base within 3000 m AGL (left), and a thickness exceeding 100, 250, 500, 750, 1000, or 1500 m (right, bottom to top). Isopleths show the percentage with thicknesses exceeding 500 m. See Figure 2 to identify peripheral stations.

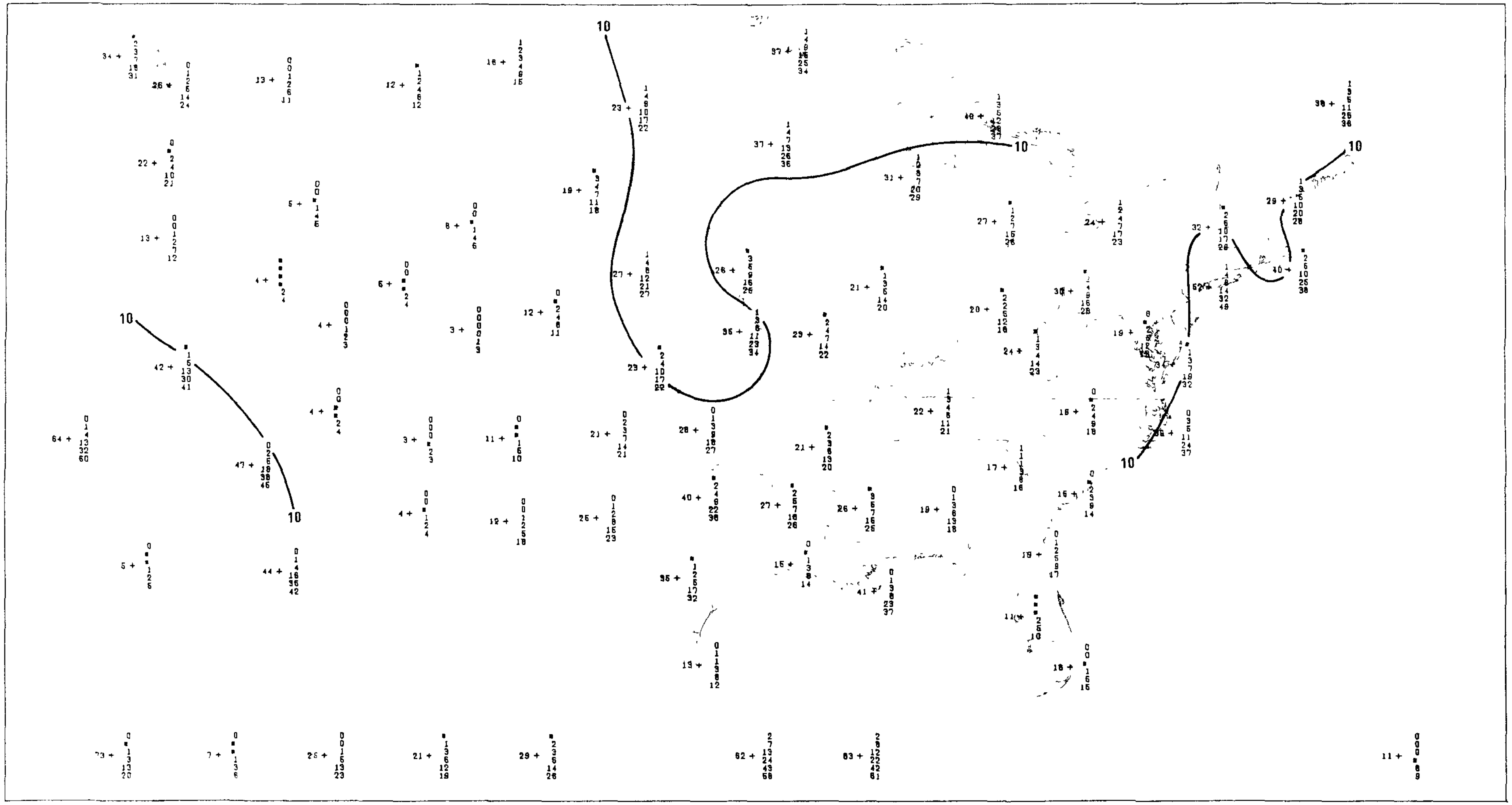

Figure 45 Percentage of autumn 1115 GMT soundings with an elevated inversion base within 3000 m AGL (left), and a thickness exceeding 100, 250, 500, 750, 1000, or 1500 m (right, bottom to top) Isopleths show the percentage with thicknesses exceeding 500 m. See Figure 2 to identify peripheral stations

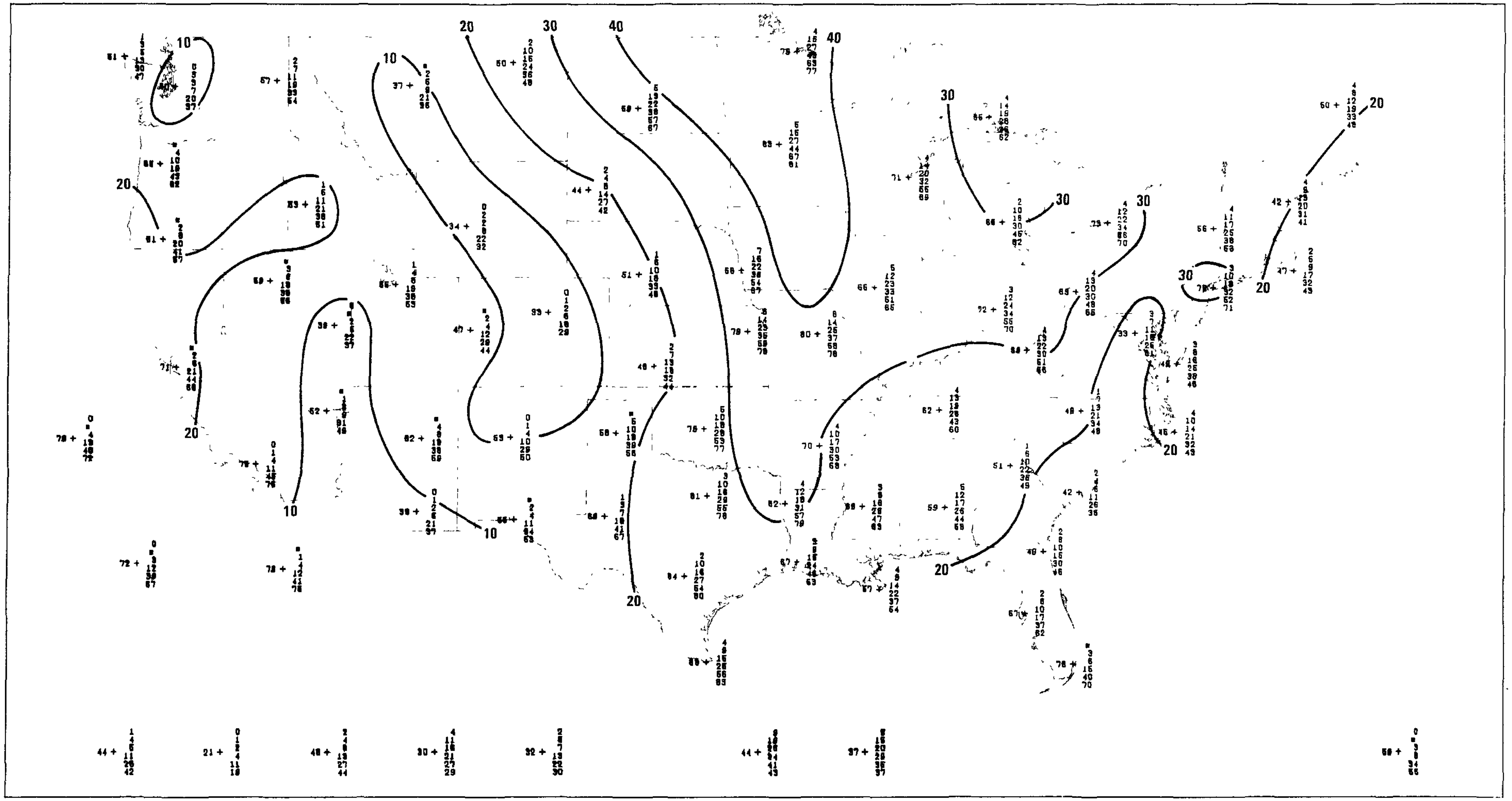

Figure 46. Percentage of winter 2315 GMT soundings with an elevated inversion base within 3000 m AGL (left), and a thickness exceeding 100, 250, 500, 750, 1000, or 1500 m (right, bottom to top). Isopleths show the percentage with thicknesses exceeding 500 m. See Figure 2 to identify peripheral stations.

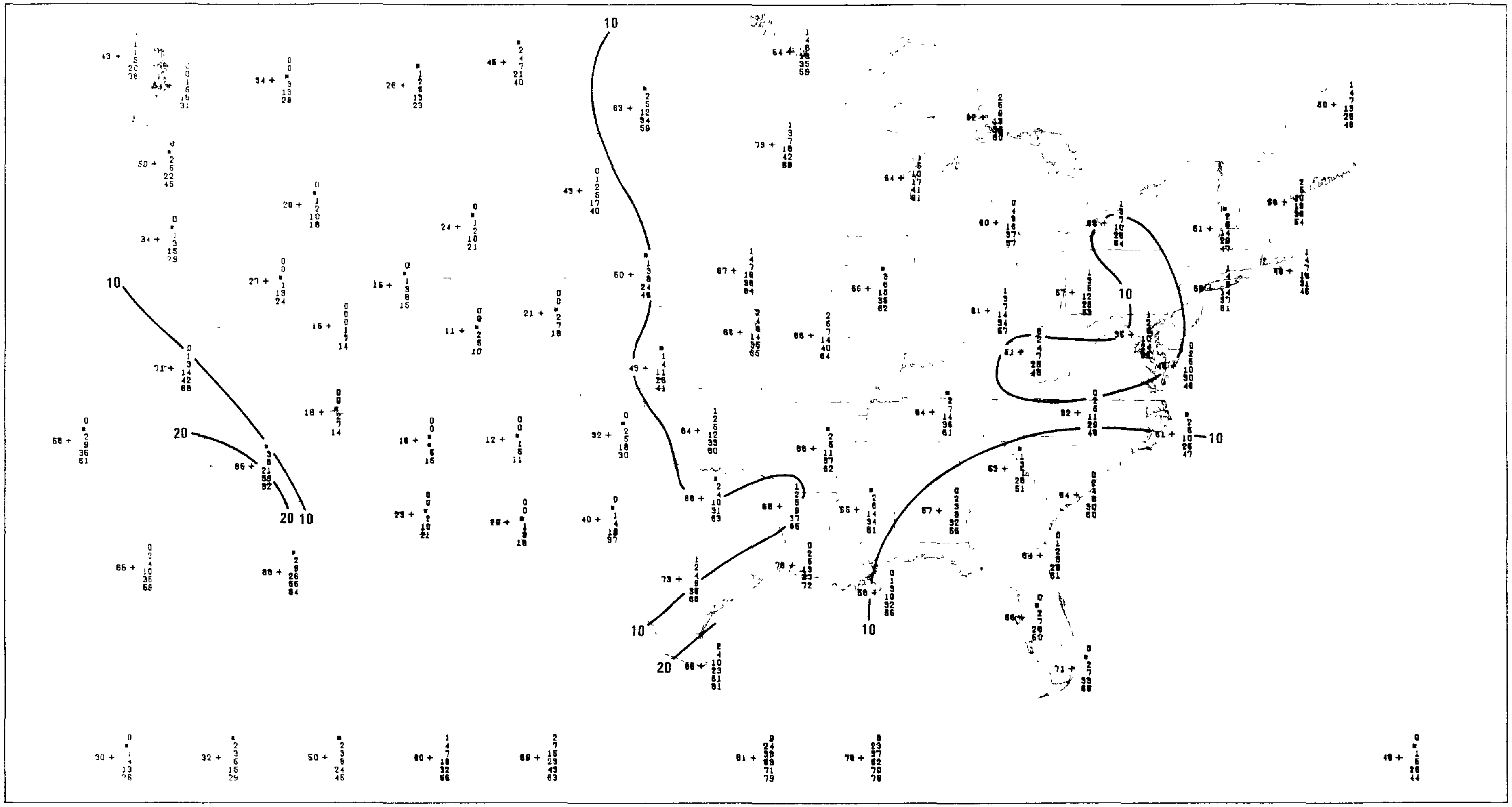

Figure 47. Percentage of spring 2315 GMT soundings with an elevated inversion base within 3000 m AGL (left), and a thickness exceeding 100, 250, 500, 750, 1000, or 1500 m (right, bottom to top). Isopleths show the percentage with thicknesses exceeding 500 m. See Figure 2 to identify peripheral stations

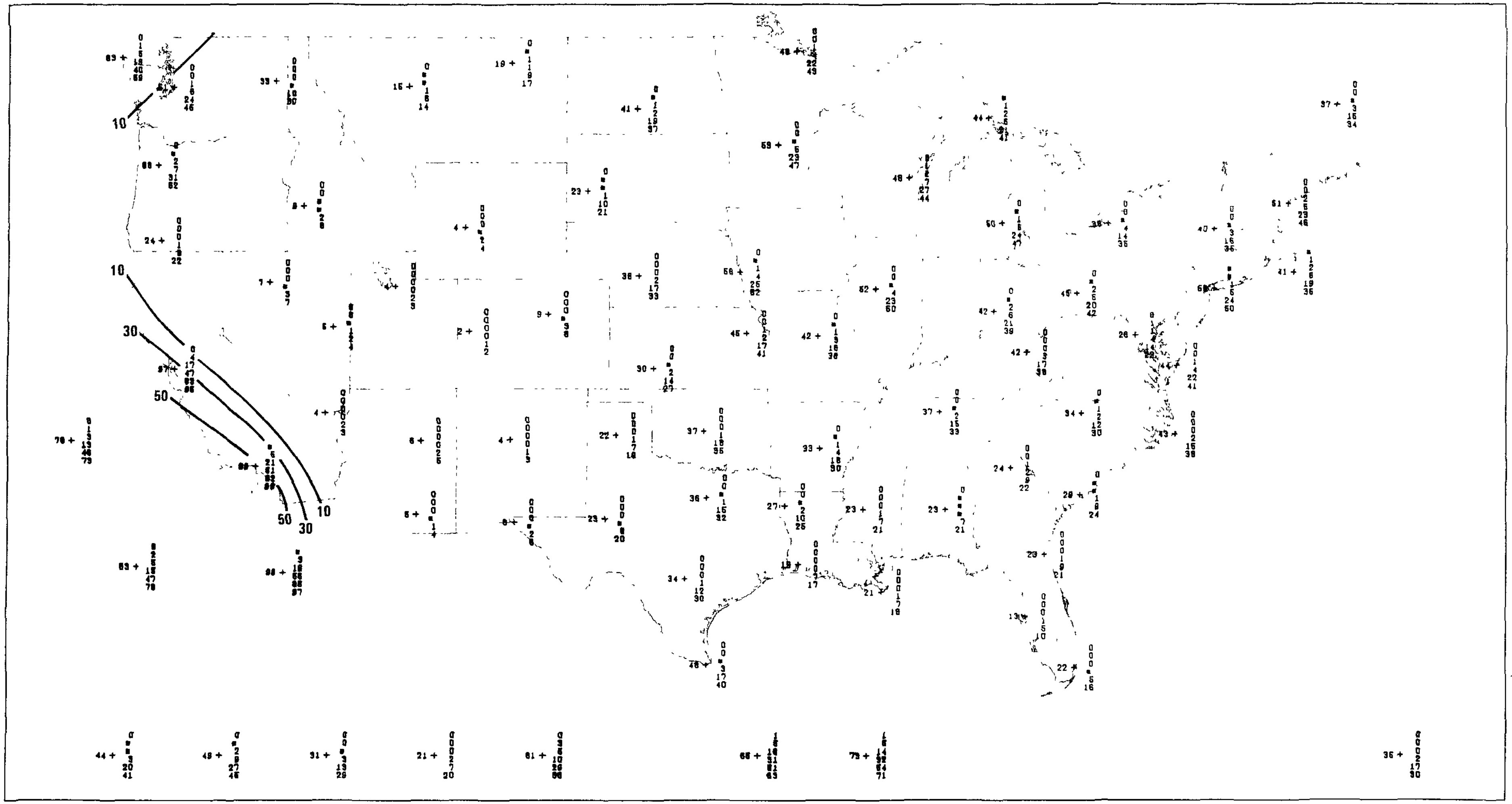

Figure 48 Percentage of summer 2315 GMT soundings with an elevated inversion base within 3000 m AGL (left), and a thickness exceeding 100, 250, 500, 750, 1000, or 1500 m (right, bottom to top) Isopleths show the percentage with thicknesses exceeding 500 m. See Figure 2 to identify peripheral stations.

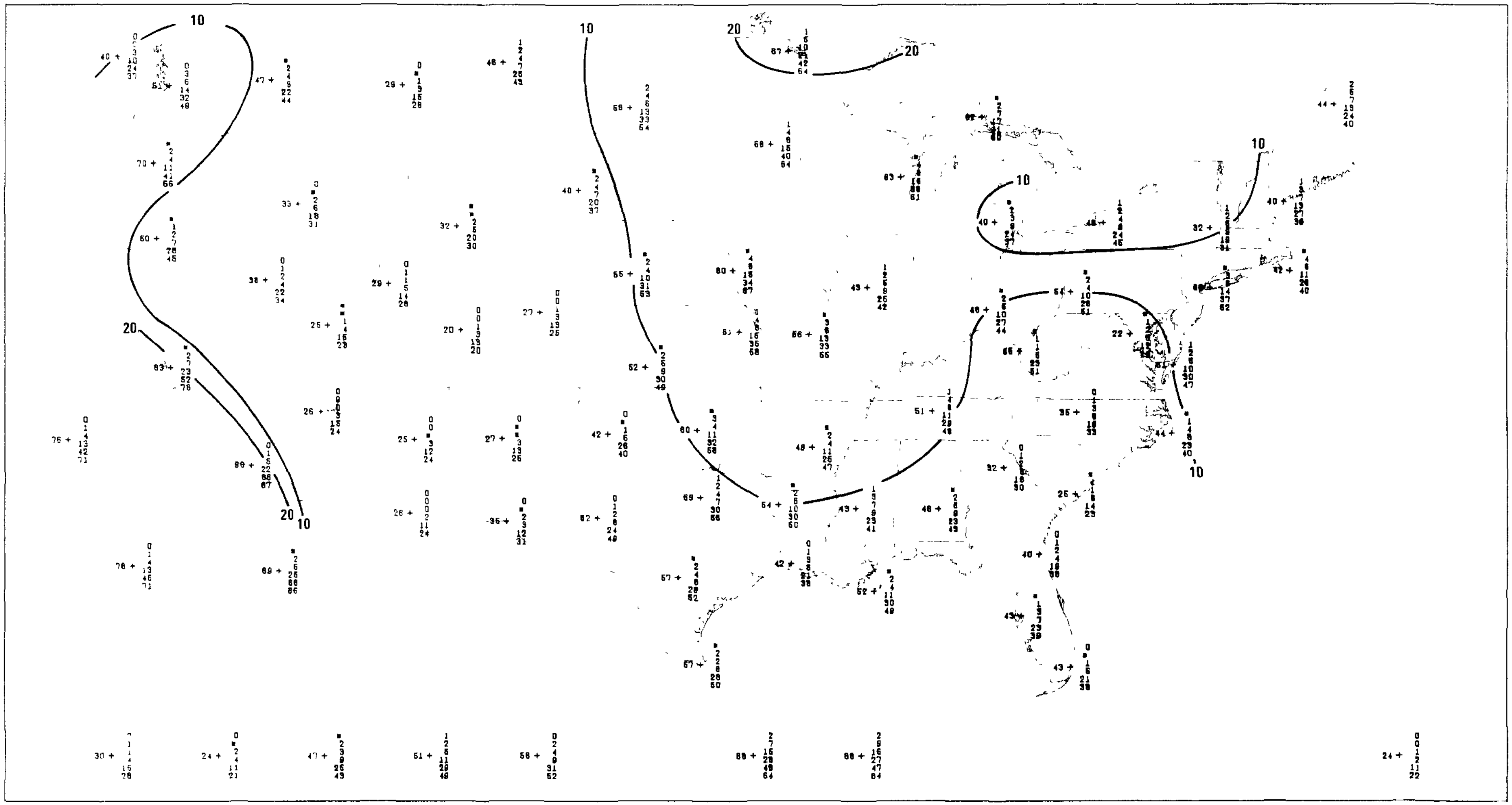

Figure 49  Percentage of autumn 2315 GMT soundings with an elevated inversion base within 3000 m AGL (left), and a thickness exceeding 100, 250, 500, 750, 1000, or 1500 m (right, bottom to top)  Isopleths show the percentage with thicknesses exceeding 500 m  See Figure 2 to identify peripheral stations

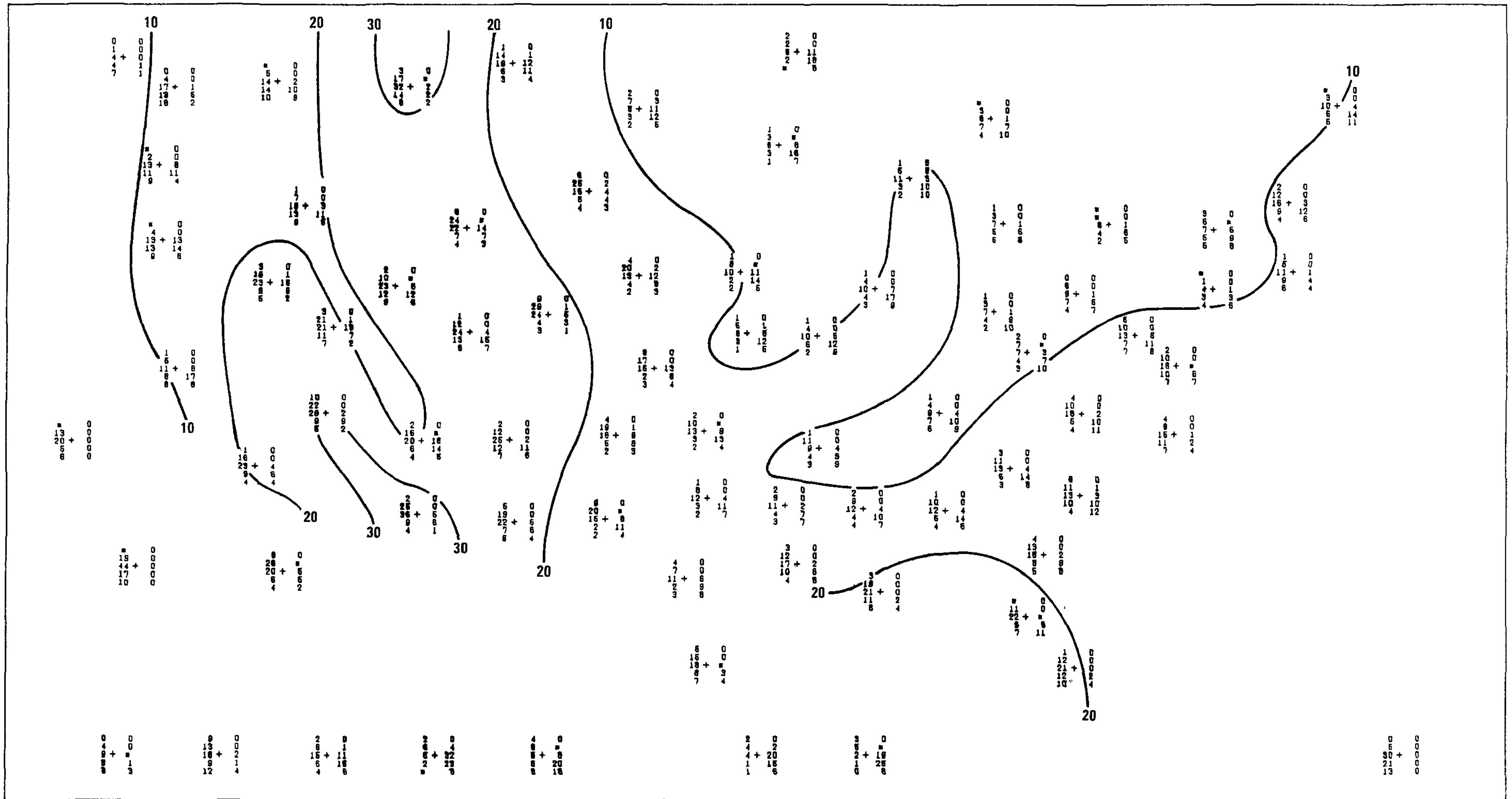


Figure 50. Percentage of winter 1115 GMT soundings with a surface-based inversion and a thickness of 500 m or less (left), or greater than 500 m (right) with a $\Delta T/\Delta H$ of 0-0 47, 0.48-1.14, 1.15-2.82, 2.83-6.00, or $> 6.0$ °C/100 m (bottom to top) Isopleths are for a thickness of 500 m or less and a $\Delta T/\Delta H$ of 1.15-2.82 °C/100 m See Figure 2 to identify peripheral stations

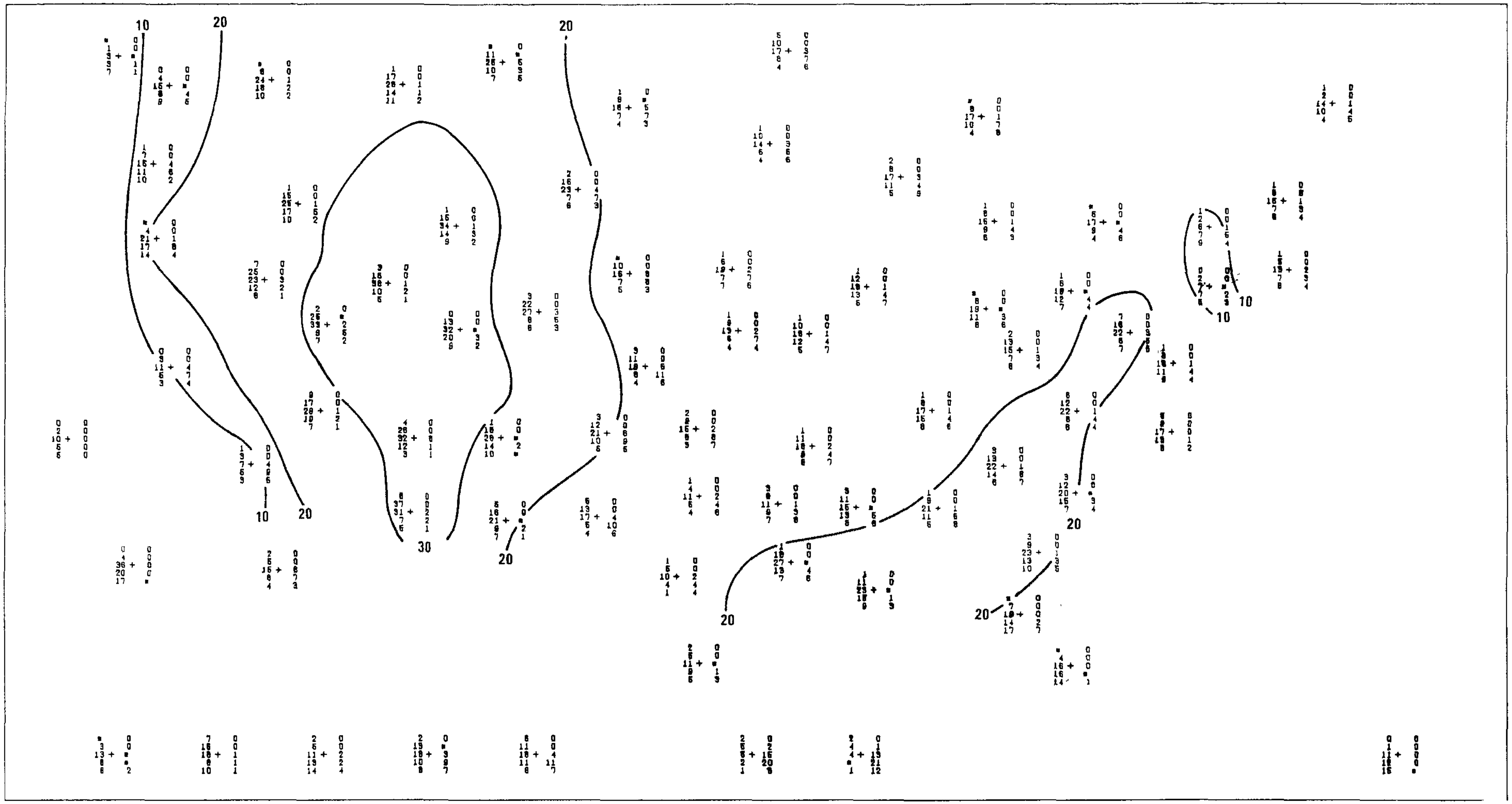


Figure 51 Percentage of spring 1115 GMT soundings with a surface-based inversion and a thickness of 500 m or less (left) or greater than 500 m (right) with a ΔT/ΔH of 0-0 47, 0 48-1 14, 1.15-2 82, 2.83-6.00, or > 6 0 °C/100 m (bottom to top). Isopleths are for a thickness of 500 m or less and a ΔT/ΔH of 1 15-2.82 °C/100 m. See Figure 2 to identify peripheral stations

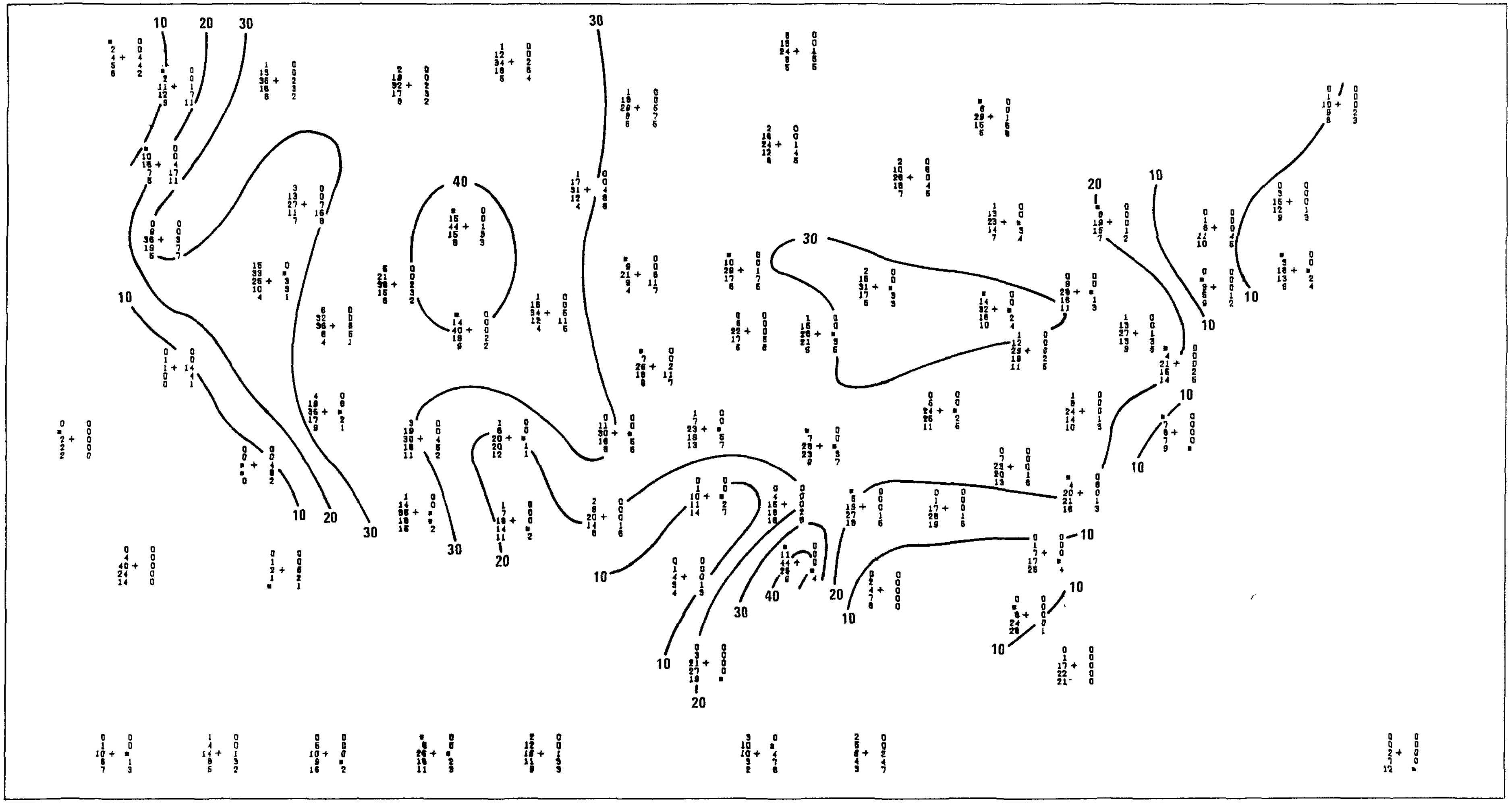


Figure 52 Percentage of summer 1115 GMT soundings with a surface-based inversion and a thickness of 500 m or less (left) or greater than 500 m (right) with a ΔT/ΔH of 0-0.47, 0.48-1.14, 1.15-2.82, 2.83-6.00, or > 6.0 °C/100 m (bottom to top). Isopleths are for a thickness of 500 m or less and a ΔT/ΔH of 1.15-2.82 °C/100 m. See Figure 2 to identify peripheral stations.

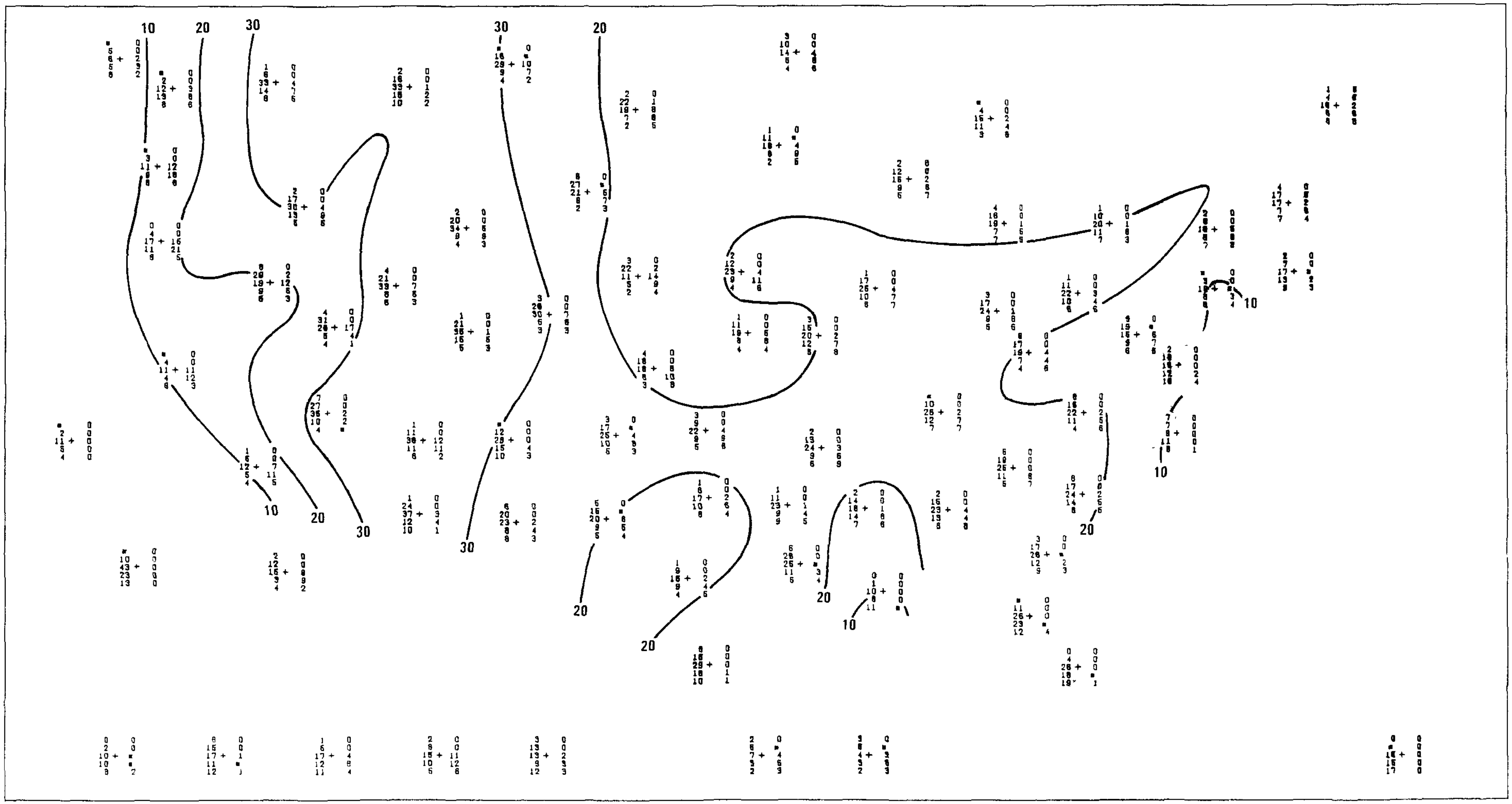

Figure 53 Percentage of autumn 1115 GMT soundings with a surface-based inversion and a thickness of 500 m or less (left) or greater than 500 m (right) with a $\Delta T/\Delta H$ of 0-0 47, 0 48-1.14, 1 15-2 82, 2 83-6 00, or $>$ 6.0 °C/100 m (bottom to top) Isopleths are for a thickness of 500 m or less and a $\Delta T/\Delta H$ of 1 15-2.82 °C/100 m See Figure 2 to identify peripheral stations

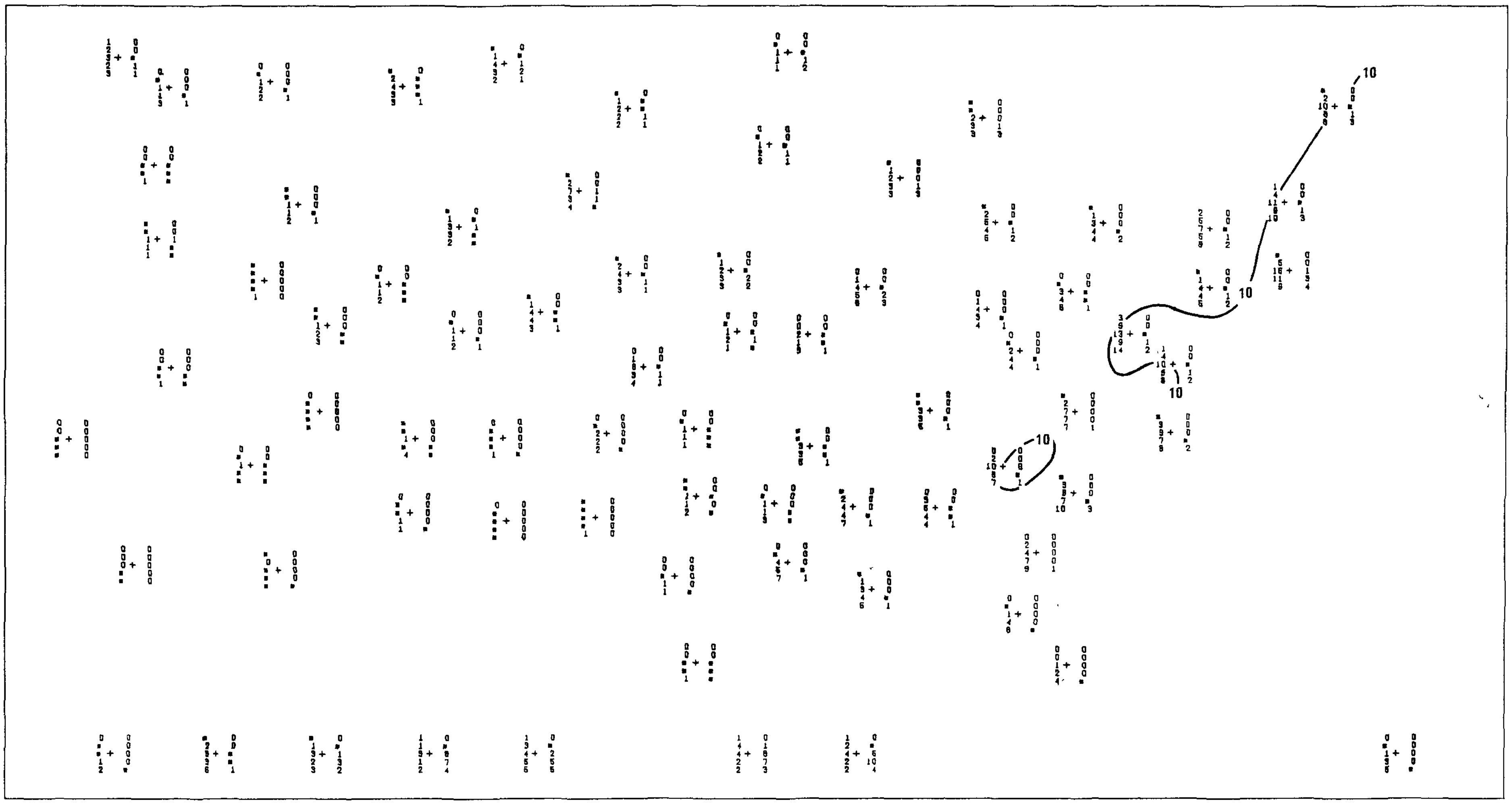


Figure 54. Percentage of all 2315 GMT soundings with a surface-based inversion having a thickness of 500 m or less (left) or greater than 500 m (right) with a $\Delta T/\Delta H$ of 0-0.47, 0.48-1.14, 1.15-2.82, 2.83-6.00 or > 6.0 °C/100 m (bottom to top). Isopleths are for a thickness of 500 m or less and a $\Delta T/\Delta H$ of 1 15-2.82 °C/100 m. See Figure 2 to identify peripheral stations.

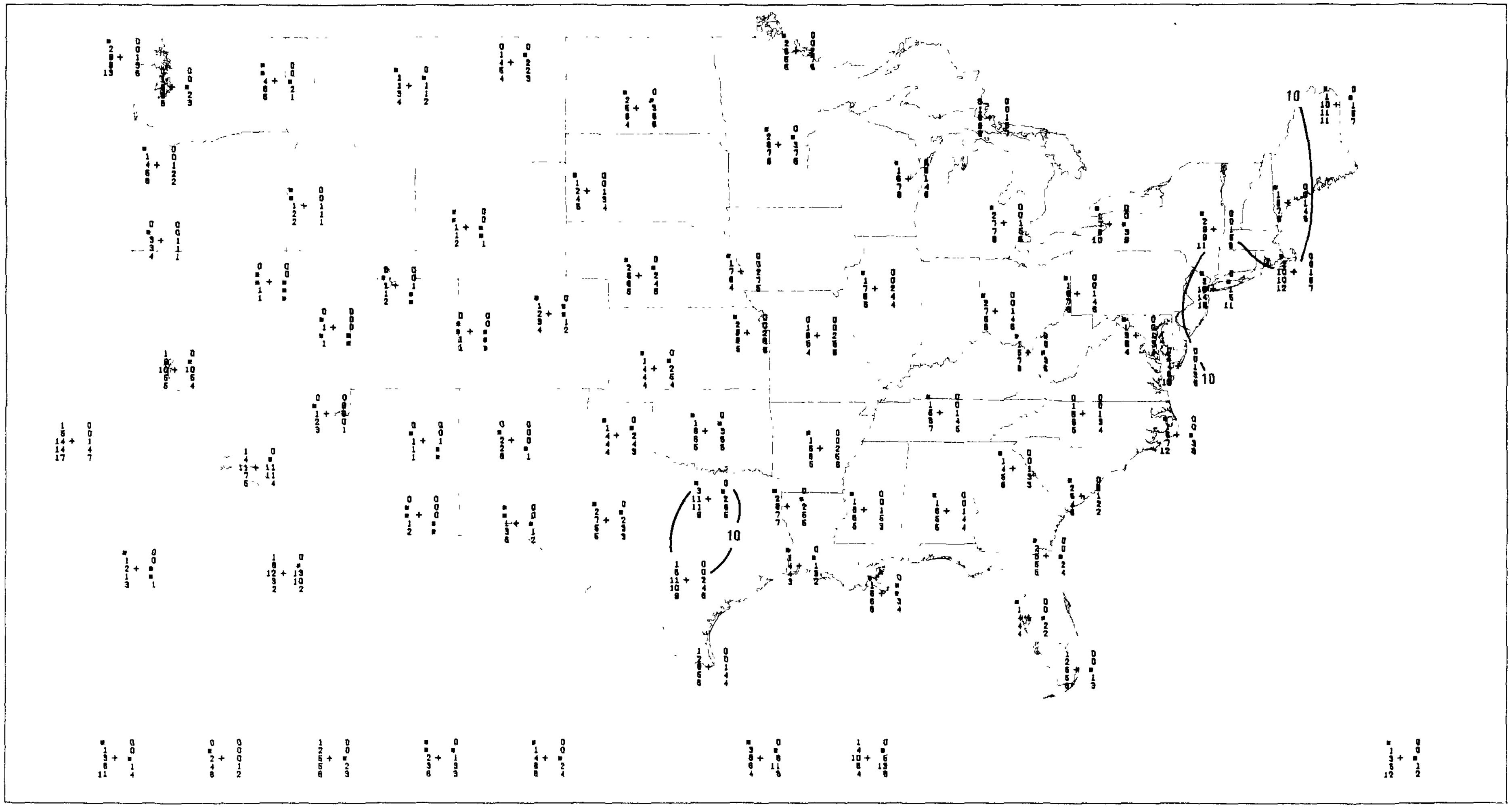

Figure 55 Percentage of all 1115 GMT soundings with an elevated inversion base below 3000 m AGL, and a thickness of 500 m or less (left) or greater than 500 m (right) with a ΔT/ΔH of 0-0 47, 0 48-1 14, 1 15-2 82, 2 83-6 00, or > 6.0 °C/100 m *(bottom to top)* Isopleths are for a thickness of 500 m or less and a ΔT/ΔH of 0 48-1 14 °C/100 m See Figure 2 to identify the peripheral stations

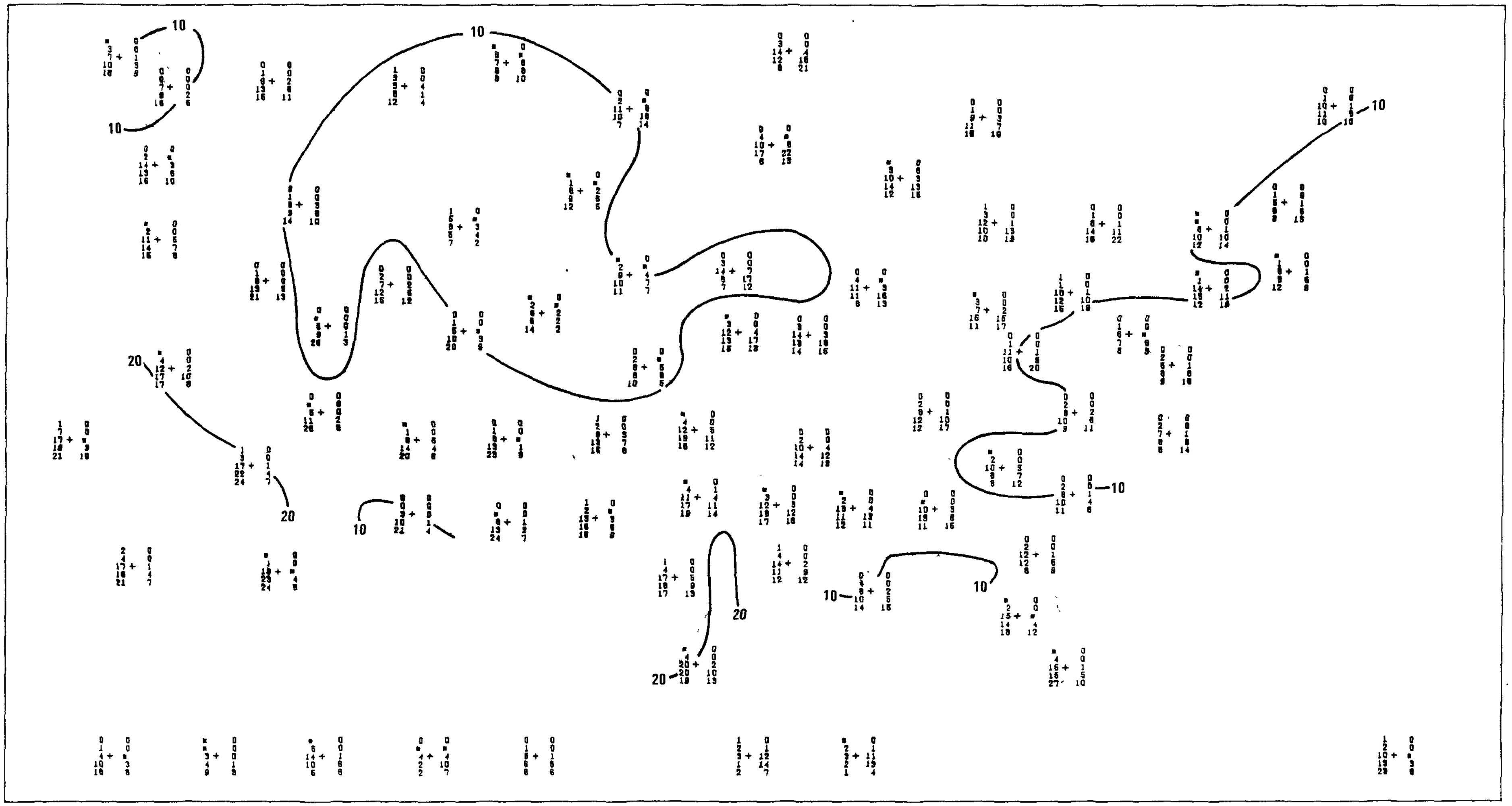

Figure 56. Percentage of winter 2315 GMT soundings with an elevated inversion base within 3000 m AGL, and a thickness of 500 m or less (left) or greater than 500 m (right) with a ΔT/ΔH of 0-0.47, 0.48-1.14, 1.15-2.82, 2.83-6.00, or > 6.0 °C/100 m (bottom to top). Isopleths are for a thickness of 500 m or less and a ΔT/ΔH of 0.48-1.14 °C/100 m. See Figure 2 to identify the peripheral stations.

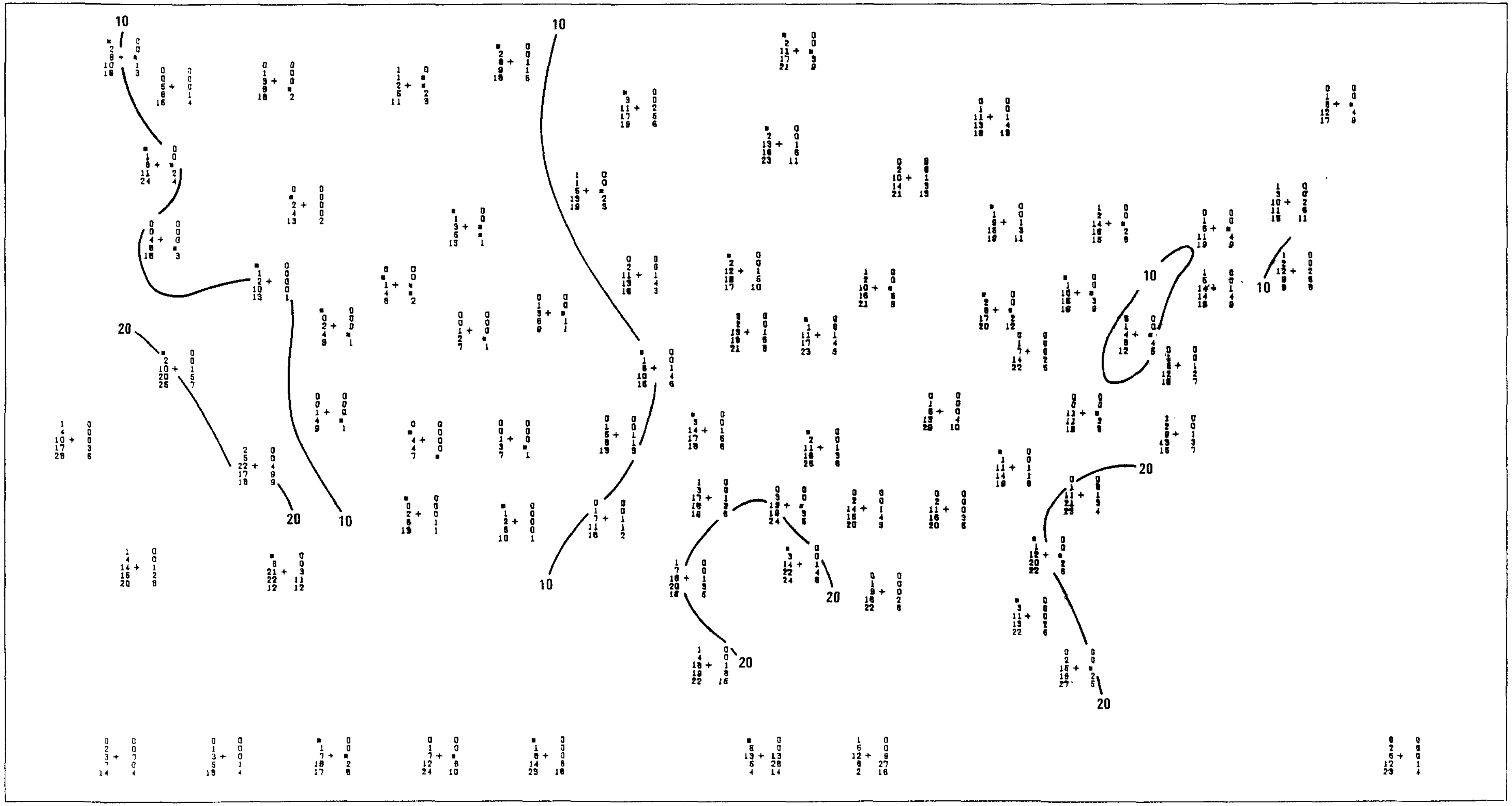

Figure 57  Percentage of spring 2315 GMT soundings with an elevated inversion base within 3000 m AGL, and a thickness of 500 m or less (left) or greater than 500 m (right) with a $\Delta T/\Delta H$ of 0-0.47, 0.48-1.14, 1.15-2.82, 2.83-6.00, or $> 6.0$ °C/100 m (bottom to top). Isopleths are for a thickness of 500 m or less and a $\Delta T/\Delta H$ of 0.48-1.14 °C/100 m. See Figure 2 to identify the peripheral stations.

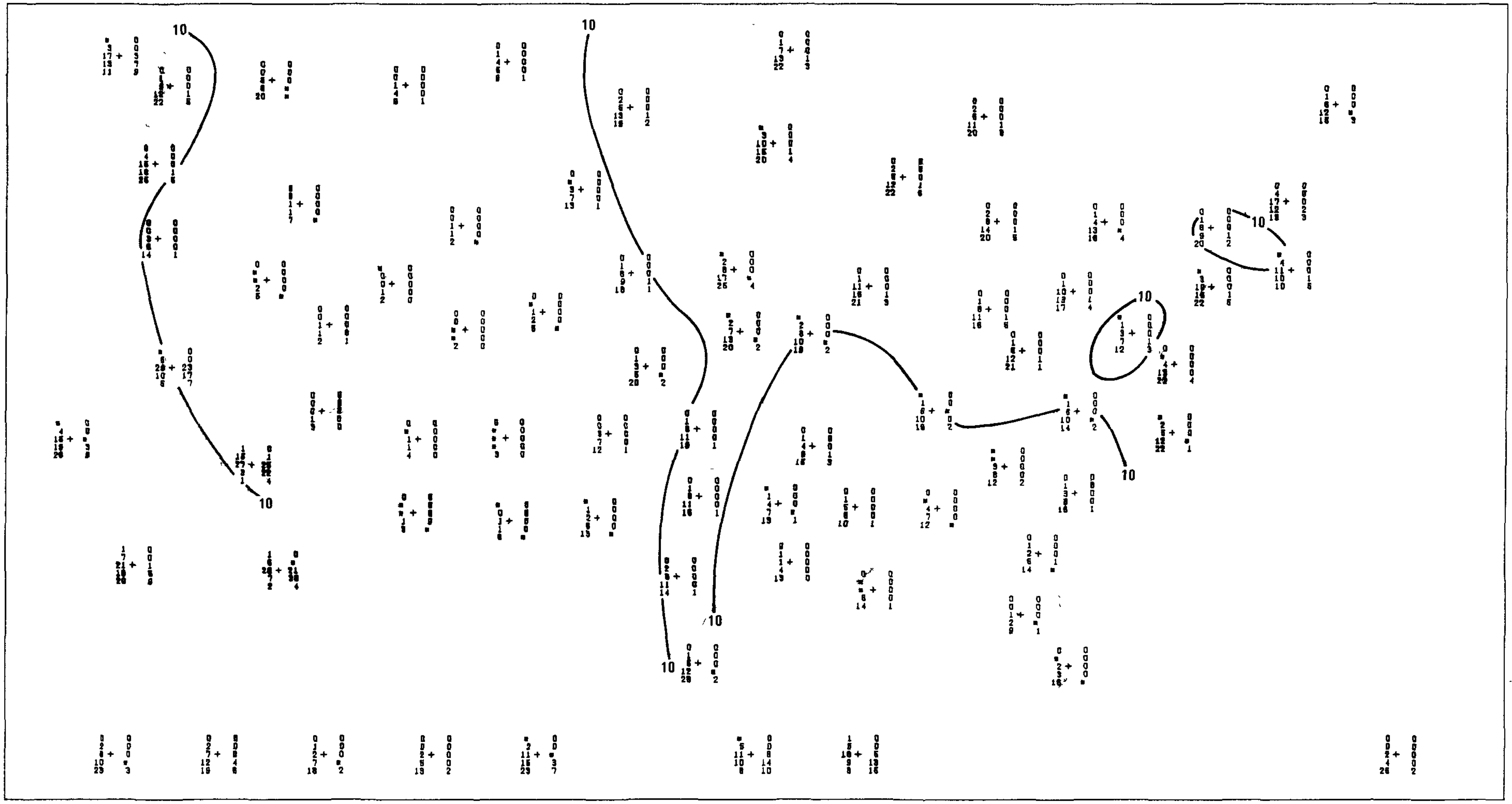

Figure 58. Percentage of summer 2315 GMT soundings with an elevated inversion base within 3000 m AGL, and a thickness of 500 m or less (left) or greater than 500 m (right) with a ΔT/ΔH of 0-0.47, 0.48-1.14, 1.15-2.82, 2.83-6.00, or > 6.0 °C/100 m (bottom to top). Isopleths are for a thickness of 500 m or less and a ΔT/ΔH of 0.48-1.14 °C/100 m. See Figure 2 to identify the peripheral stations.

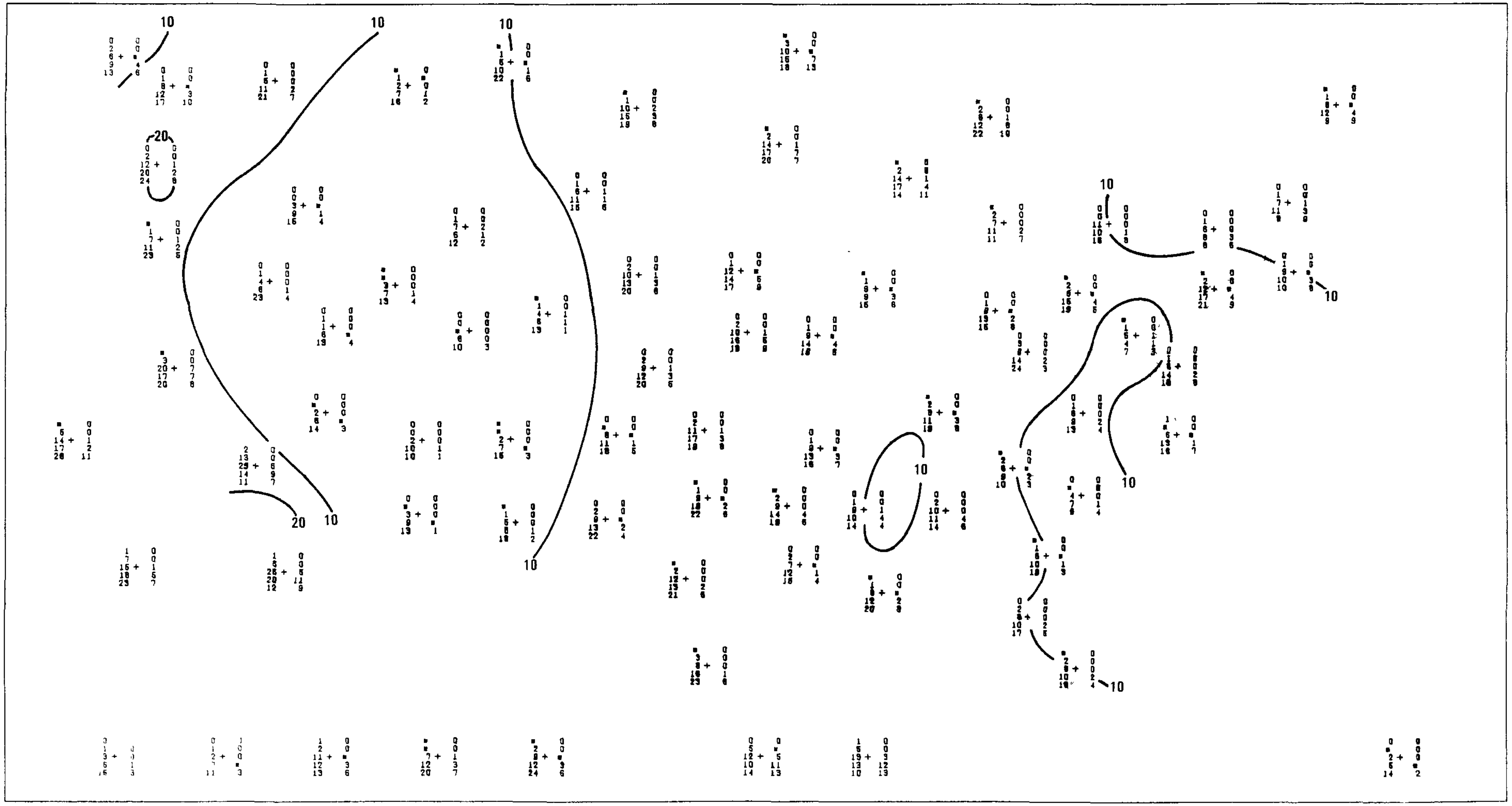

Figure 59 Percentage of autumn 2315 GMT soundings with an elevated inversion base within 3000 m AGL, and a thickness of 500 m or less (left) or greater than 500 m (right) with a ΔT/ΔH of 0-0 47, 0 48-1 14, 1 15-2 82, 2 83-6 00, or > 6.0 °C/100 m (bottom to top) Isopleths are for a thickness of 500 m or less and a ΔT/ΔH of 0 48-1 14 °C/100 m See Figure 2 to identify peripheral stations

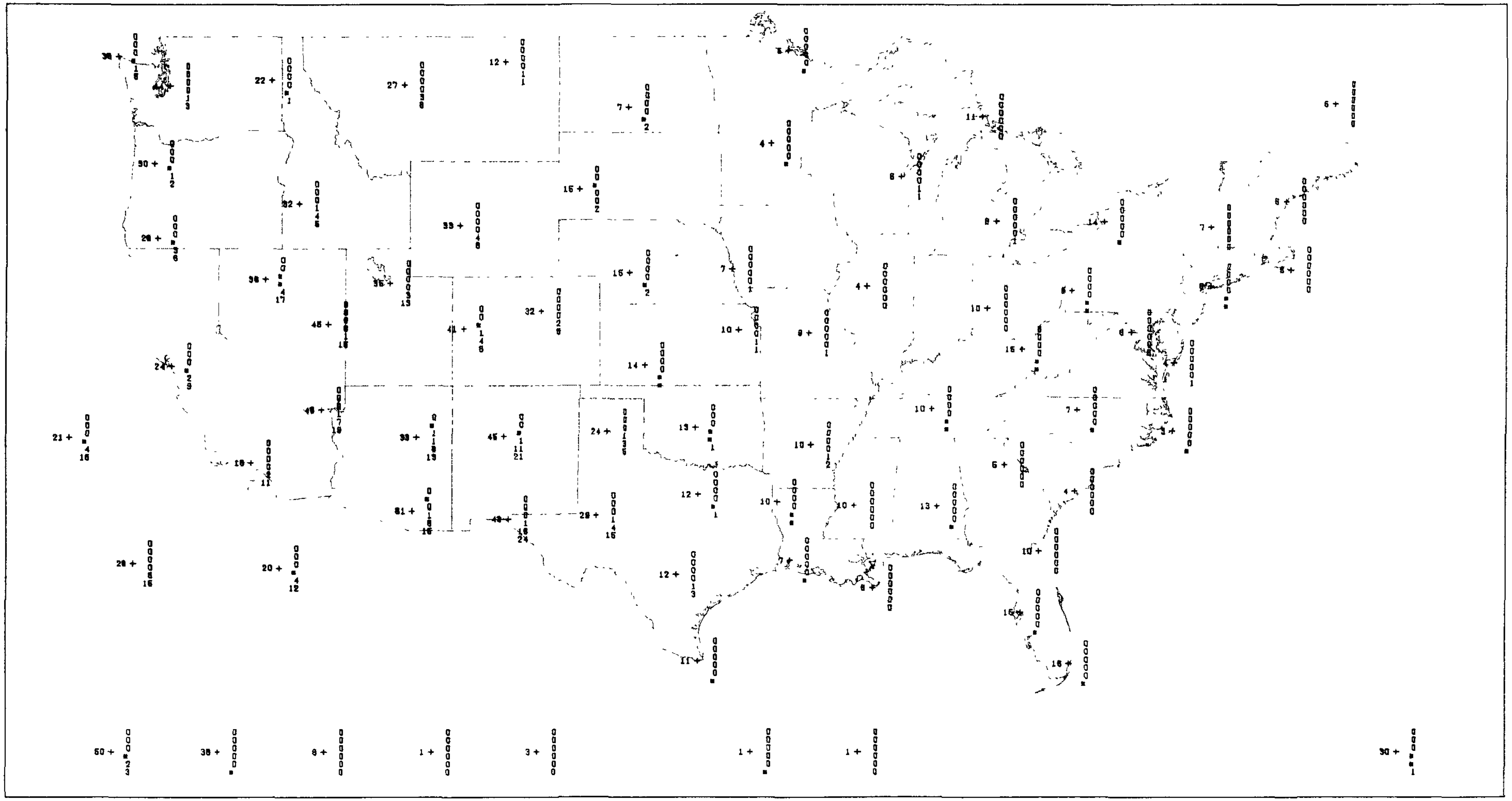

Figure 60. Percentage of winter 2315 GMT soundings with no inversion below 3000 m AGL (left) and with a decreasing temperature with height ($-\Delta T/\Delta H$) greater than 1.2 °C/100 m in the layers 1-100, 101-250, 251-500, 501-750, 751-1000, or 1001-1500 m AGL (right, bottom to top). See Figure 2 to identify the peripheral stations.

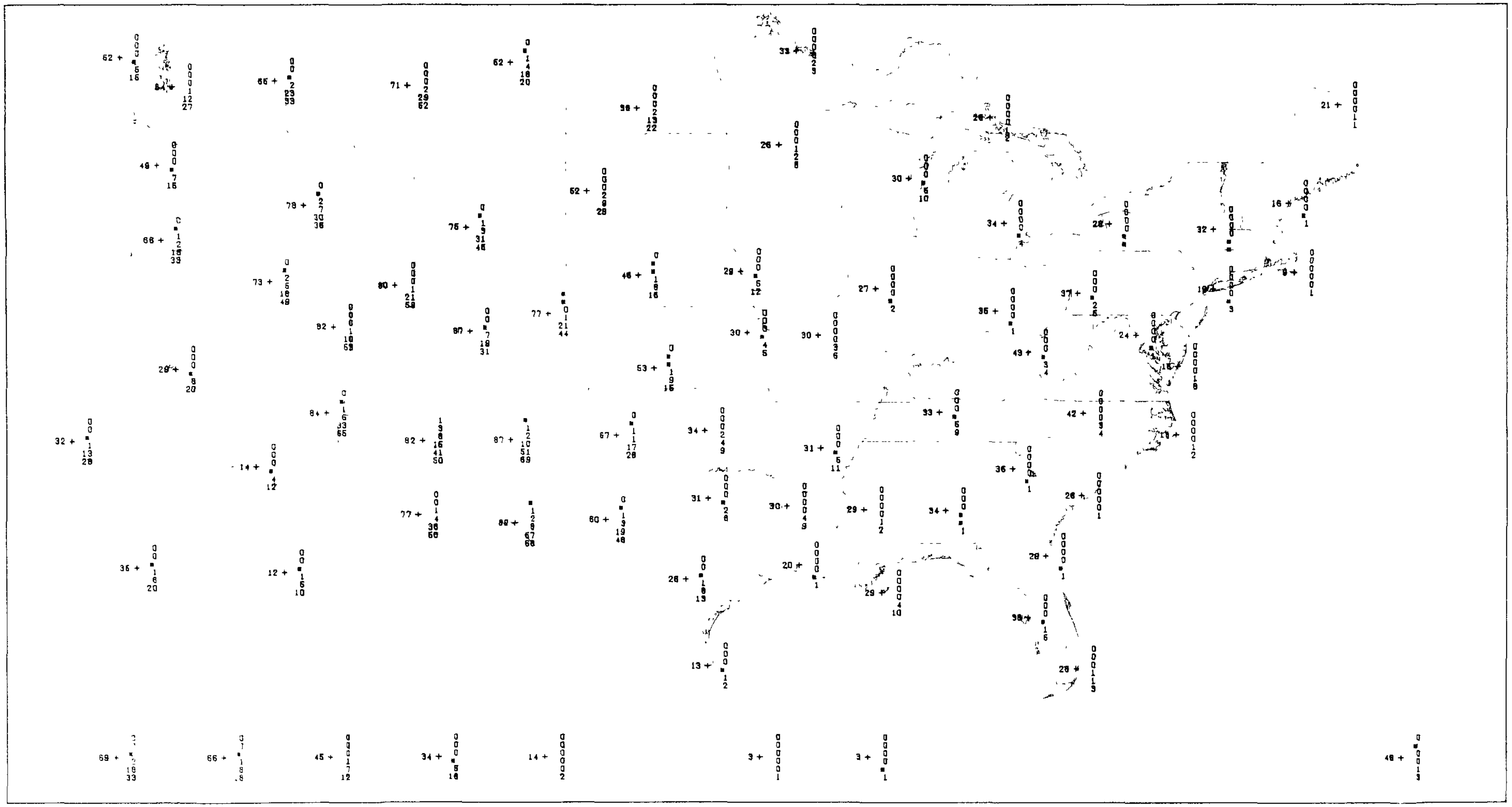

Figure 61  Percentage of spring 2315 GMT soundings with no inversion below 3000 m (left) and with a decreasing temperature with height (-ΔT/ΔH) greater than 1.2 °C/100 m in the layers 1-100, 101-250, 251-500, 501-750, 751-1000, or 1001-1500 m AGL (right, bottom to top). See Figure 2 to identify the peripheral stations

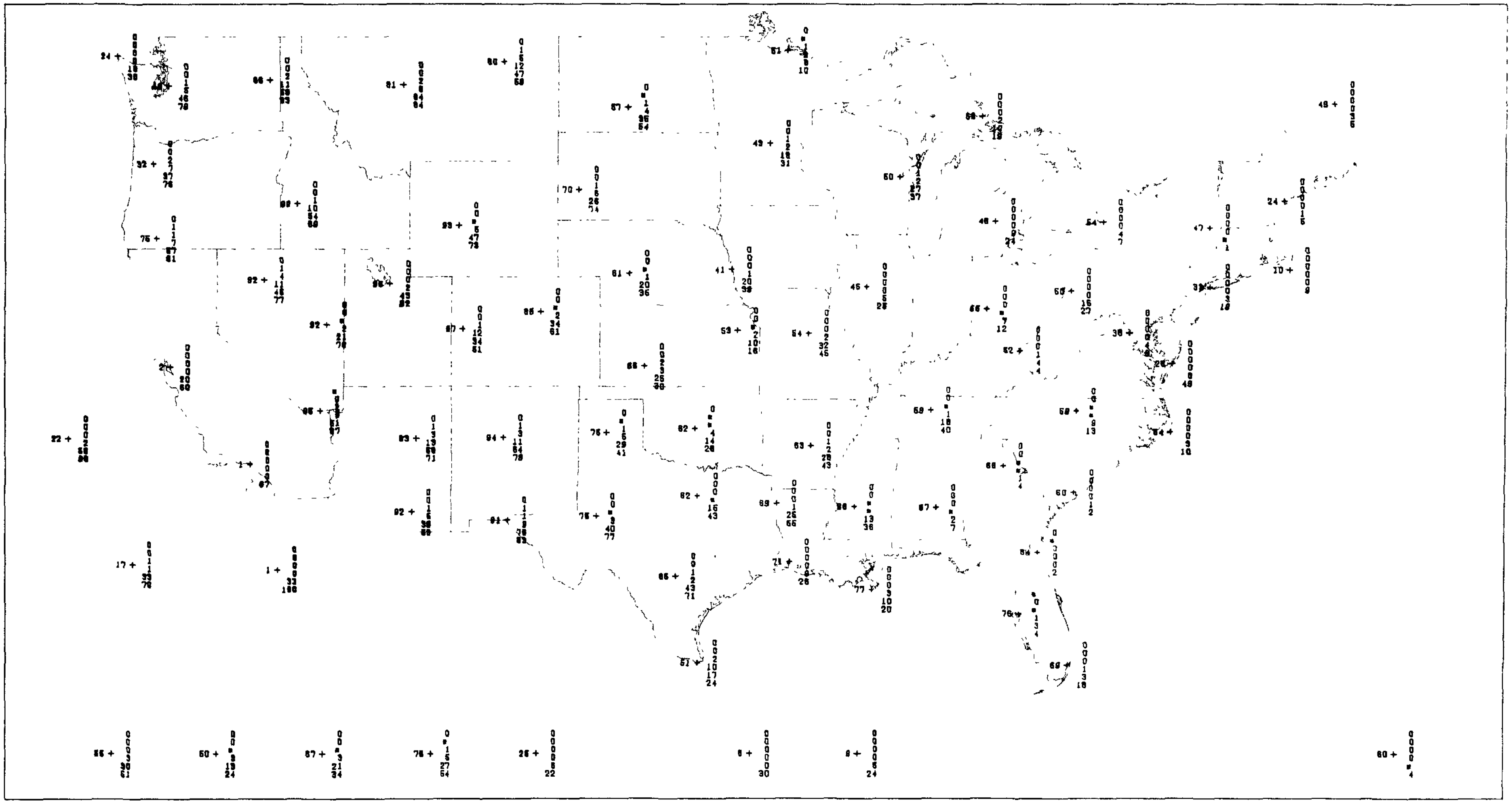

Figure 62 Percentage of summer 2315 GMT soundings with no inversion below 3000 m (left) and with a decreasing temperature with height (-ΔT/ΔH) greater than 1.2 °C/100 m in the layers 1-100, 101-250, 251-500, 501-750, 751-1000, or 1001-1500 m AGL (right, bottom to top). See Figure 2 to identify the peripheral stations.

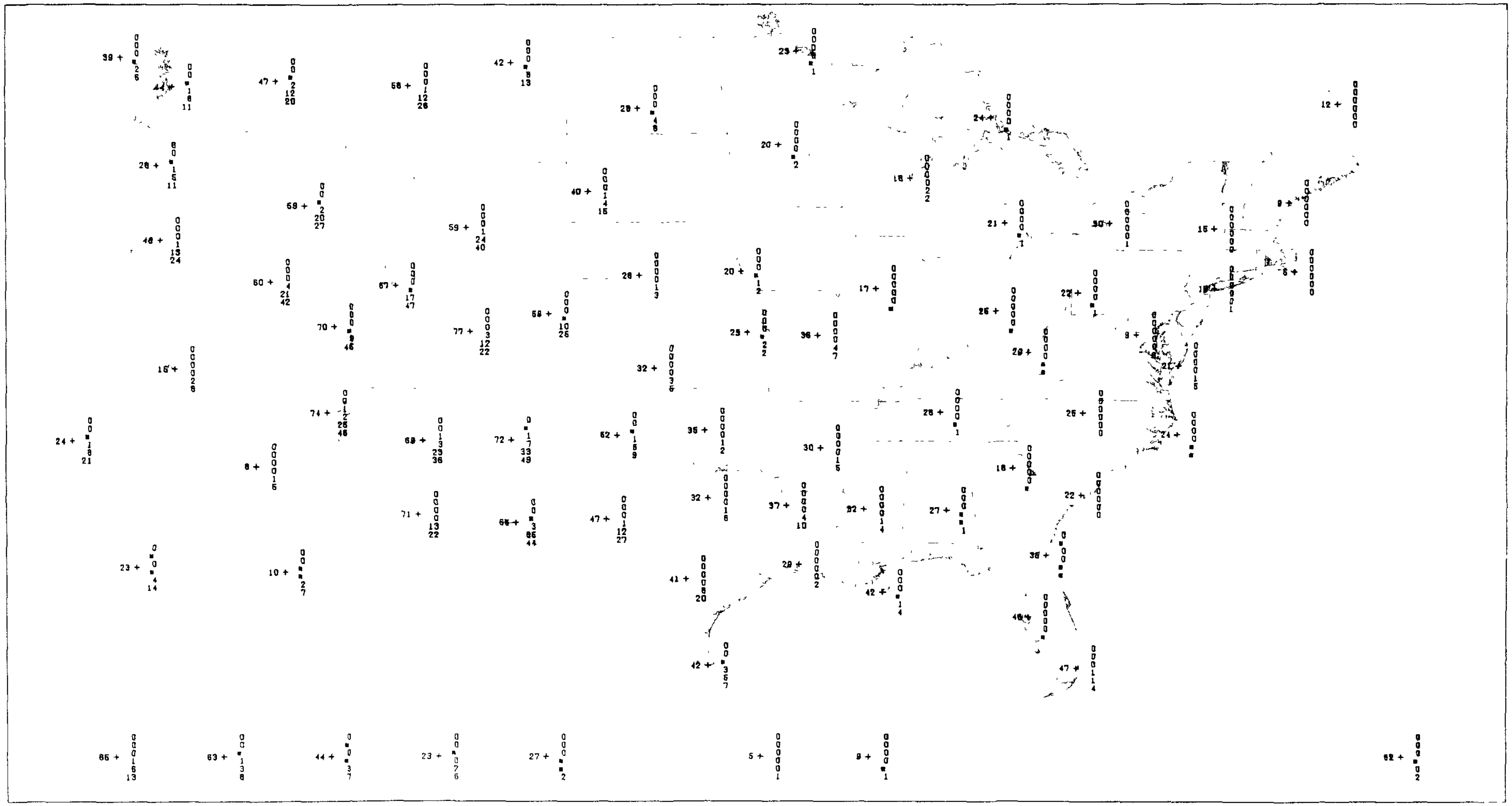

Figure 63. Percentage of autumn 2315 GMT soundings with no inversion below 3000 m (left) and with a decreasing temperature with height (-ΔT/ΔH) greater than 1.2 °C/100 m in the layers 1-100, 101-250, 251-500, 501-750, 751-1000, or 1001-1500 m AGL (right, bottom to top). See Figure 2 to identify peripheral stations

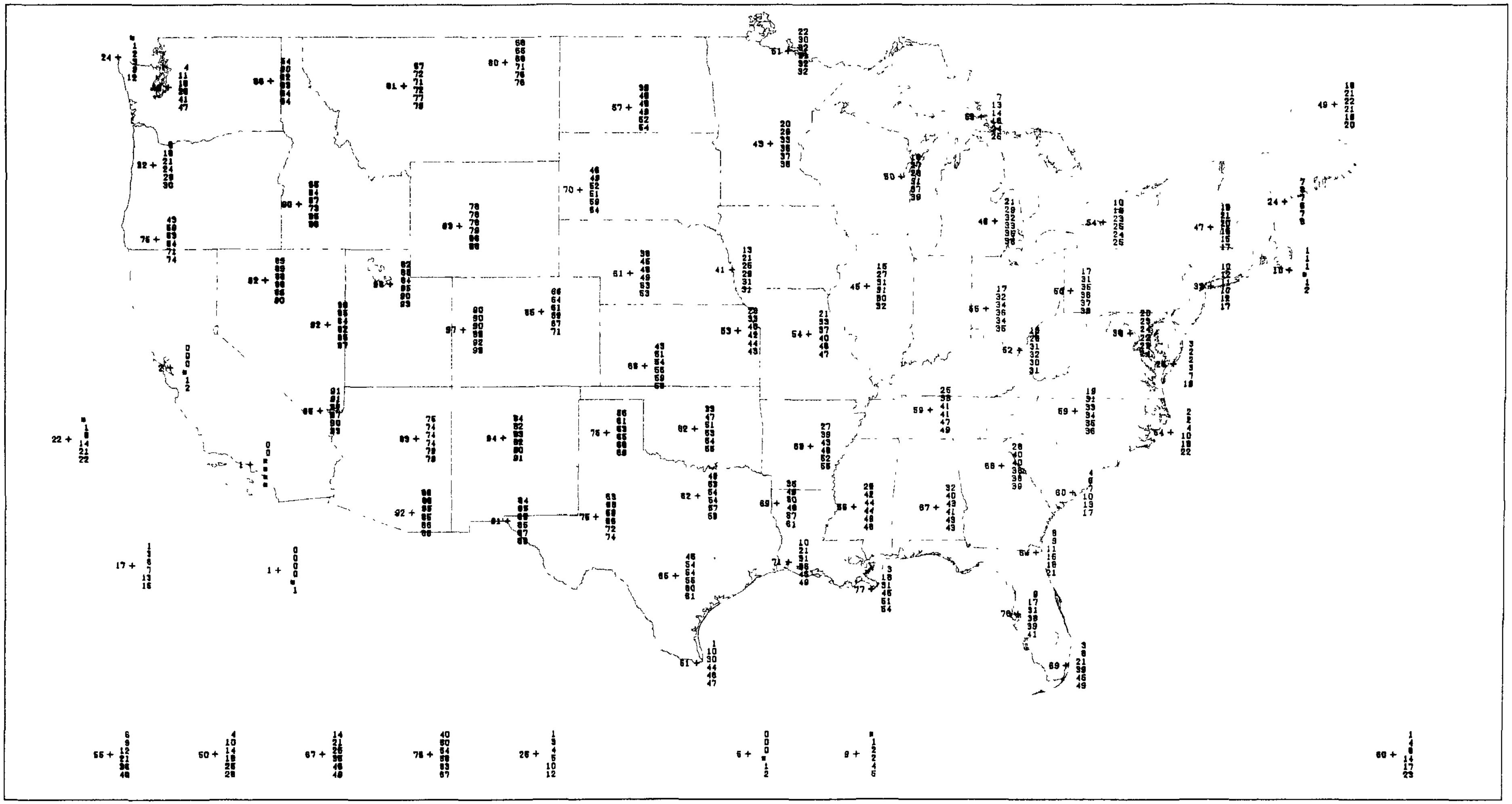

Figure 64. Percentage of summer 2315 GMT soundings with no inversion below 3000 m (left) and with a temperature decrease with height (-ΔT/ΔH) greater than 0.8 °C/100 m in the layers 1-100, 101-250, 251-500, 501-750, 751-1000, or 1001-1500 m AGL (right, bottom to top). See Figure 2 to identify peripheral stations.

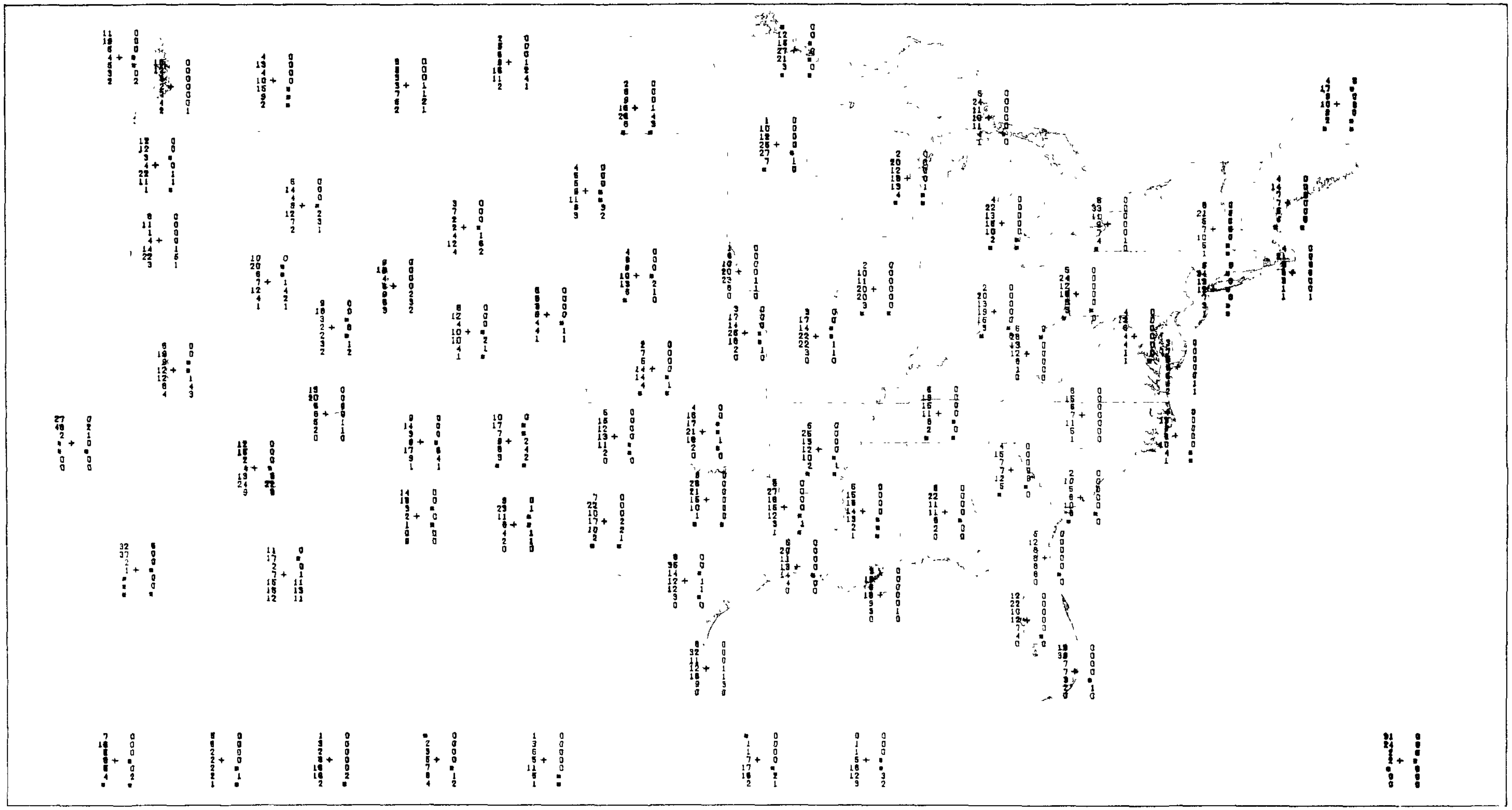

Figure 65 Percentage of winter 2315 GMT soundings with an elevated inversion base in the layer 1-100, 101-250, 251-500, 501-750, 751-1000, 1001-2000, or 2001-3000 m AGL (left, bottom to top), and a temperature decrease with height (-ΔT/ΔH) greater than 1 2 °C/100 m in the layer below (right, bottom to top) See Figure 2 to identify the peripheral stations

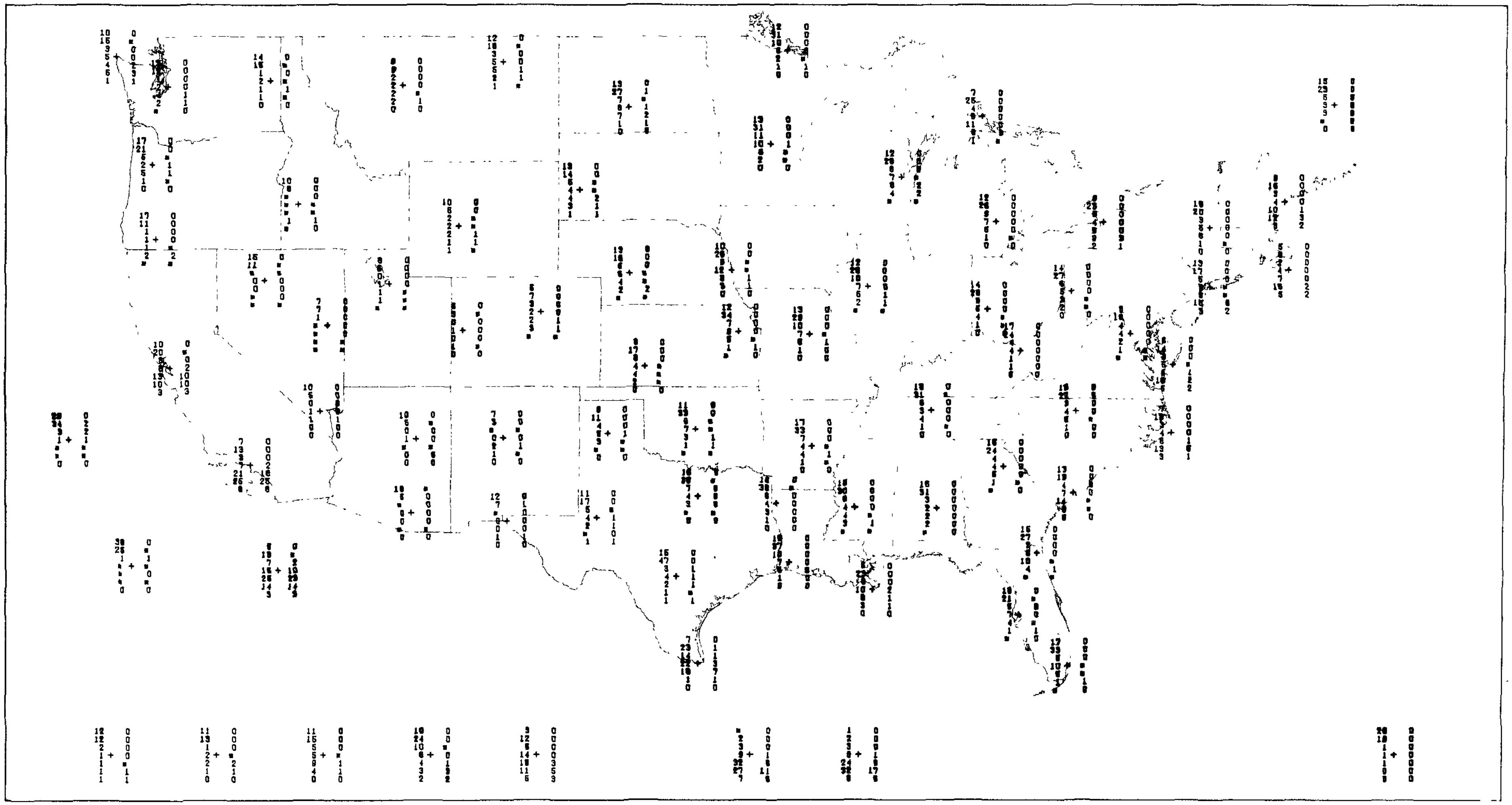

Figure 66. Percentage of spring 2315 GMT soundings with an elevated inversion base in the layer 1-100, 101-250, 251-500, 501-750, 751-1000, 1001-2000, or 2001-3000 m AGL (left, bottom to top) and a temperature decrease with height (-ΔT/ΔH) greater than 1.2 °C/100 m in the layer below (right, bottom to top) See Figure 2 to identify the peripheral stations

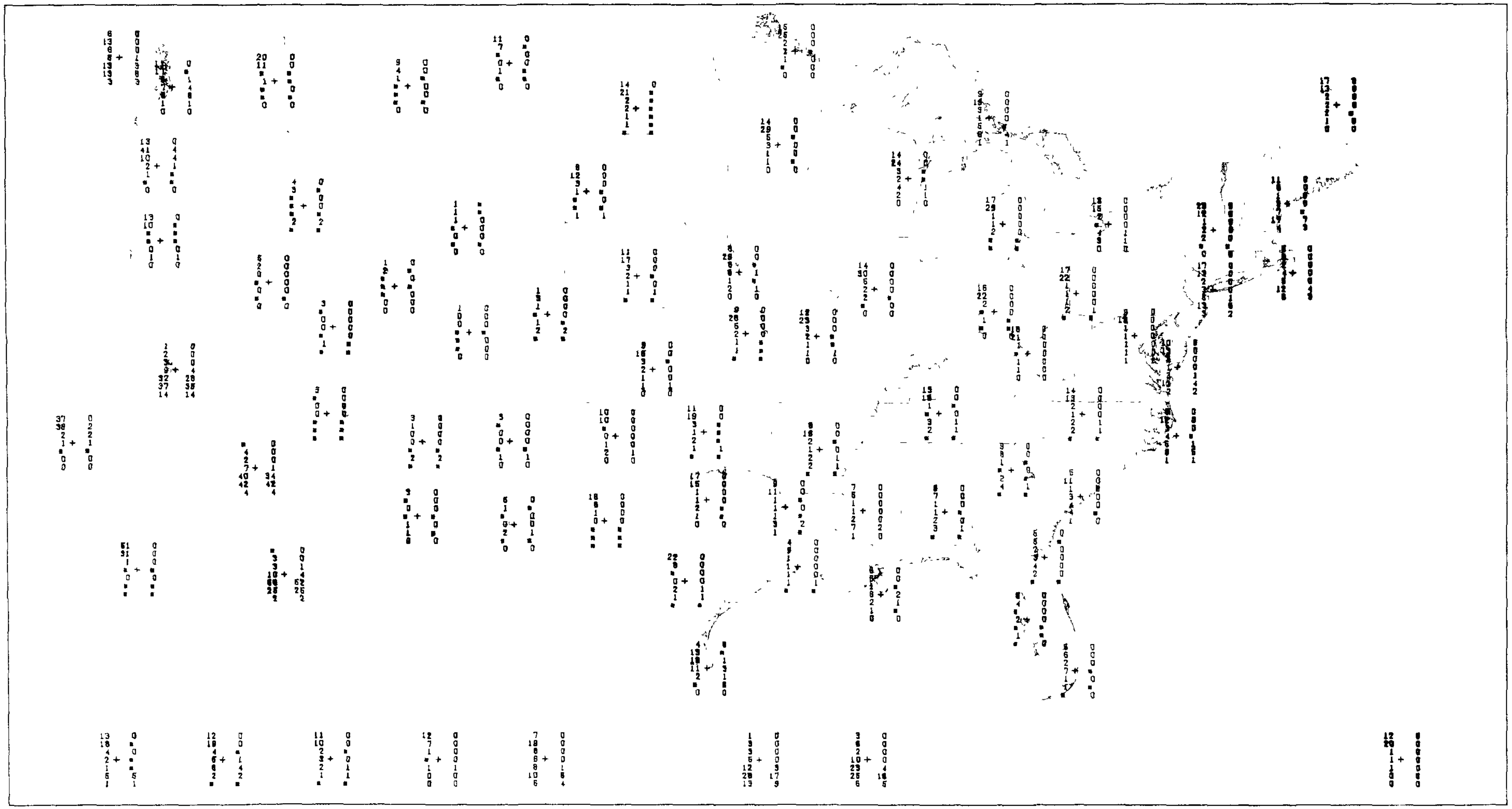

Figure 67 Percentage of summer 2315 GMT soundings with an elevated inversion base in the range 1-100, 101-250, 251-500, 501-750, 751-1000, 1001-2000, or 2001-3000 m AGL (left, bottom to top) and a temperature decrease with height ($-\Delta T/\Delta H$) greater than 1 2 °C/100 m in the layer below (right, bottom to top) See Figure 2 to identify the peripheral stations

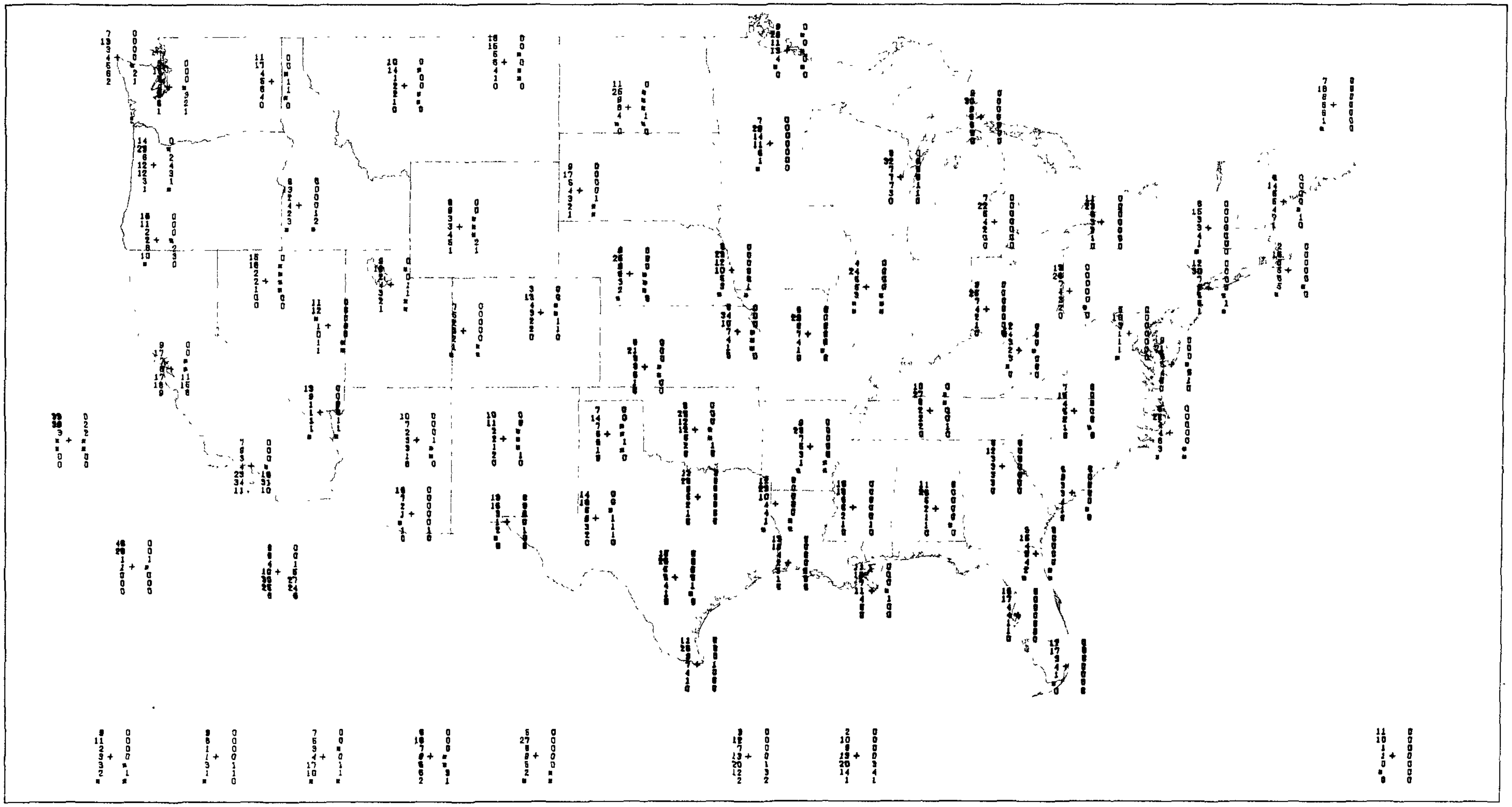

Figure 68. Percentage of autumn 2315 GMT soundings with an elevated inversion base in the range 1-100, 101-250, 251-500, 501-750, 751-1000, 1001-2000, or 2001-3000 m AGL (left, bottom to top) and a temperature decrease with height (-ΔT/ΔH) greater than 1.2 °C/100 m in the layer below (right, bottom to top). See Figure 2 to identify the peripheral stations.

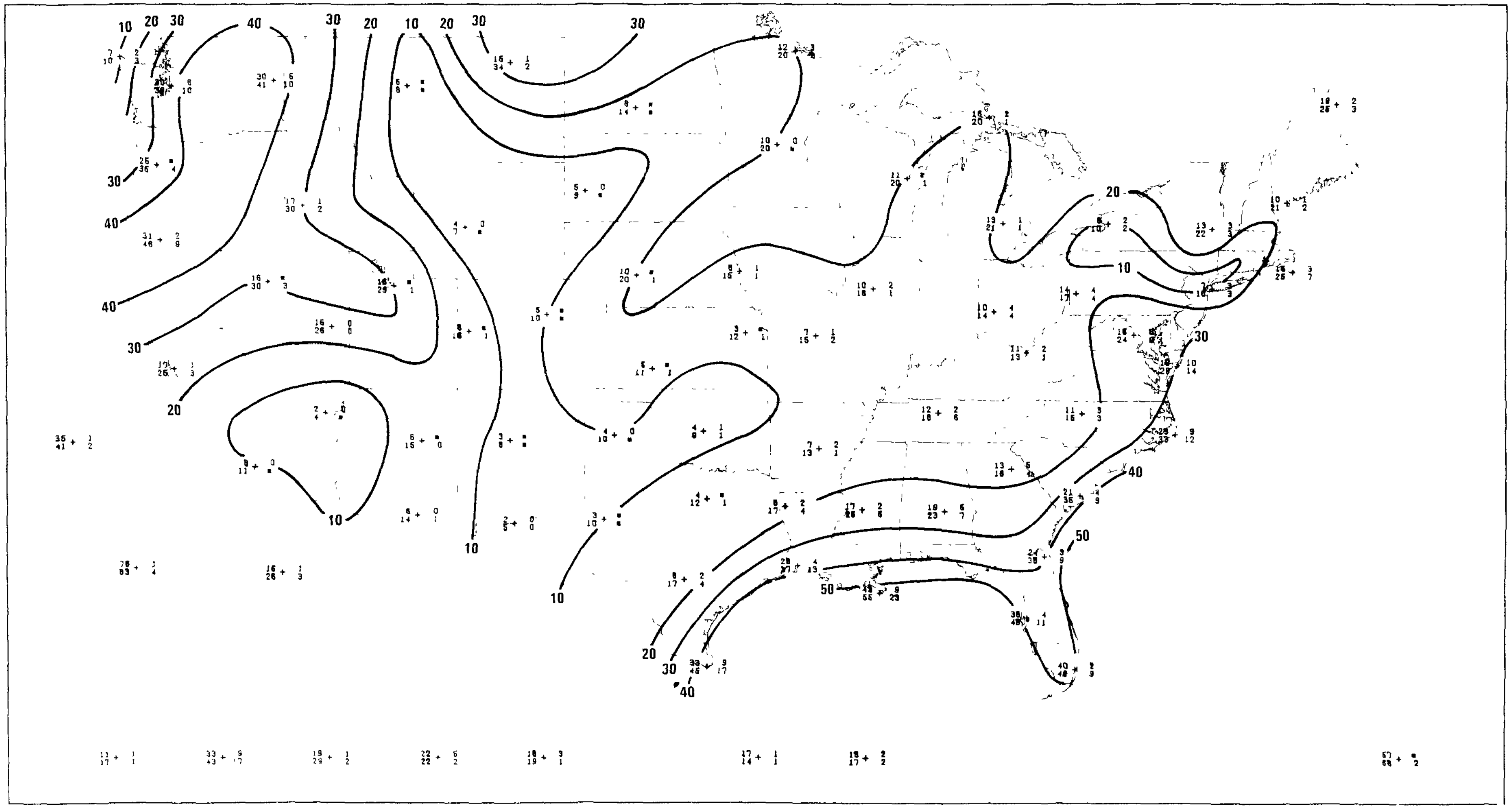

Figure 69. Percentage of winter 1115 GMT soundings with a surface-based inversion and an average relative humidity in the inversion (bottom) and in the 300-m layer above the inversion top (top) of >69% (left) and >89% (right). Isopleths are for surface-based inversions in which the average relative humidity is >69% See Figure 2 to identify the peripheral stations

SEASON 1 TIME 1' MAP

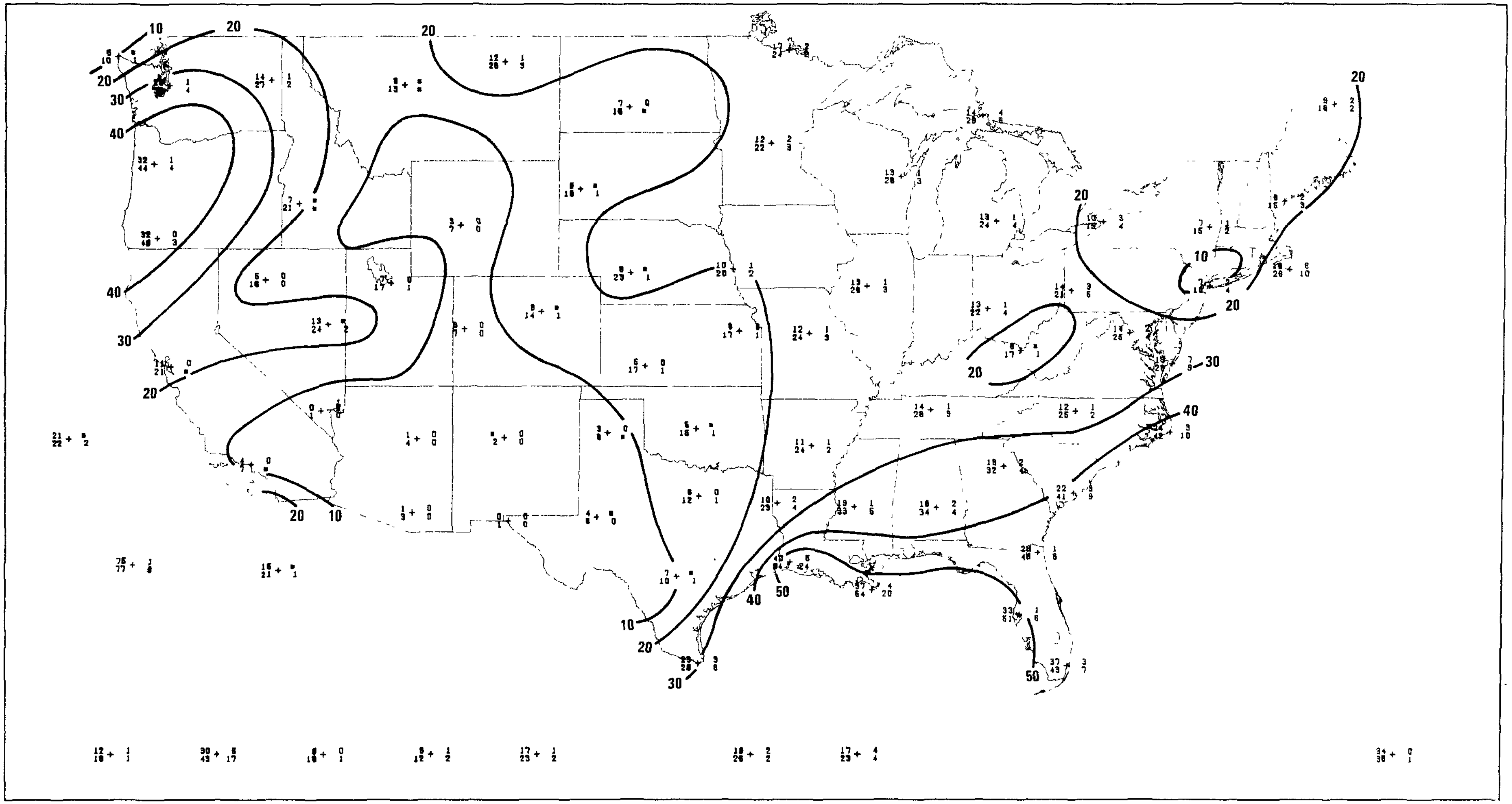

Figure 70. Percentage of spring 1115 GMT soundings with a surface-based inversion and an average relative humidity in the inversion (bottom) and in the 300-m layer above the inversion top (top) of >69% (left) and >89% (right). Isopleths are for surface-based inversions in which the average relative humidity is >69%. See Figure 2 to identify the peripheral stations.

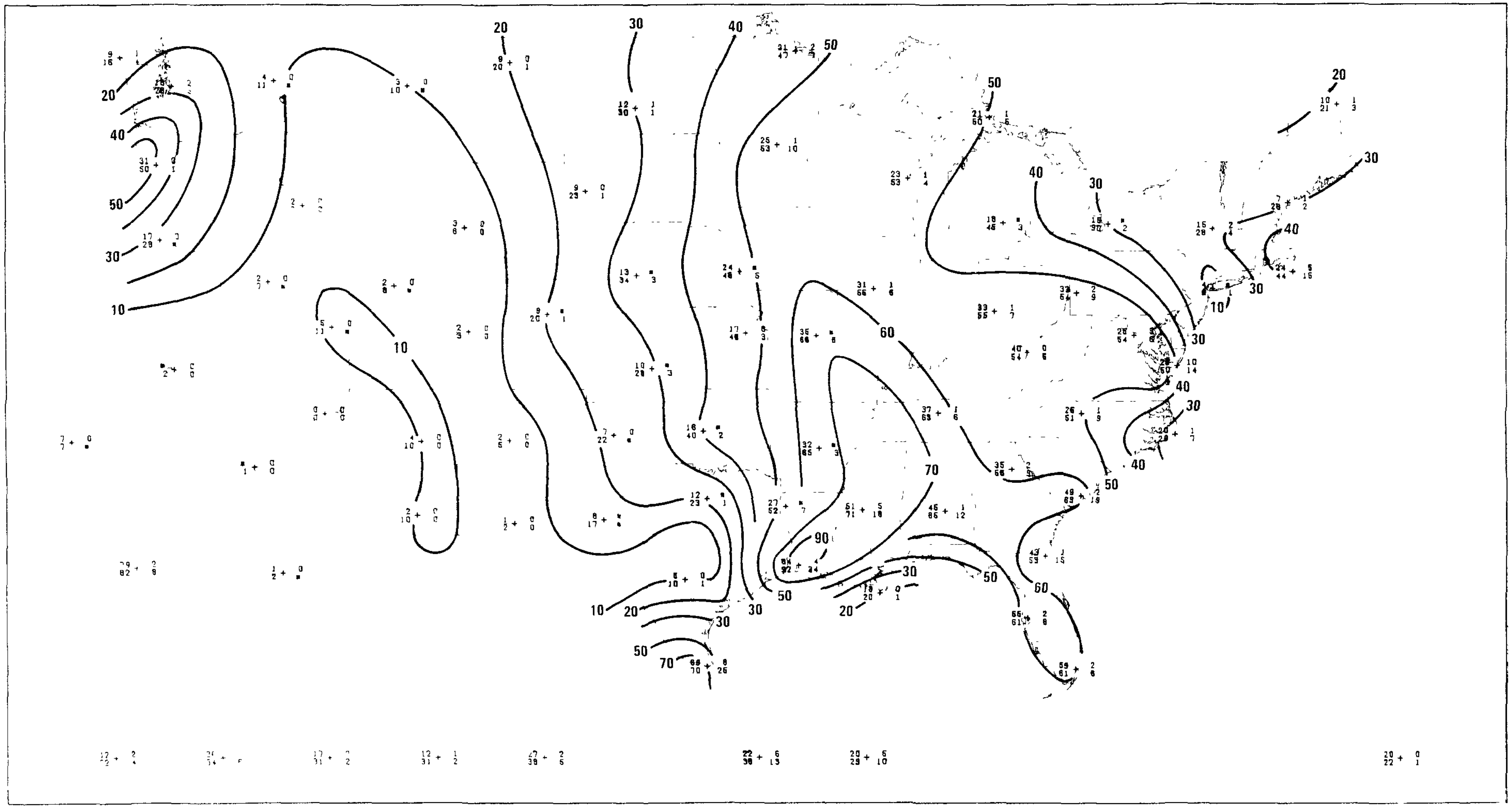


Figure 71 Percentage of summer 1115 GMT soundings with a surface-based inversion and an average relative humidity in the inversion (bottom) and in the 300-m layer above the inversion top (top) of >69% (left) and >89% (right) Isopleths are for surface-based inversions in which the average relative humidity is >69%. See Figure 2 to identify the peripheral stations

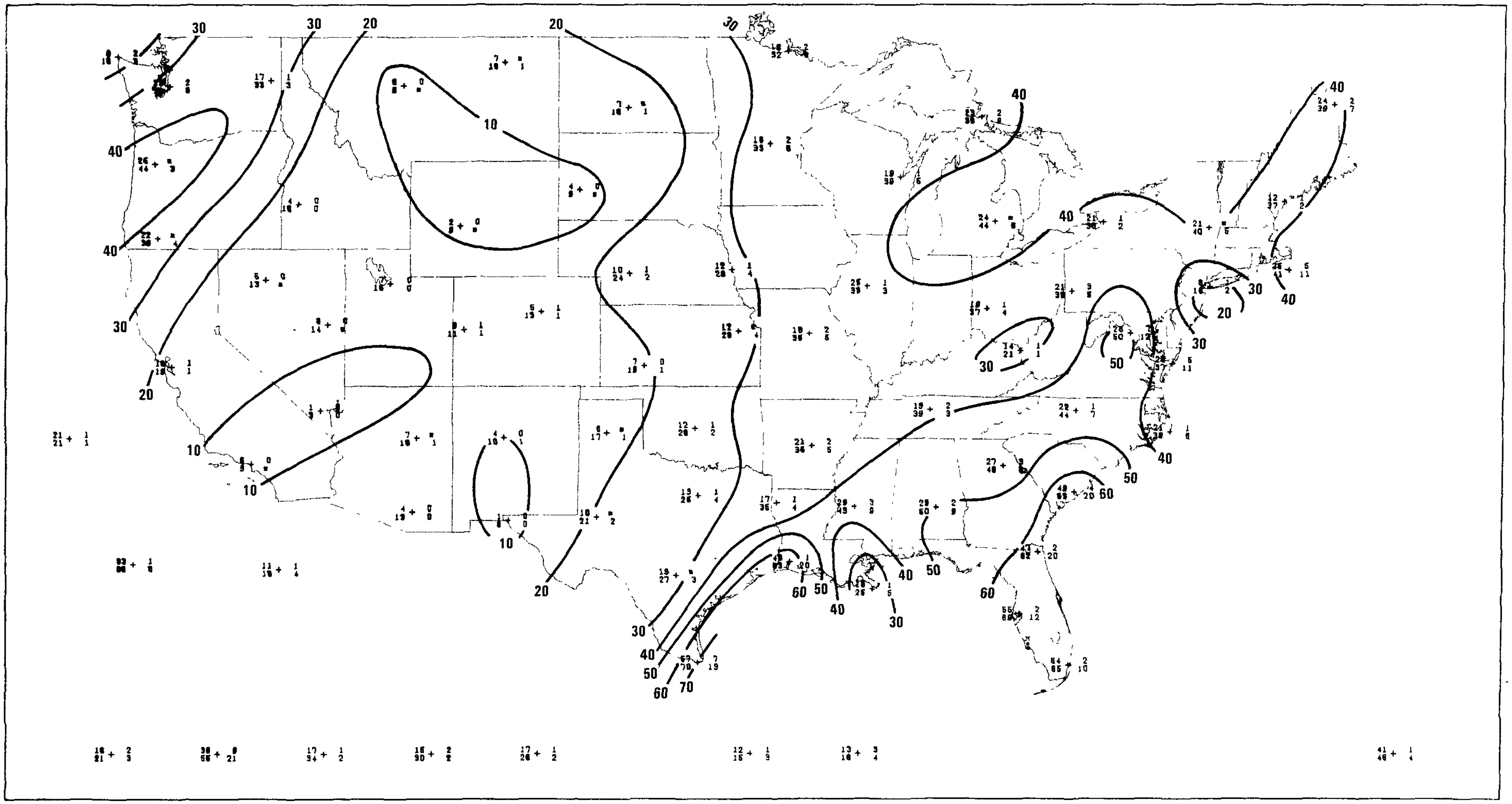


Figure 72. Percentage of autumn 1115 GMT soundings with a surface-based inversion and an average relative humidity in the inversion (bottom) and in the 300-m layer above the inversion top (top) of >69% (left) and >89% (right). Isopleths are for surface-based inversions in which the average relative humidity is >69%. See Figure 2 to identify the peripheral stations.

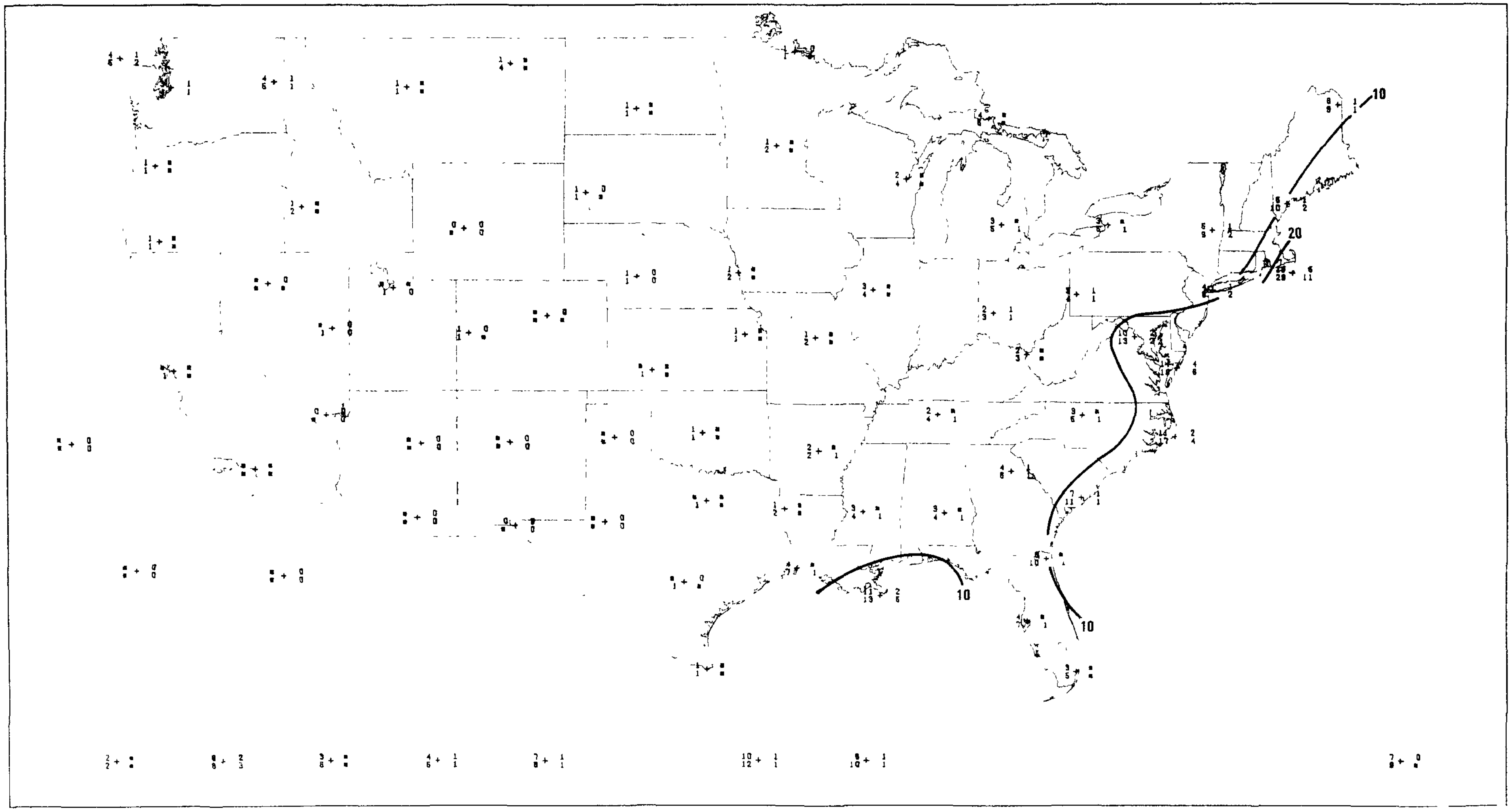


Figure 73 Percentage of all 2315 GMT soundings with a surface-based inversion and an average relative humidity in the inversion (bottom) and in the 300-m layer above the inversion top (top) of >69% (left) and >89% (right). Isopleths are for surface-based inversions in which the average relative humidity is >69%. See Figure 2 to identify the peripheral stations

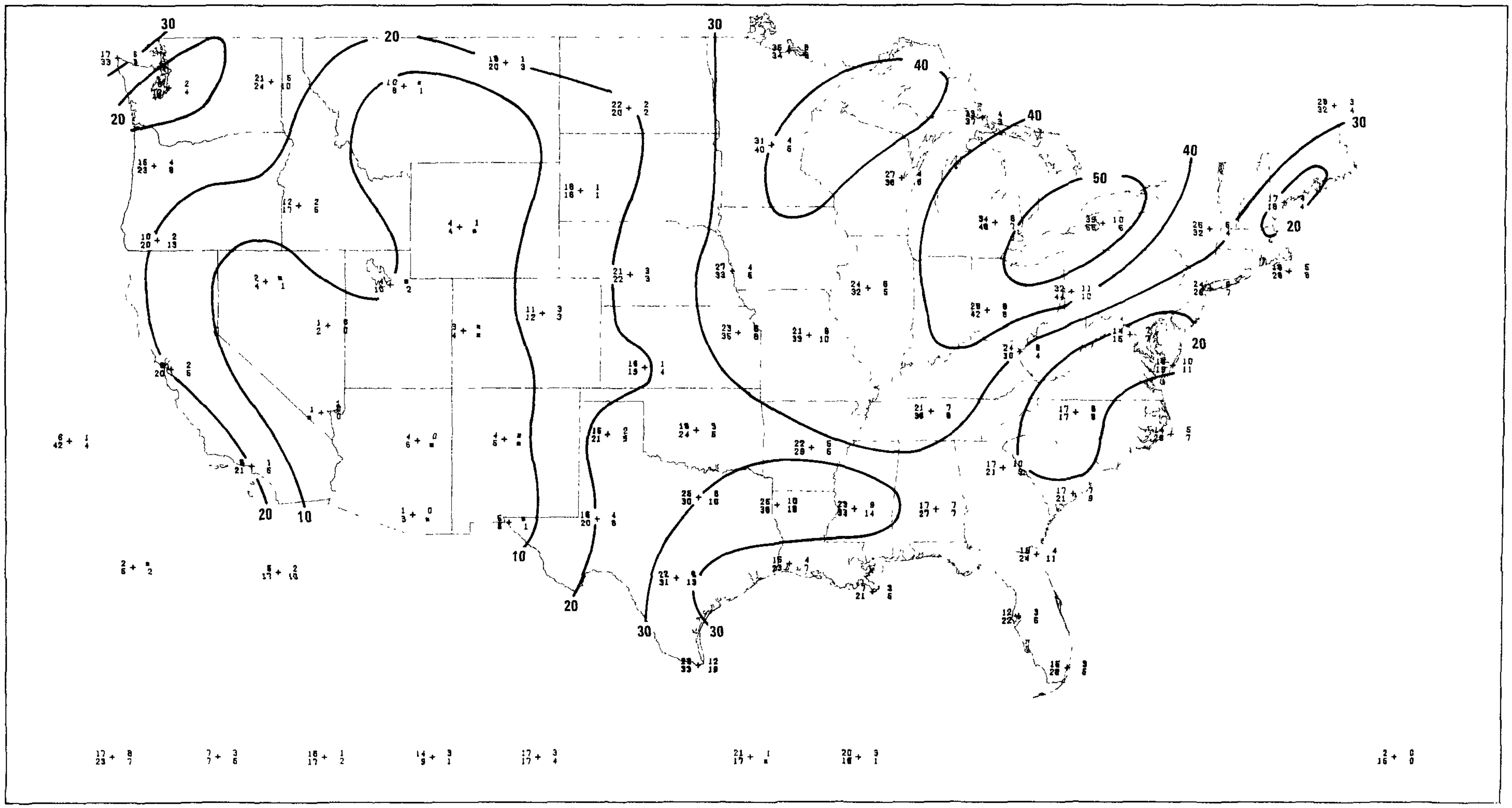


Figure 74. Percentage of winter 1115 GMT soundings with an elevated inversion based within 3000 m AGL and an average relative humidity in the entire layer below the inversion base (bottom) and in the inversion (top) of >69% (left) and >89% (right). Isopleths are for elevated inversions below which the average relative humidity is >69%. See Figure 2 to identify the peripheral stations.

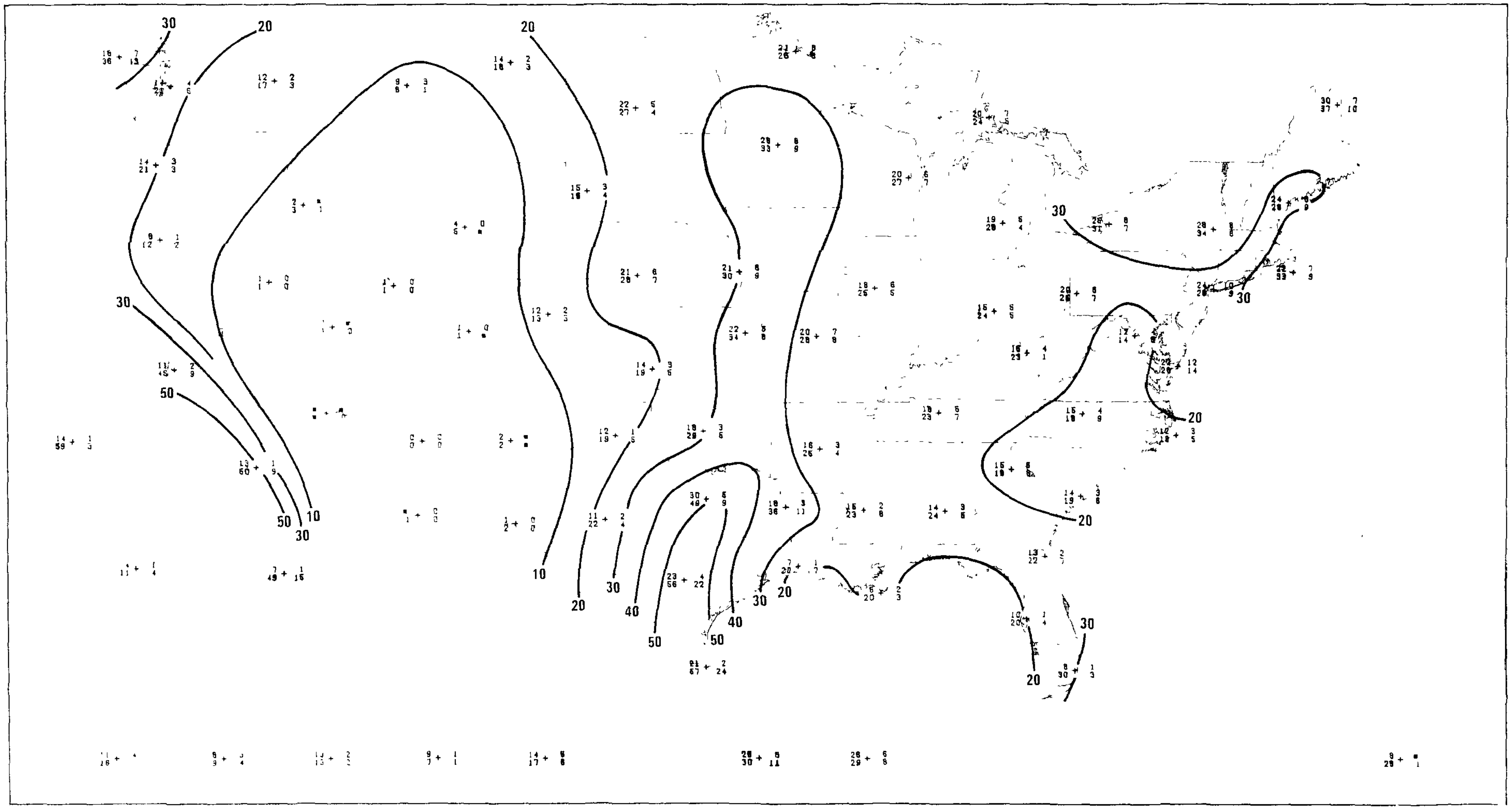


Figure 75  Percentage of spring 1115 GMT soundings with an elevated inversion base within 3000 m AGL and an average relative humidity in the entire layer below the inversion base (bottom) and in the inversion (top) of >69% (left) and >89% (right)  Isopleths are for elevated inversions below which the average relative humidity is >69%  See Figure 2 to identify the peripheral stations

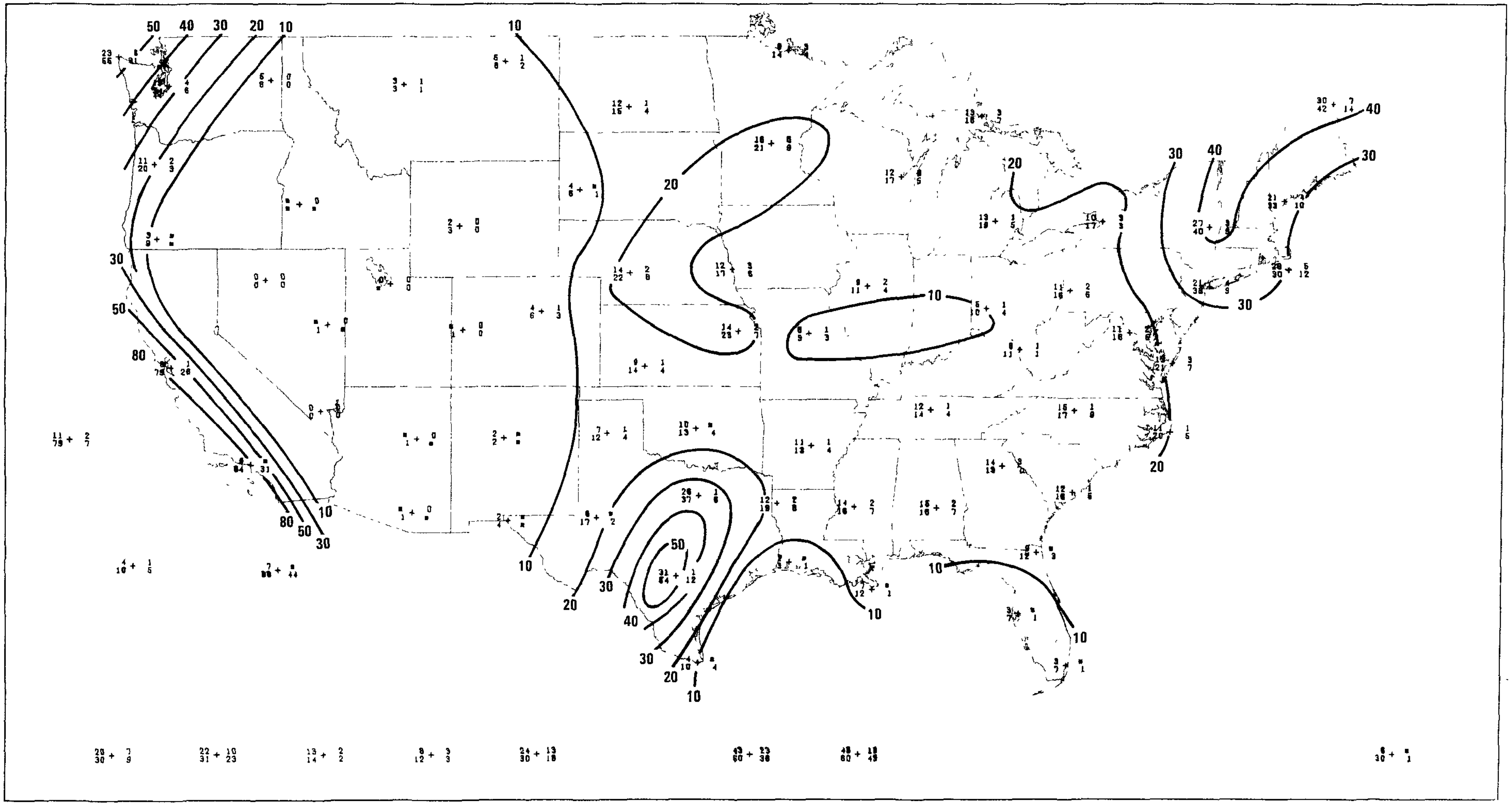

Figure 76. Percentage of summer 1115 GMT soundings with an elevated inversion base within 3000 m AGL and an average relative humidity in the entire layer below the inversion base (bottom) and in the inversion (top) of >69% (left) and >89% (right). Isopleths are for elevated inversions below which the average relative humidity is >69%. See Figure 2 to identify the peripheral stations.

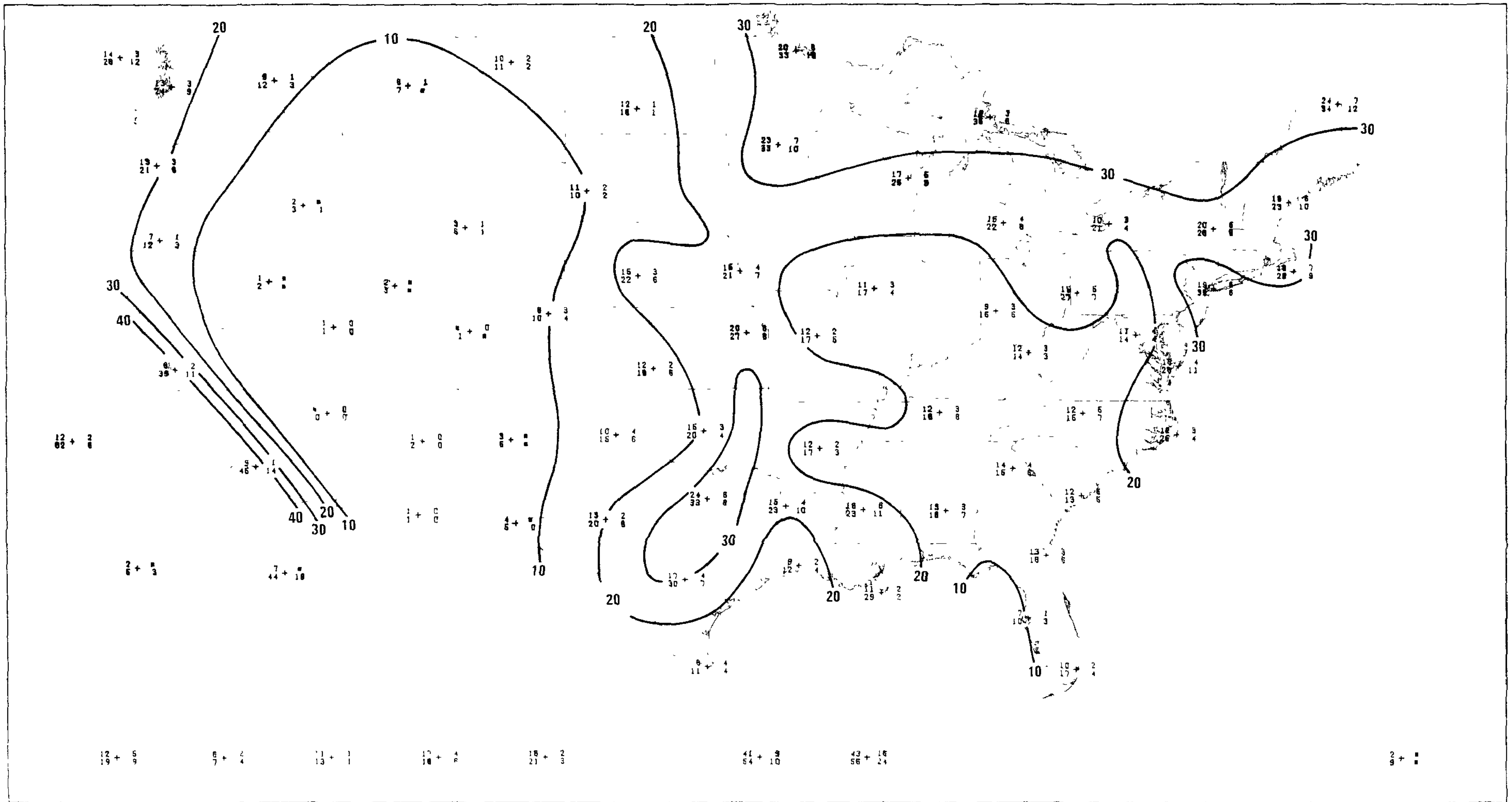

Figure 77 Percentage of autumn 1115 GMT soundings with an elevated inversion base within 3000 m AGL and an average relative humidity in the entire layer below the inversion base (bottom) and in the inversion (top) of >69% (left) and >89% (right). Isopleths are for elevated inversions below which the average relative humidity is >69%. See Figure 2 to identify the peripheral stations

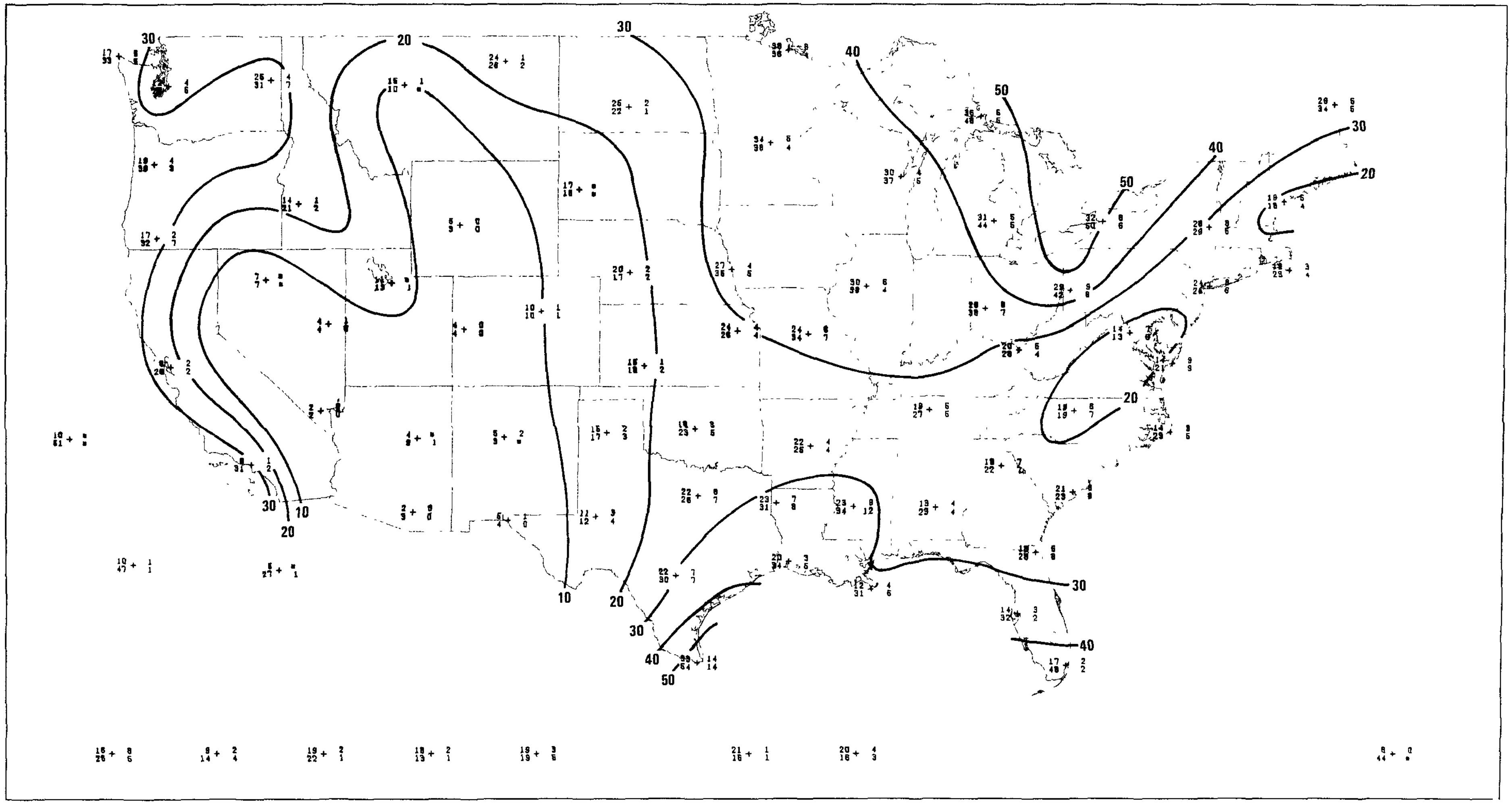


Figure 78. Percentage of winter 2315 GMT soundings with an elevated inversion base within 3000 m AGL and an average relative humidity in the entire layer below the inversion base (bottom) and in the inversion (top) of >69% (left) and >89% (right). Isopleths are for elevated *inversions below which the average relative humidity is >69%. See Figure 2 to identify the peripheral stations.*

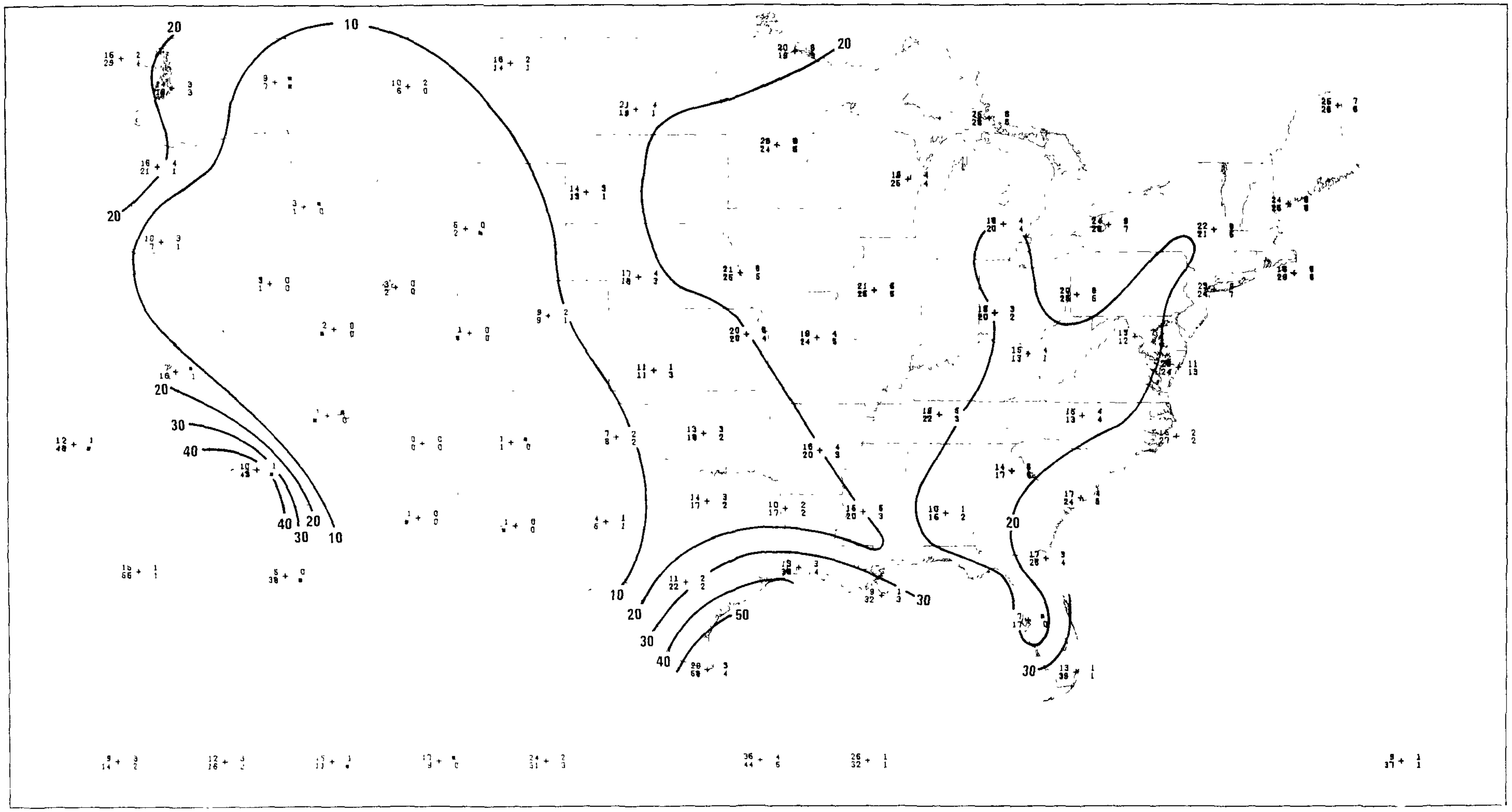


Figure 79  Percentage of spring 2315 GMT soundings with an elevated inversion base within 3000 m AGL and an average relative humidity in the entire layer below the inversion base (bottom) and in the inversion (top) of >69% (left) and >89% (right)  Isopleths are for elevated inversions below which the average relative humidity is >69%  See Figure 2 to identify the peripheral stations.

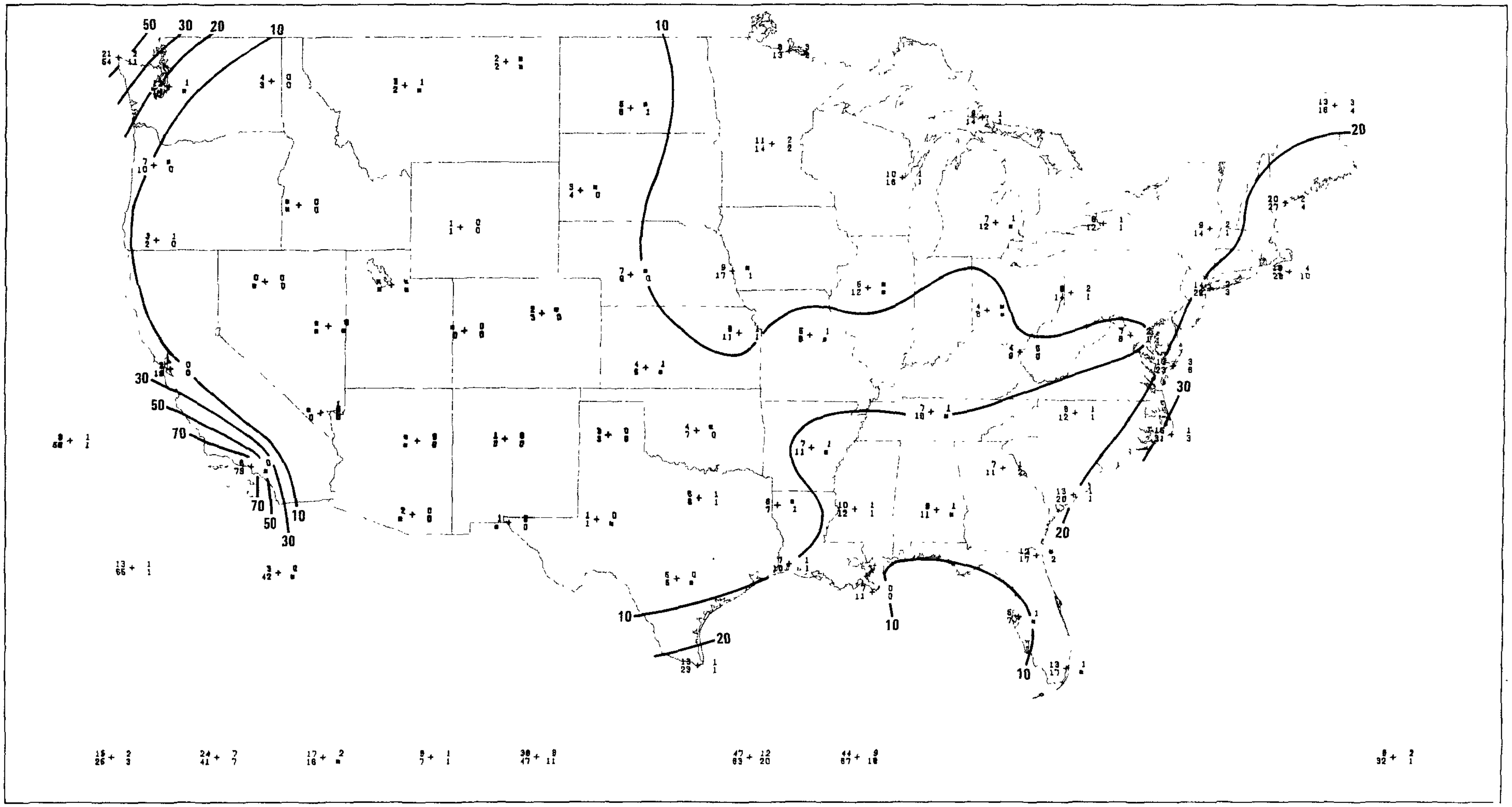


Figure 80. Percentage of summer 2315 GMT soundings with an elevated inversion base within 3000 m AGL and an average relative humidity in the entire layer below the inversion base (bottom) and in the inversion (top) of >69% (left) and >89% (right). Isopleths are for elevated inversions below which the average relative humidity is >69%. See Figure 2 to identify the peripheral stations.

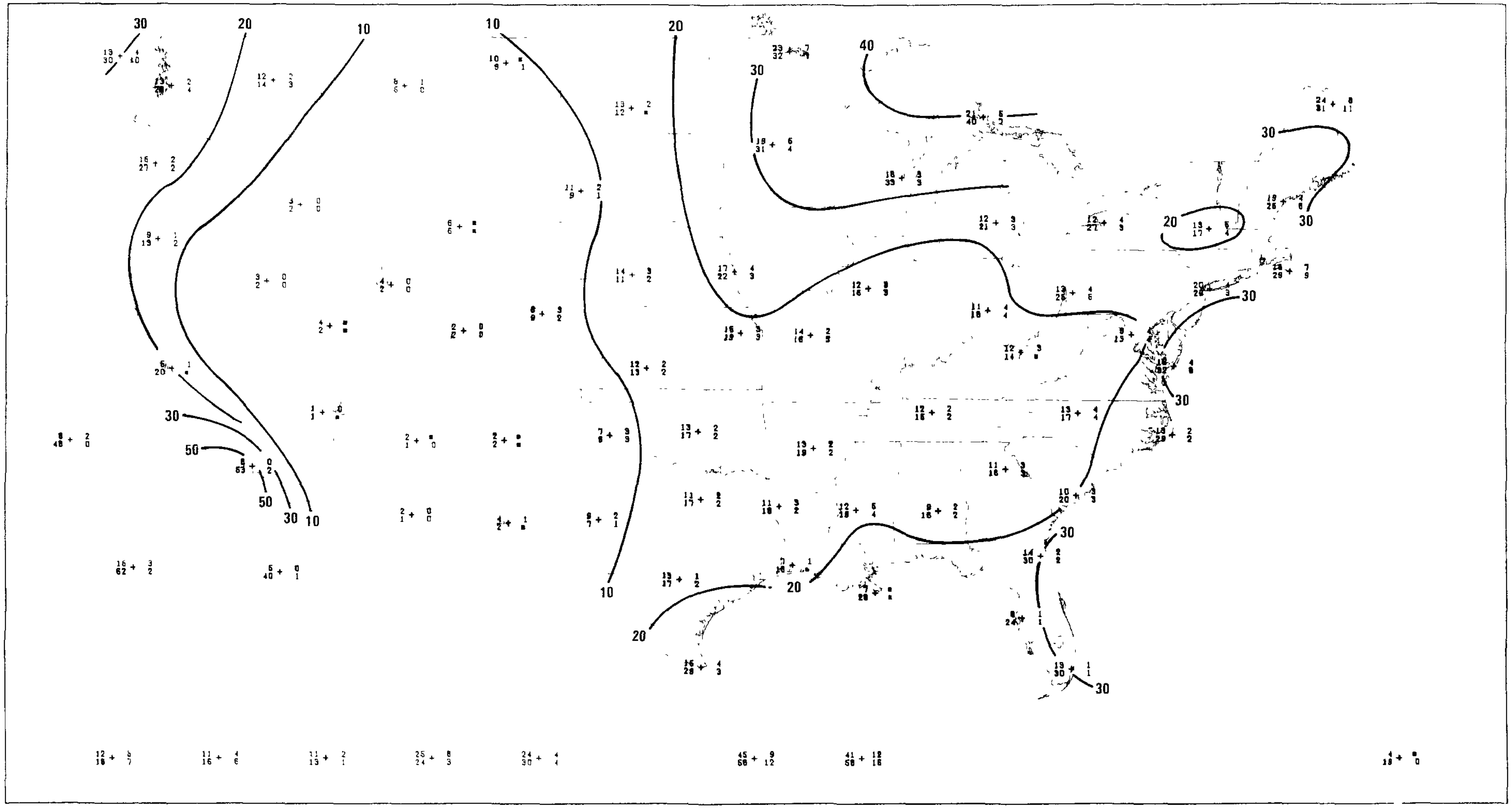

Figure 81 Percentage of autumn 2315 GMT soundings with an elevated inversion base within 3000 m AGL and an average relative humidity in the entire layer below the inversion base (bottom) and in the inversion (top) of >69% (left) and >89% (right). Isopleths are for elevated inversions below which the average relative humidity is >69% See Figure 2 to identify the peripheral stations.

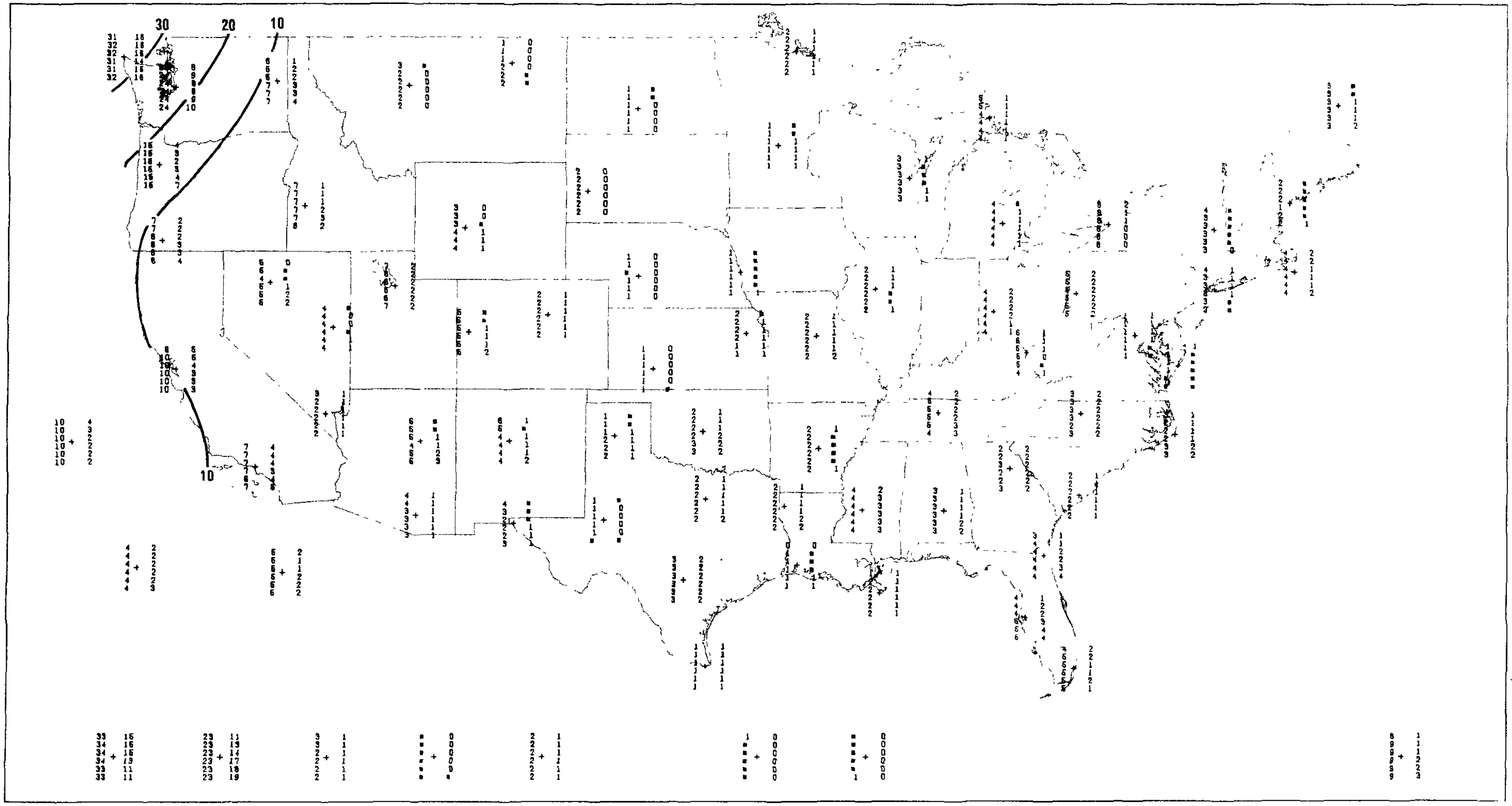

Figure 82 Percentage of winter 1115 GMT soundings with no inversion below 3000 m AGL and an average relative humidity >69% (left) and >89% (right) in the layers 1-100, 101-250, 251-500, 501-750, 751-1000, and 1001-1500 m AGL (bottom to top). Isopleths are for an average relative humidity >69% in the layer 251-500 m AGL. See Figure 2 to identify the peripheral stations.

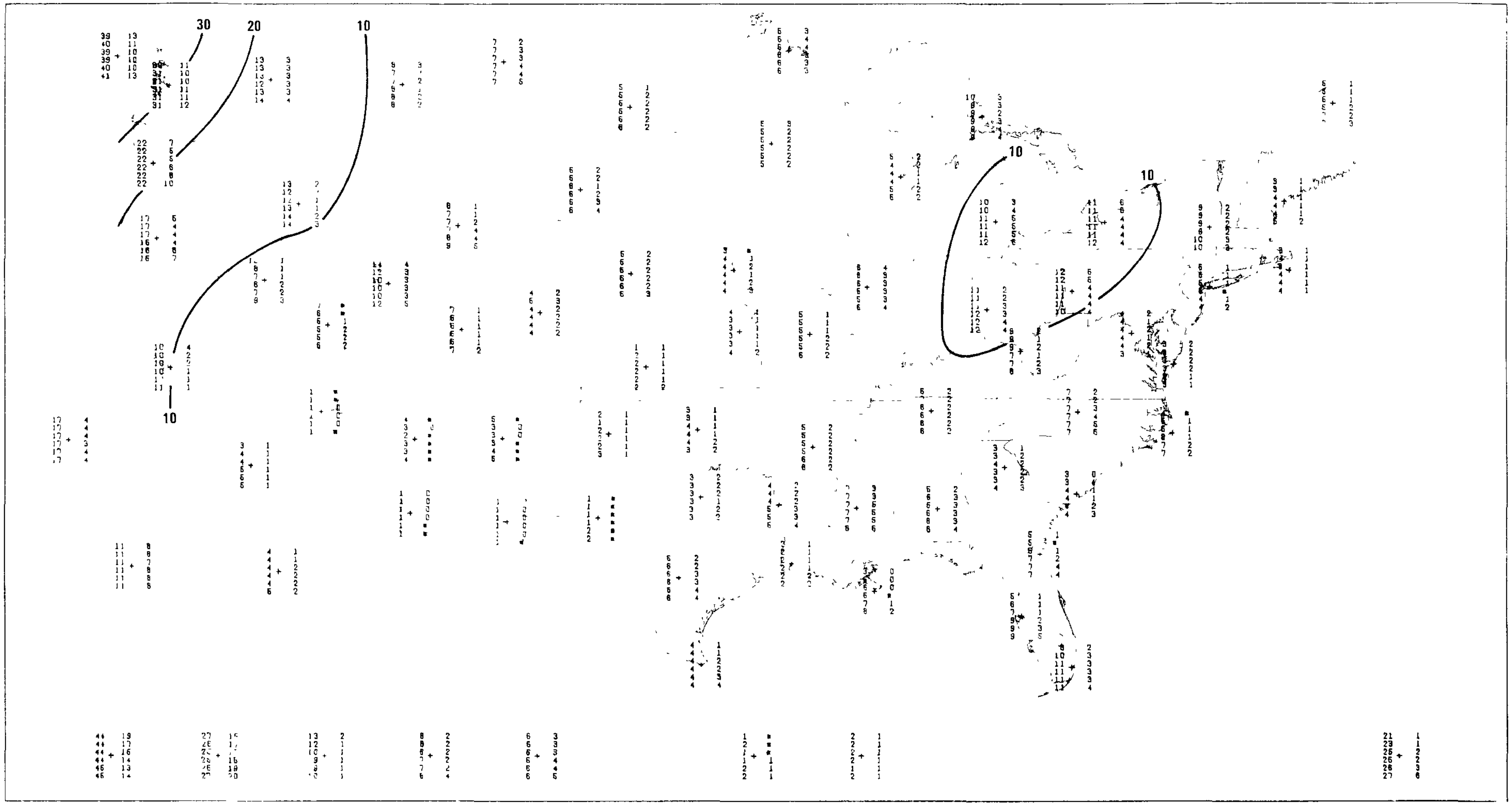


Figure 83 Percentage of spring 1115 GMT soundings with no inversion below 3000 m AGL and an average relative humidity >69% (left) and >89% (right) in the layers 1-100, 101-250, 251-500, 501-750, 751-1000, and 1001-1500 m AGL (bottom to top). Isopleths are for an average relative humidity >69% in the layer 251-500 m AGL. See Figure 2 to identify the peripheral stations.

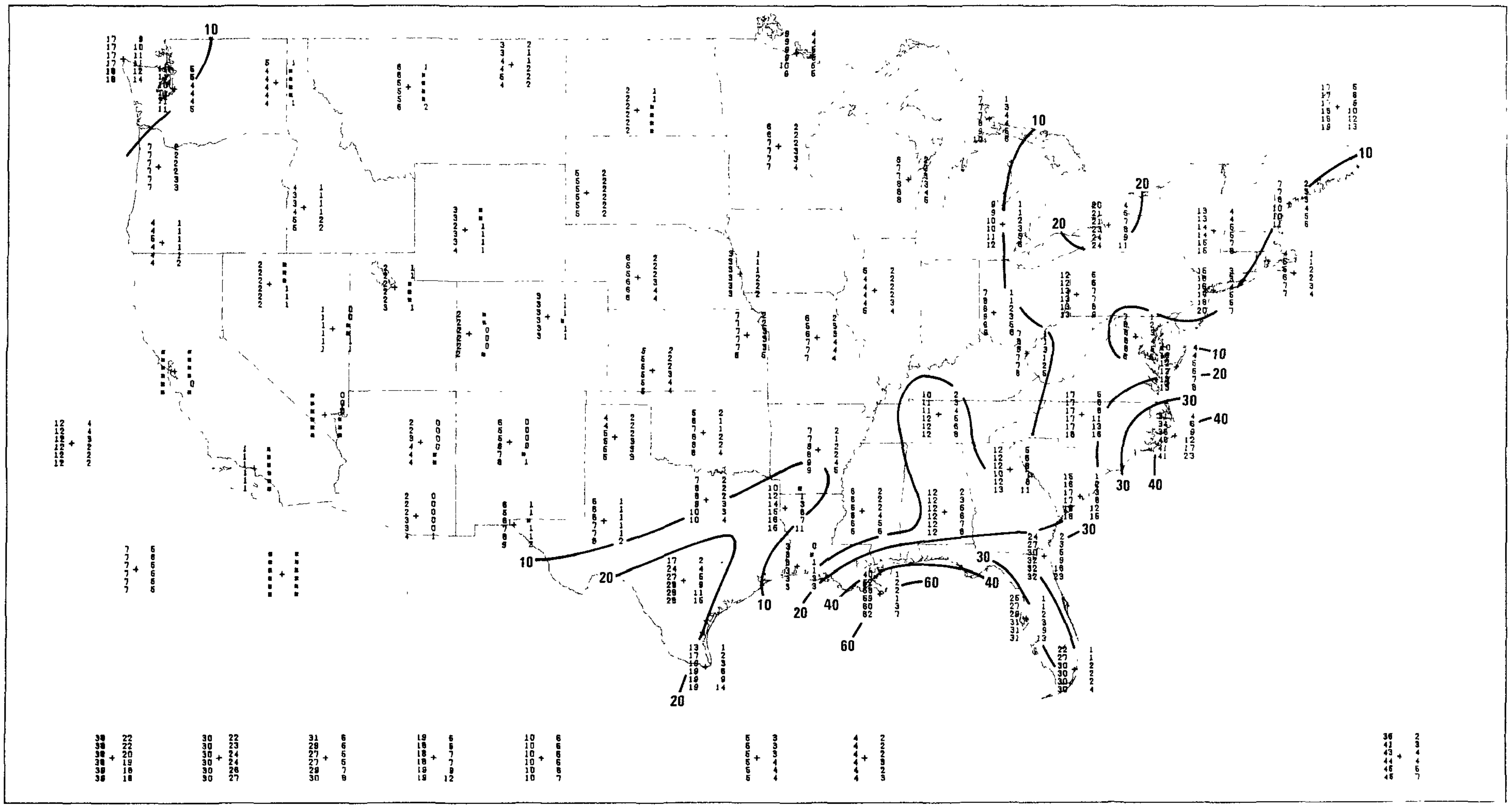

Figure 84. Percentage of summer 1115 GMT soundings with no inversion below 3000 m AGL and an average relative humidity >69% (left) and >89% (right) in the layers 1-100, 101-250, 251-500, 501-750, 751-1000, and 1001-1500 m AGL (bottom to top). Isopleths are for an average relative humidity >69% in the layer 251-500 m AGL. See Figure 2 to identify the peripheral stations

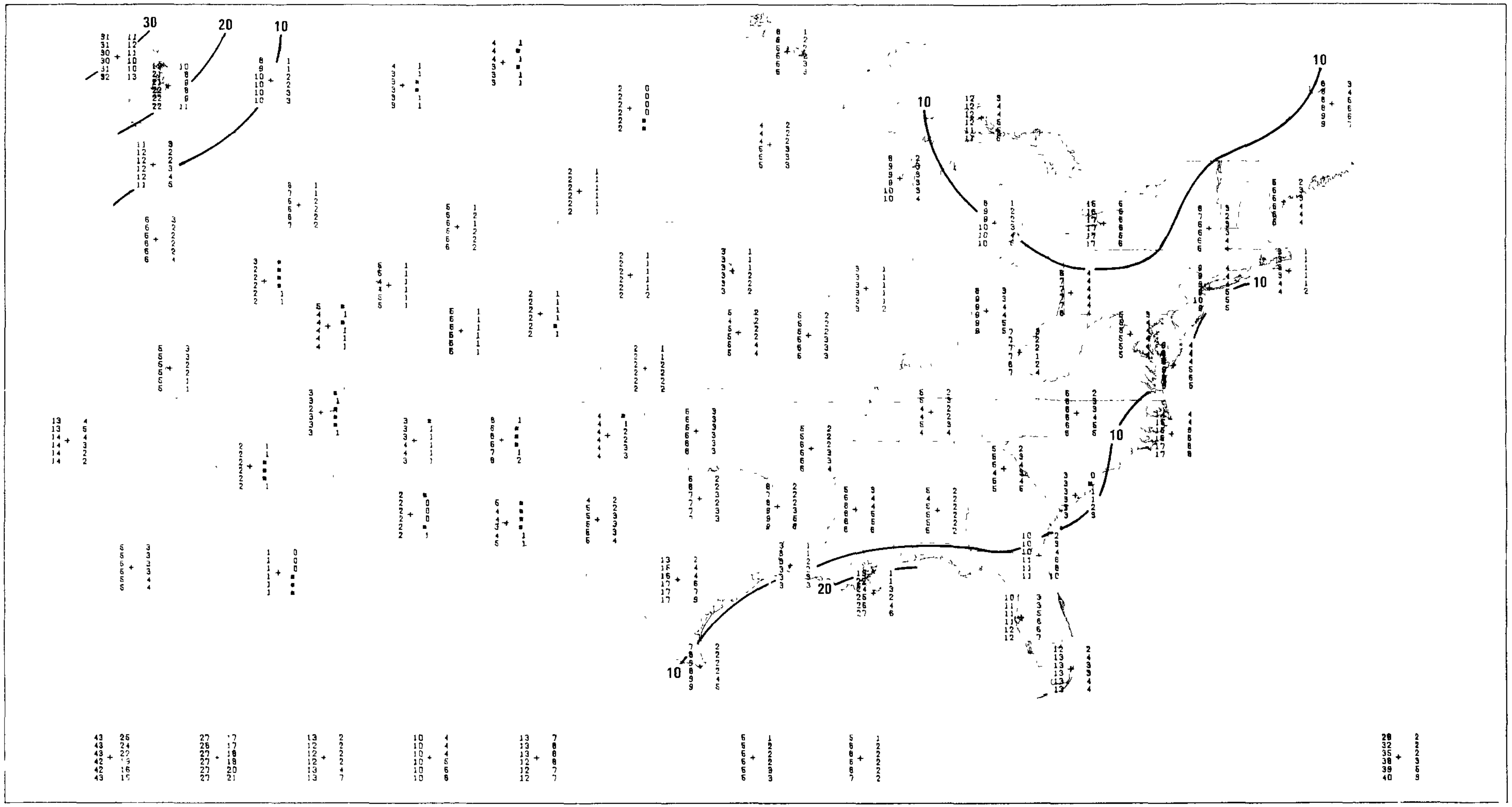

Figure 85 Percentage of autumn 1115 GMT soundings with no inversion below 3000 m AGL and an average relative humidity >69% (left) and >89% (right) in the layers 1-100, 101-250, 251-500, 501-750, 751-1000, and 1001-1500 m AGL (bottom to top). Isopleths are for an average relative humidity >69% in the layer 251-500 m AGL. See Figure 2 to identify the peripheral stations

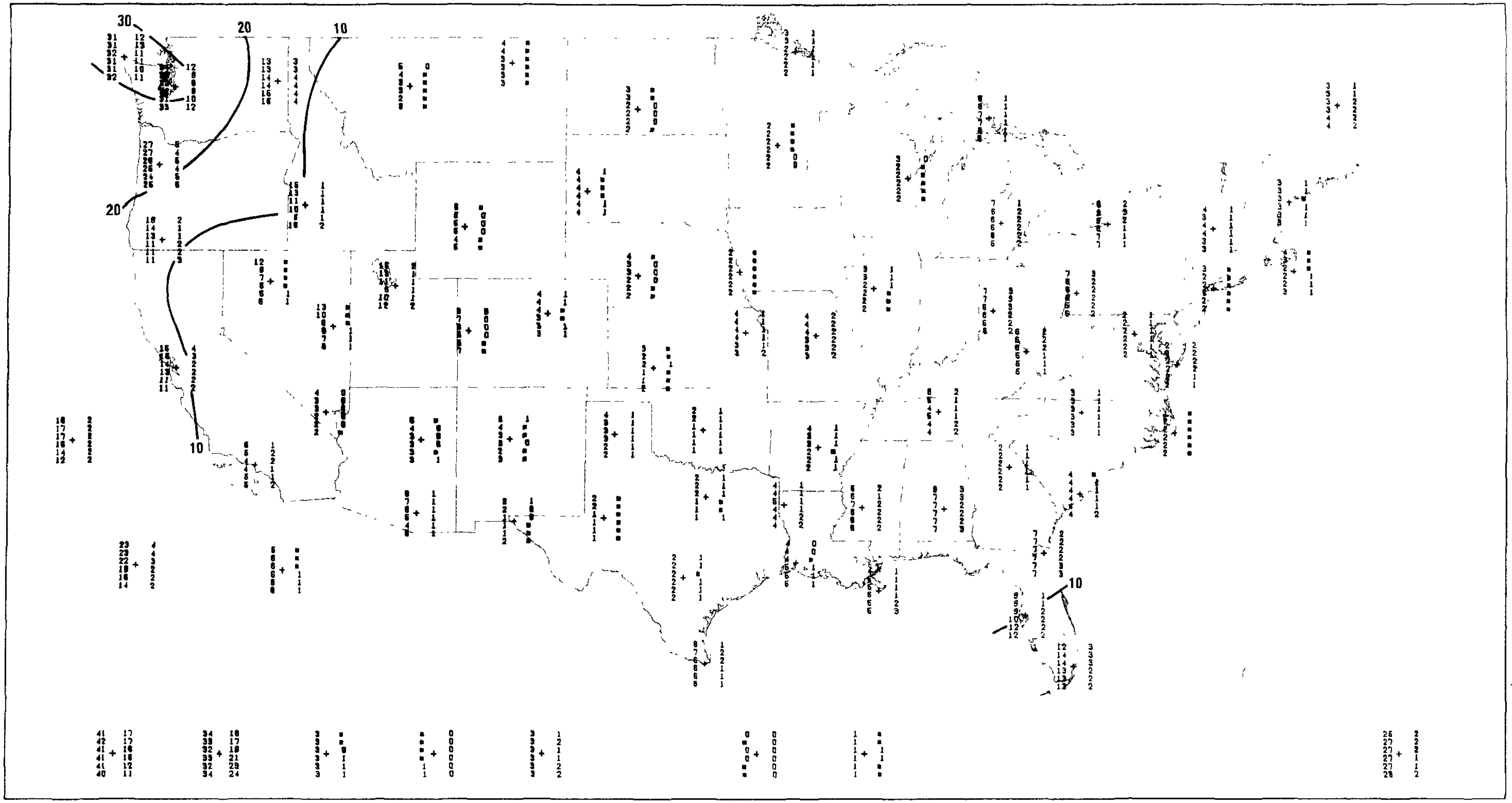

Figure 86. Percentage of winter 2315 GMT soundings with no inversion below 3000 m AGL and an average relative humidity > 69% (left) and >89% (right) in the layers 1-100, 101-250, 251-500, 501-750, 751-1000, and 1001-1500 m AGL (bottom to top). Isopleths are for an average relative humidity >69% in the layer 251-500 m AGL. See Figure 2 to identify peripheral stations.

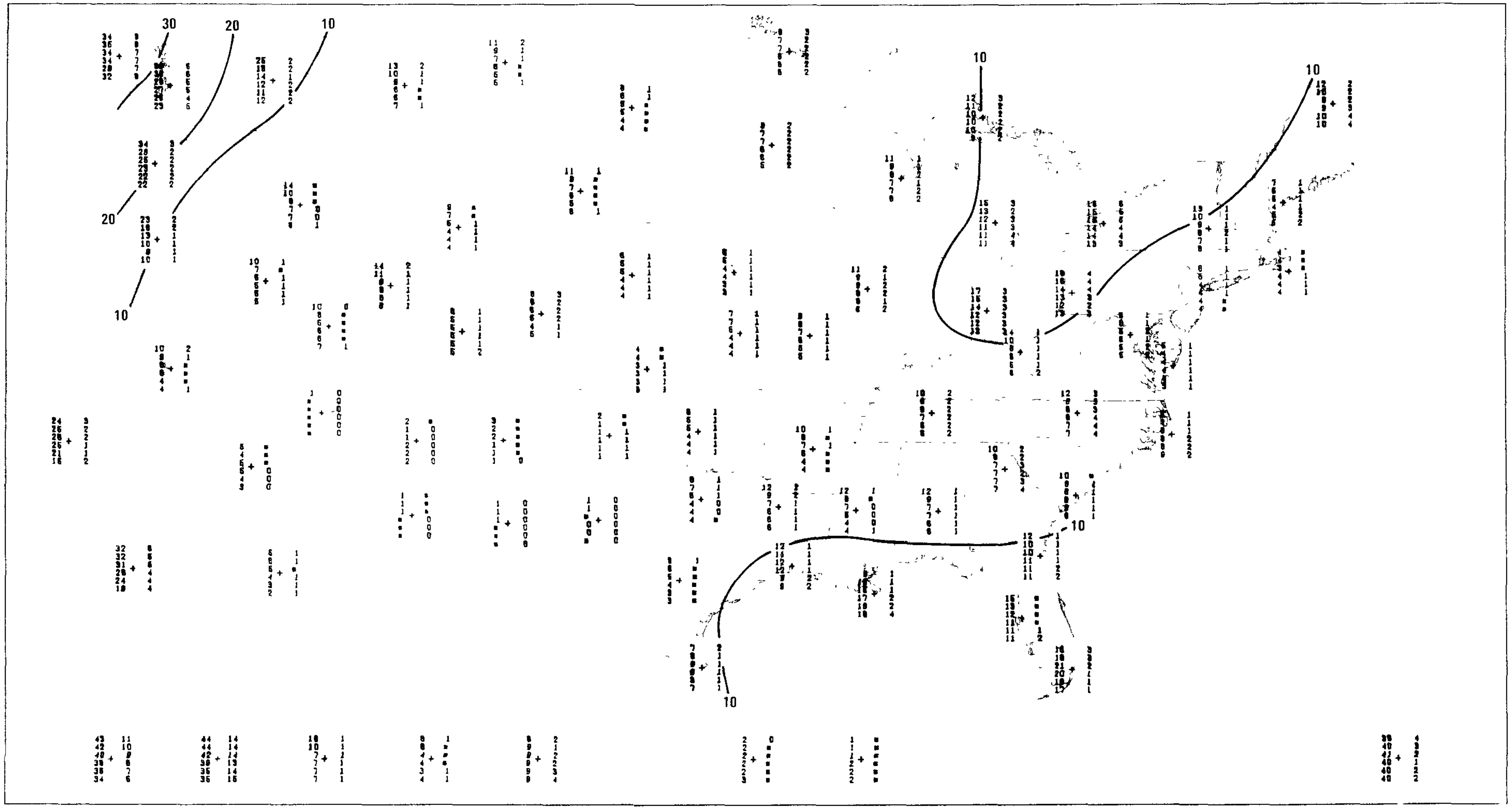

Figure 87  Percentage of spring 2315 GMT soundings with no inversion below 3000 m AGL and an average relative humidity >69% (left) and >89% (right) in the layers 1-100, 101-250, 251-500, 501-750, 751-1000, and 1001-1500 m AGL (bottom to top)  Isopleths are for an a average relative humidity >69% in the layer 251-500 m AGL  See Figure 2 to identify peripheral stations

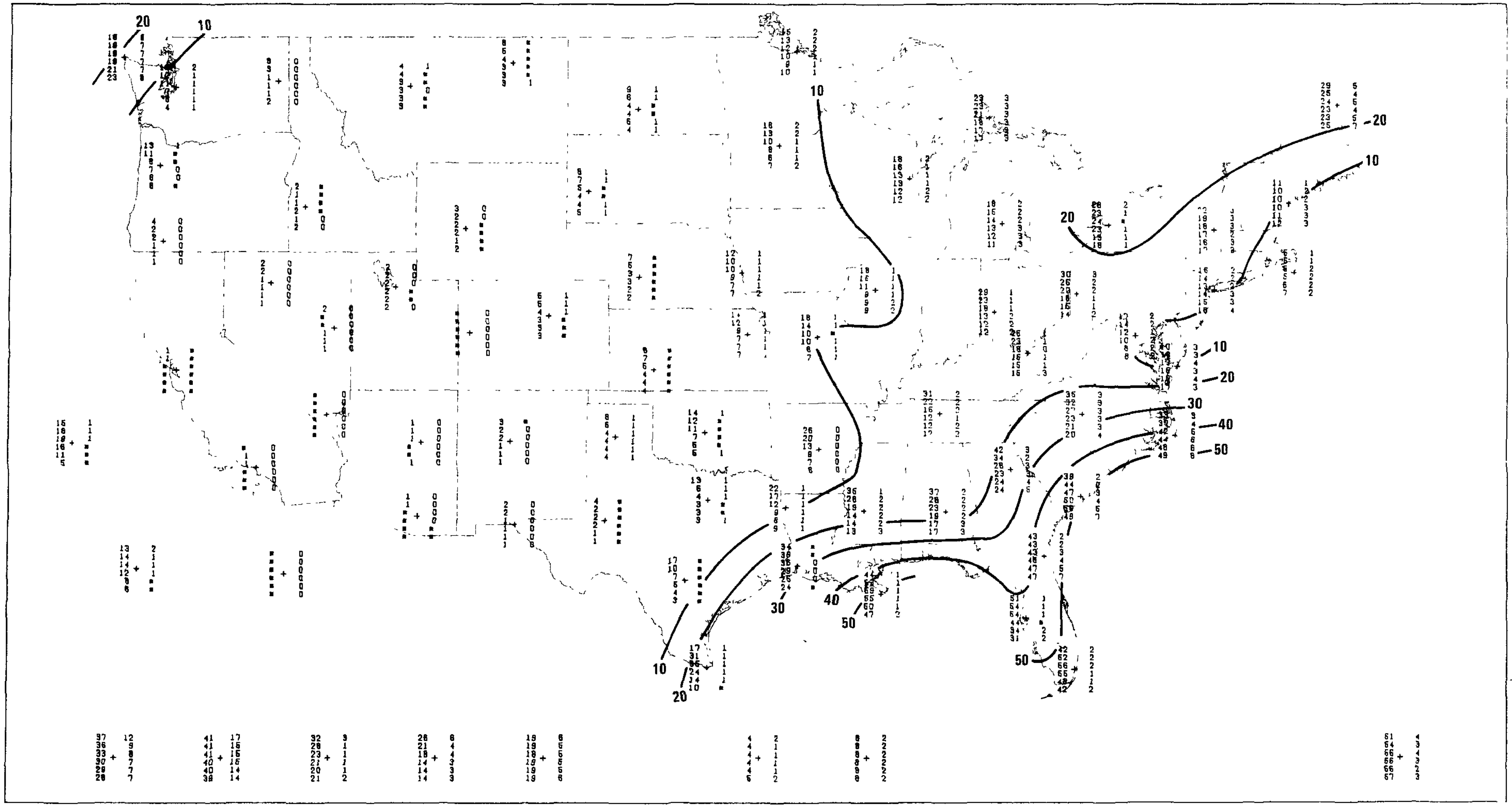

Figure 88. Percentage of summer 2315 GMT soundings with no inversion below 3000 m AGL and an average relative humidity > 69% (left) and >89% (right) in the layers 1-100, 101-250, 251-500, 501-750, 751-1000, and 1001-1500 m AGL (bottom to top) Isopleths are for an average relative humidity >69% in the layer 251-500 m AGL. See Figure 2 to identify peripheral stations.

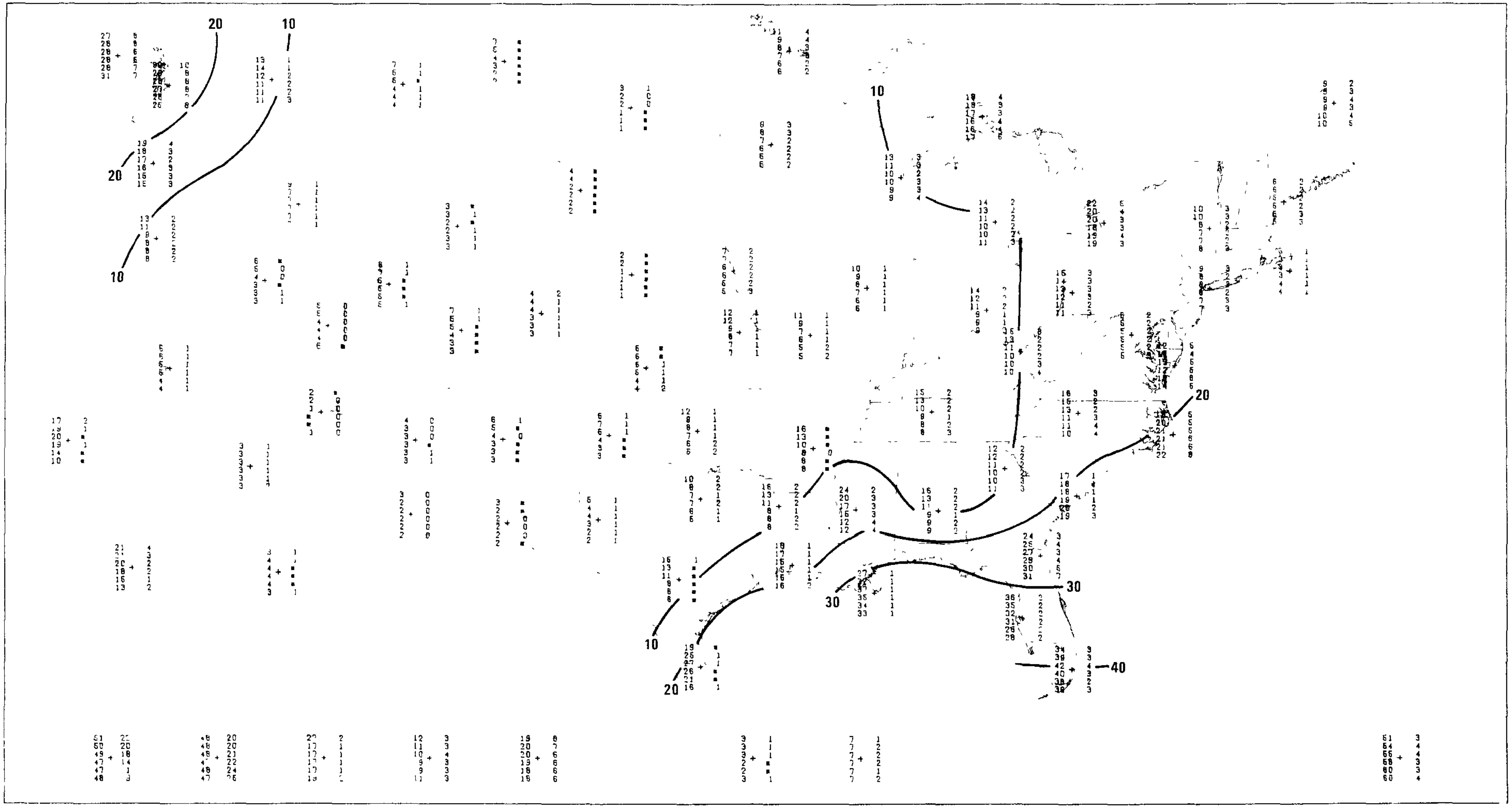

Figure 89 Percentage of autumn 2315 GMT soundings with no inversion below 3000 m AGL and an average relative humidity > 69% (left) and >89% (right) in the layers 1-100, 101-250, 251-500, 501-750, 751-1000, and 1001-1500 m AGL (bottom to top) Isopleths are for an average relative humidity >69% in the layer 251-500 m AGL See Figure 2 to identify the peripheral stations.

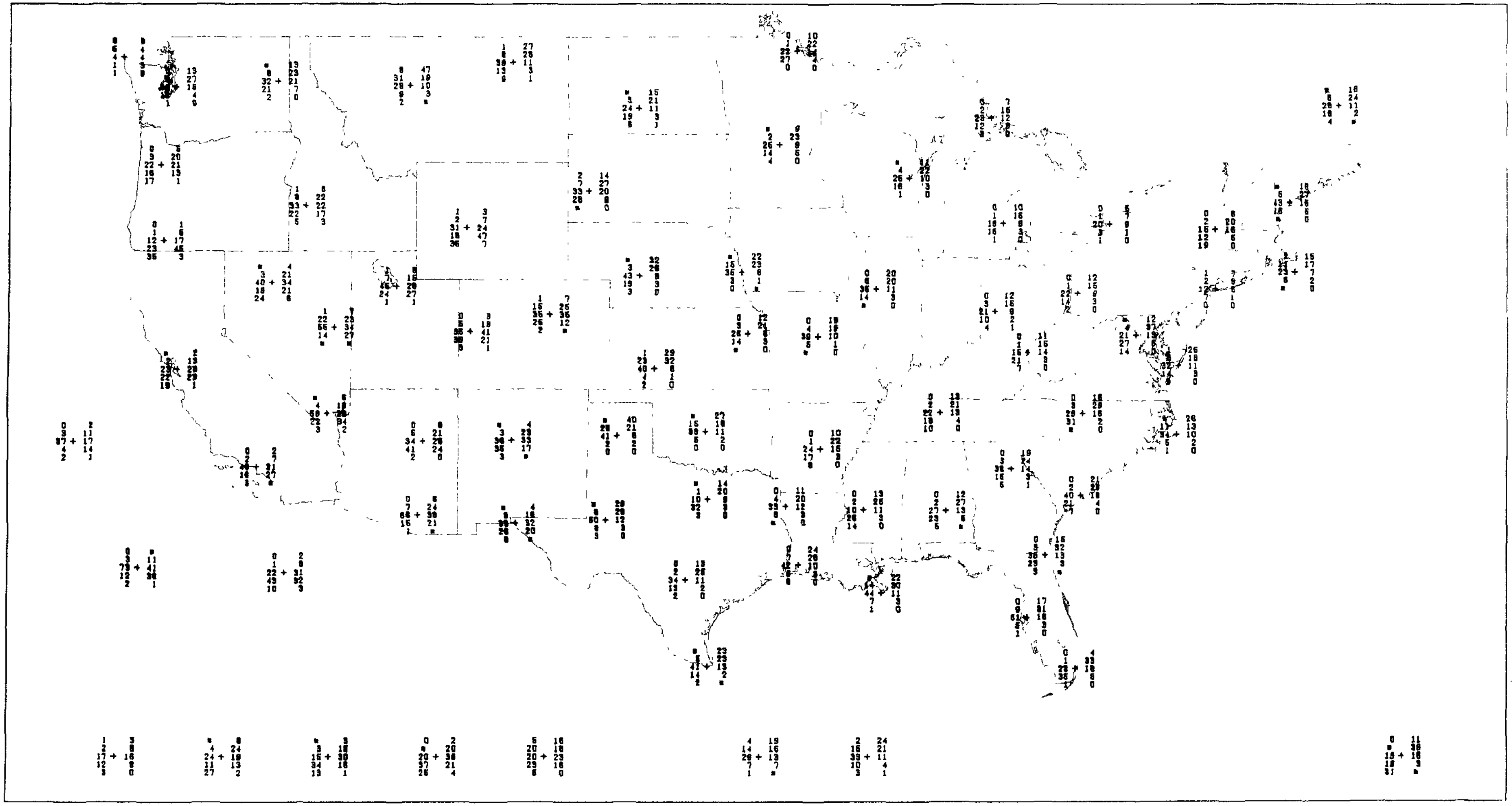

Figure 90. Percentage of winter 1115 GMT soundings with an inversion base at the surface and wind speeds at the surface (left) and at 300 m AGL (right) in the ranges calm, 0.1-2.5, 2.6-5.0, 5.1-10.0, and >10.0 m/s (bottom to top) See Figure 2 to identify peripheral stations.

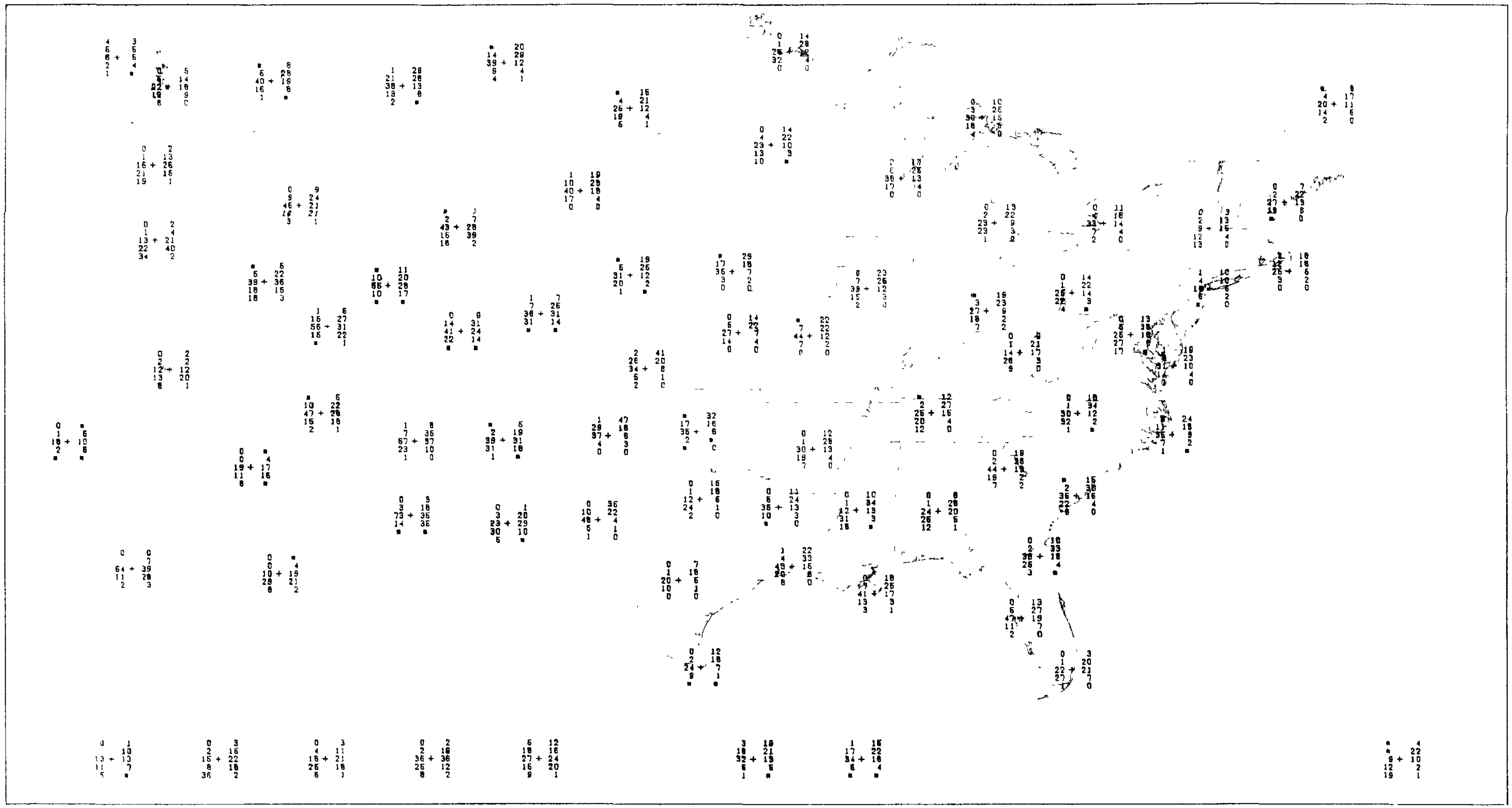

Figure 91 Percentage of spring 1115 GMT soundings with an inversion base at the surface and wind speeds at the surface (left) and at 300 m AGL (right) in the ranges calm, 0 1-2 5, 2.6-5.0, 5 1-10 0, and >10 0 m/s (bottom to top) See Figure 2 to identify peripheral stations

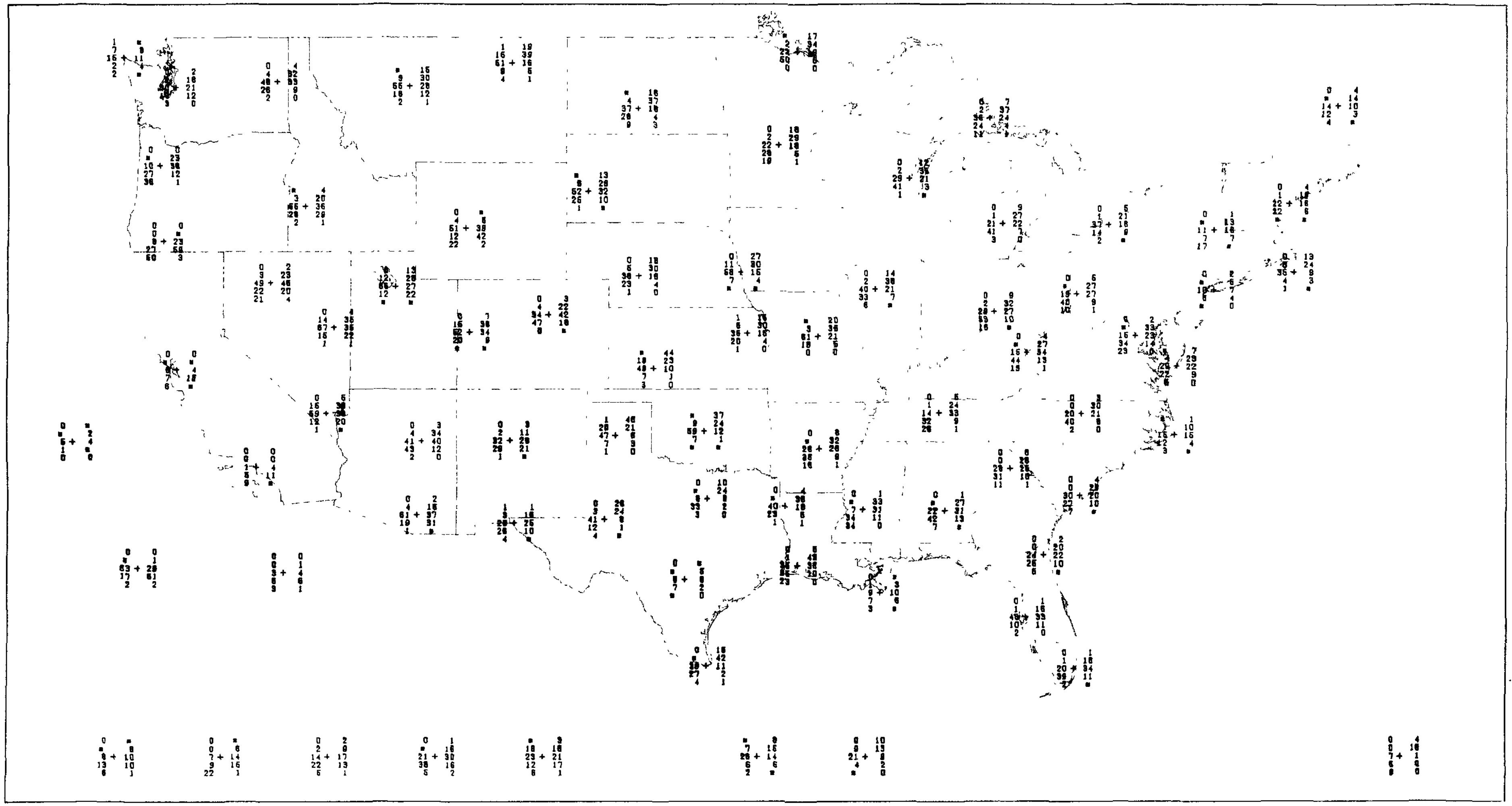

Figure 92. Percentage of summer 1115 GMT soundings with an inversion base at the surface and wind speeds at the surface (left) and at 300 m AGL (right) in the ranges calm, 0.1-2.5, 2.6-5.0, 5.1-10.0, and >10.0 m/s (bottom to top). See Figure 2 to identify peripheral stations.

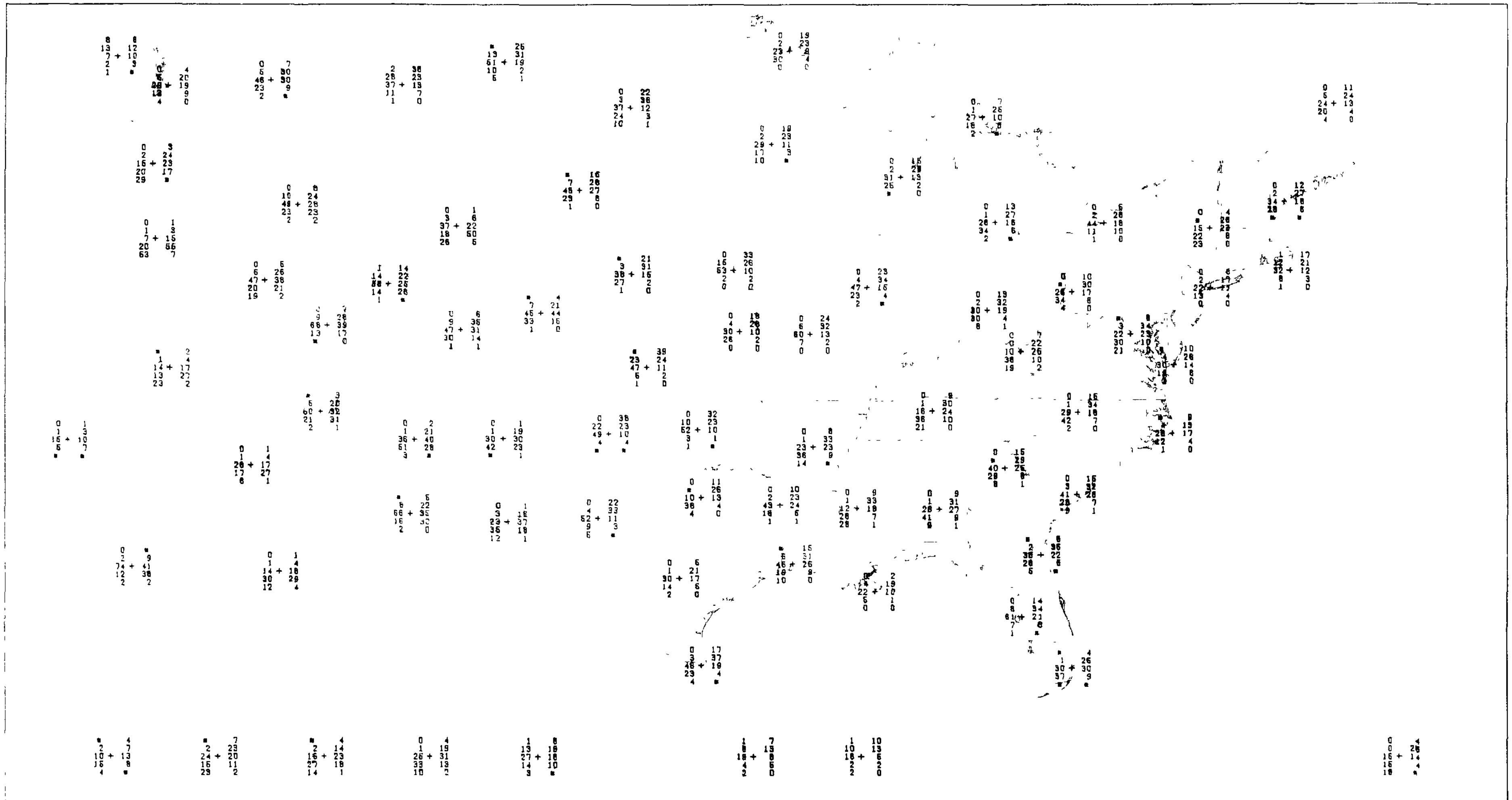

Figure 93 Percentage of autumn 1115 GMT soundings with an inversion base at the surface and wind speeds at the surface (left) and at 300 m AGL (right) in the ranges calm, 0 1-2 5, 2.6-5 0, 5 1-10.0, and >10.0 m/s (bottom to top). See Figure 2 to identify peripheral stations.

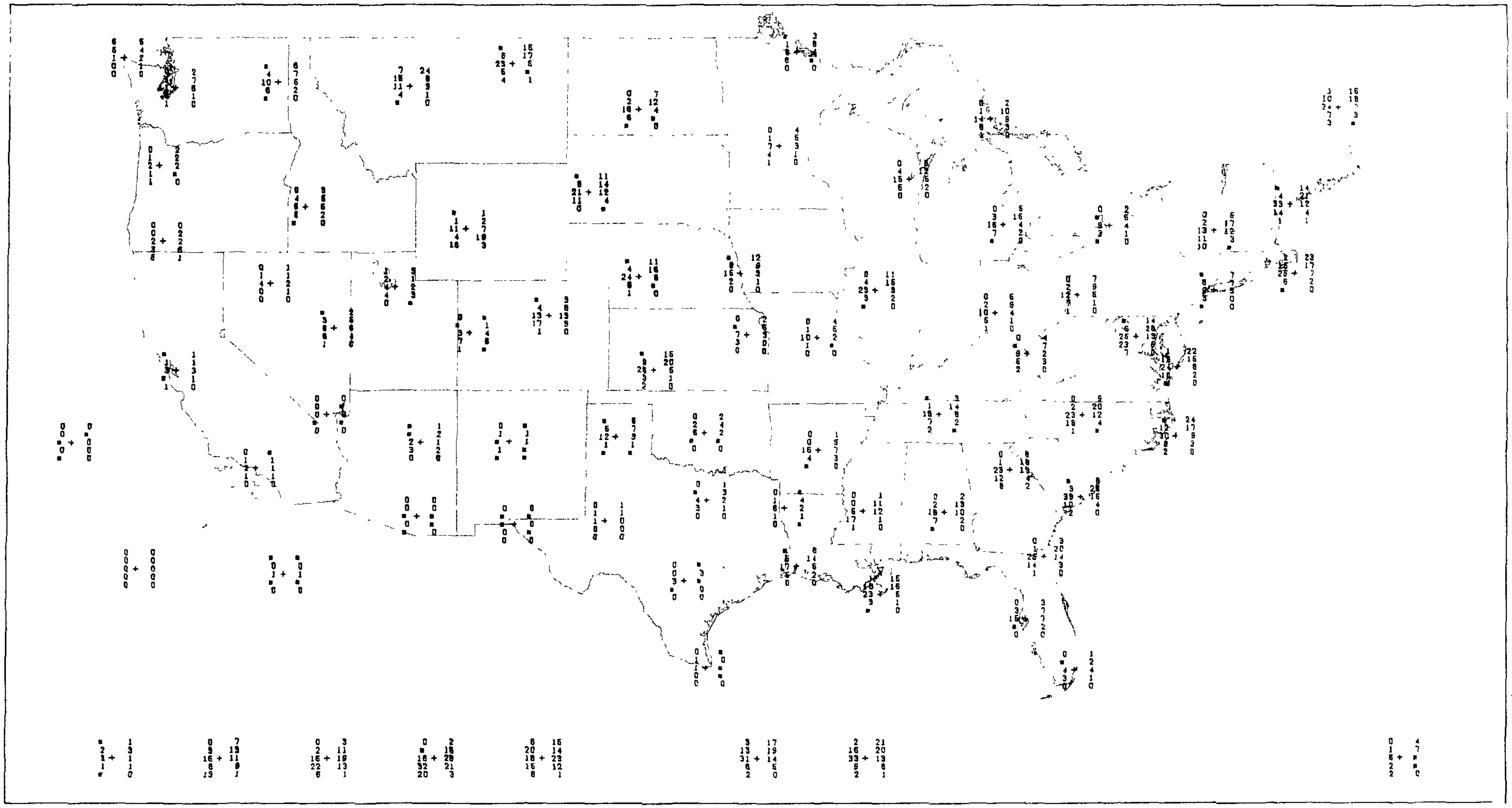

Figure 94. Percentage of winter 2315 GMT soundings with an inversion base at the surface and wind speeds at the surface (left) and at 300 m AGL (right) in the ranges calm, 0.1-2.5, 2.6-5.0, 5.1-10.0, and >10.0 m/s (bottom to top). See Figure 2 to identify peripheral stations.

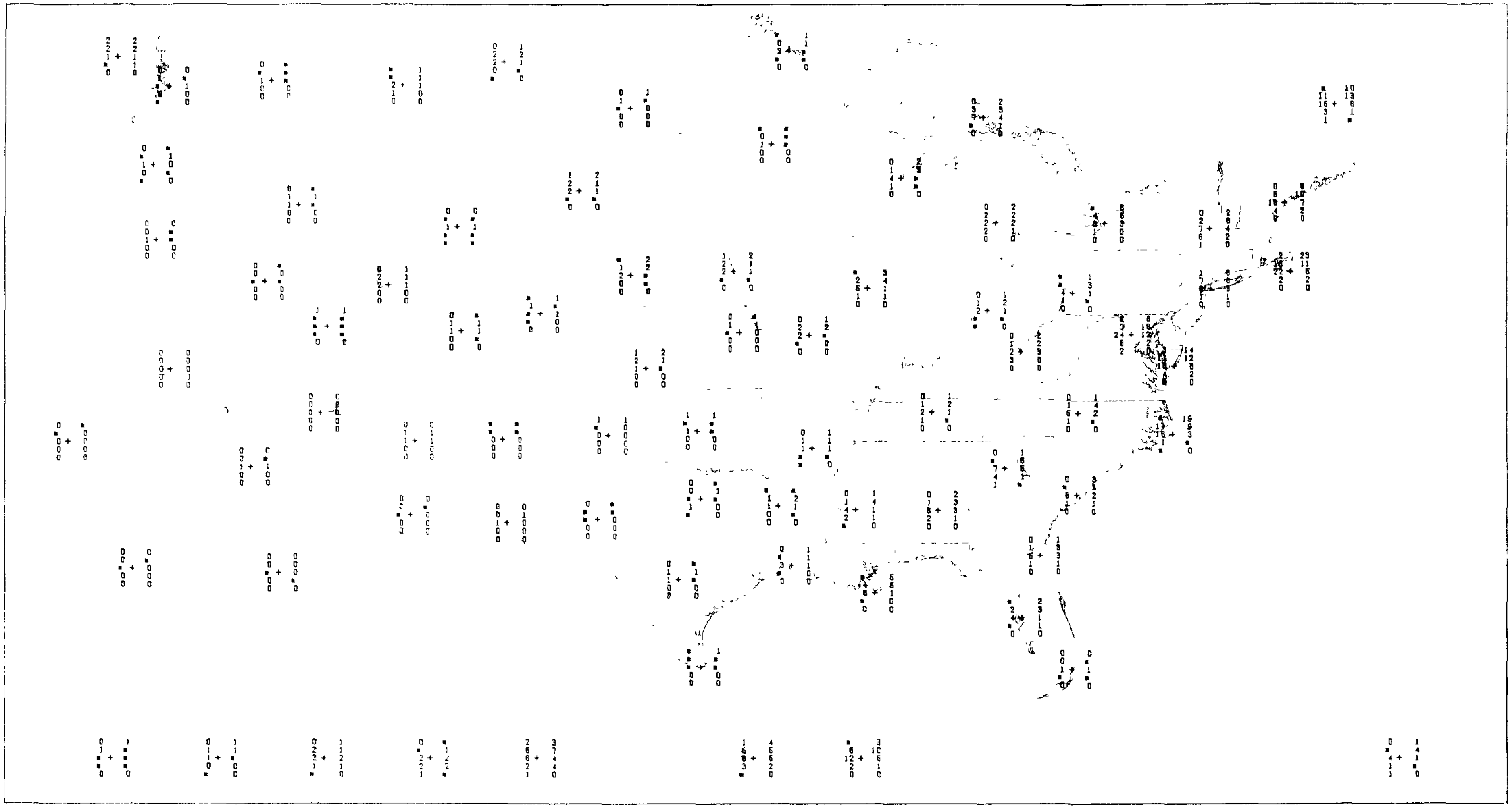

Figure 95 Percentage of spring 2315 GMT soundings with an inversion base at the surface and wind speeds at the surface (left) and at 300 m AGL (right) in the ranges calm, 0 1-2 5, 2.6-5 0, 5.1-10 0, and >10.0 m/s (bottom to top) See Figure 2 to identify peripheral stations.

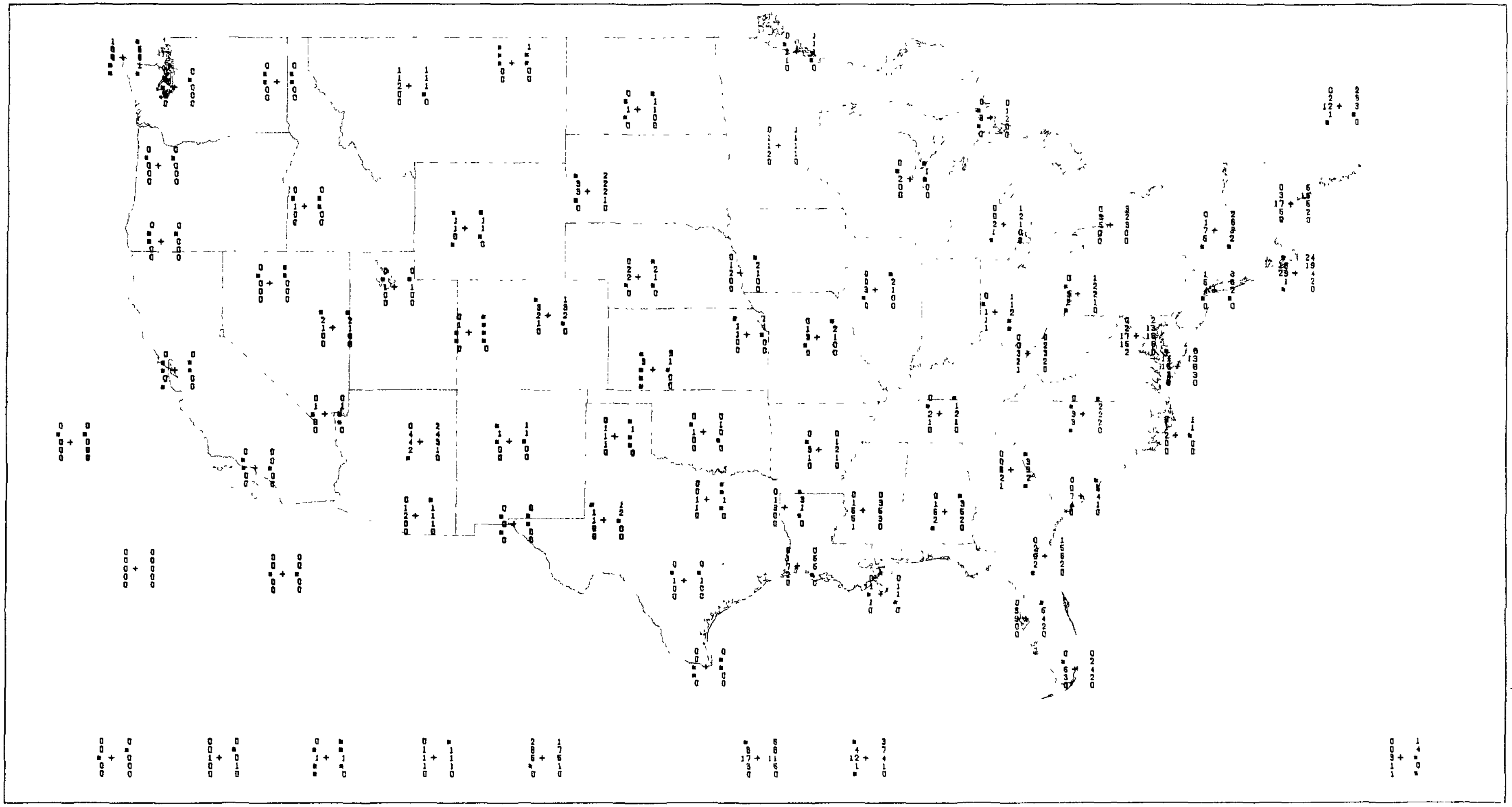

Figure 96. Percentage of summer 2315 GMT soundings with an inversion base at the surface and wind speeds at the surface (left) and at 300 m AGL (right) in the ranges calm, 0.1-2.5, 2.6-5.0, 5.1-10.0, and >10.0 m/s (bottom to top). See Figure 2 to identify the peripheral stations.

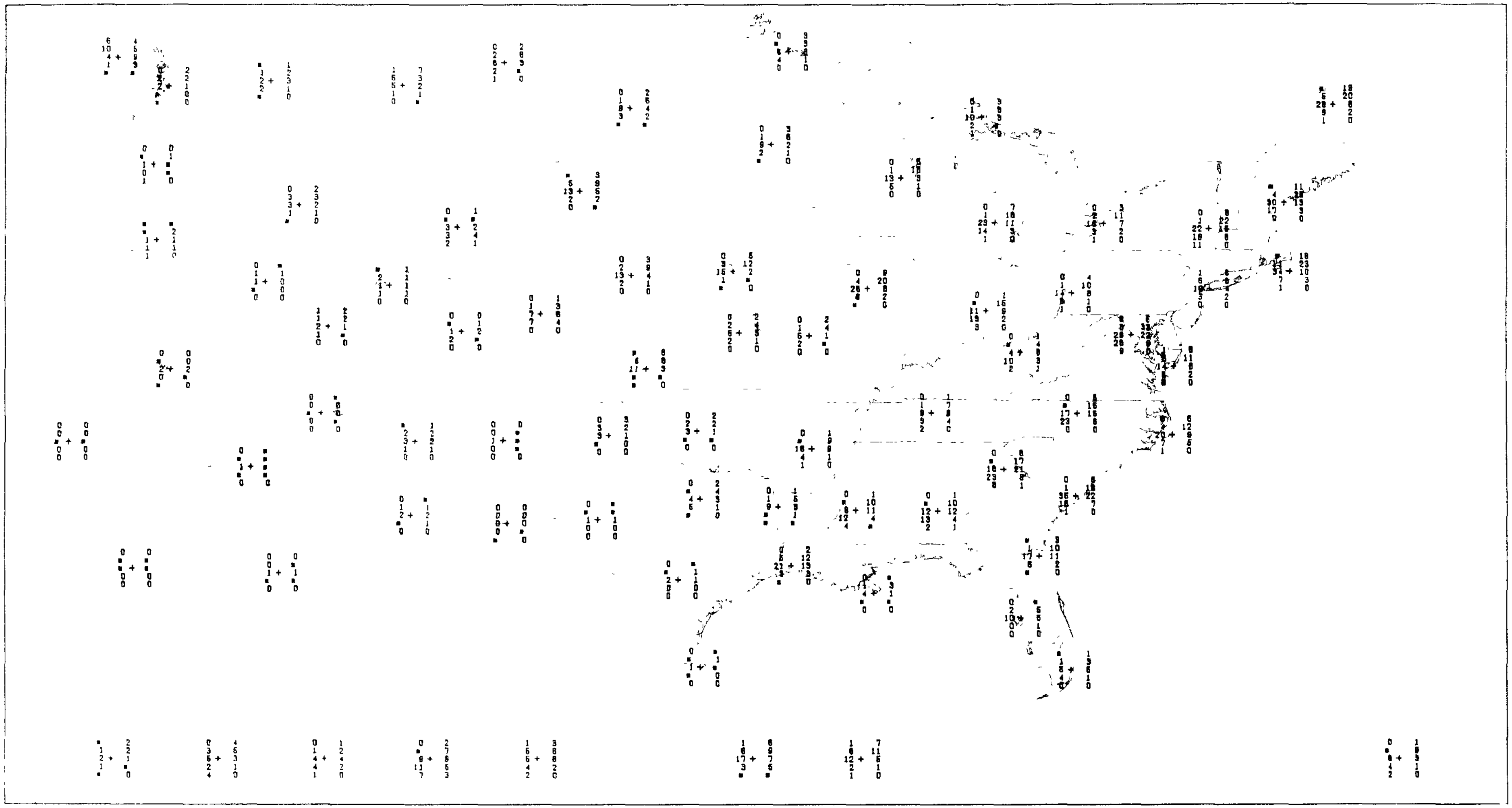

Figure 97 Percentage of autumn 2315 GMT soundings with an inversion base at the surface and wind speeds at the surface (left) and at 300 m AGL (right) in the ranges calm, 0 1-2.5, 2 6-5.0, 5 1-10.0, and >10.0 m/s (bottom to top) See Figure 2 to identify the peripheral stations

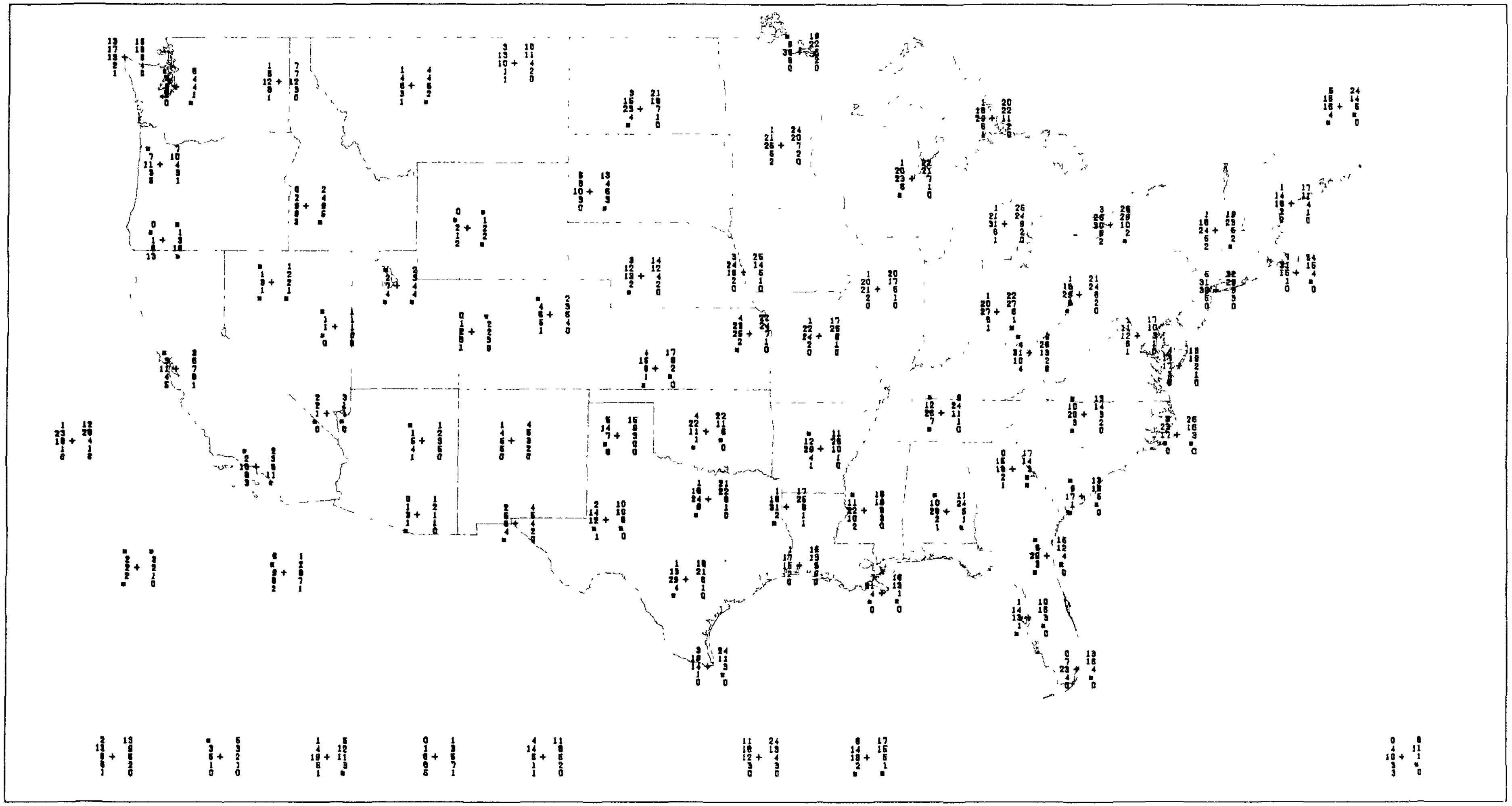

Figure 98. Percentage of winter 1115 GMT soundings with an elevated inversion base between 1-3000 m AGL and wind speeds at the surface (left) and at 300 m AGL (right) in the ranges calm, 0.1-2.5, 2.6-5.0, 5.1-10.0, and >10.0 m/s (bottom to top). See Figure 2 to identify the peripheral stations.

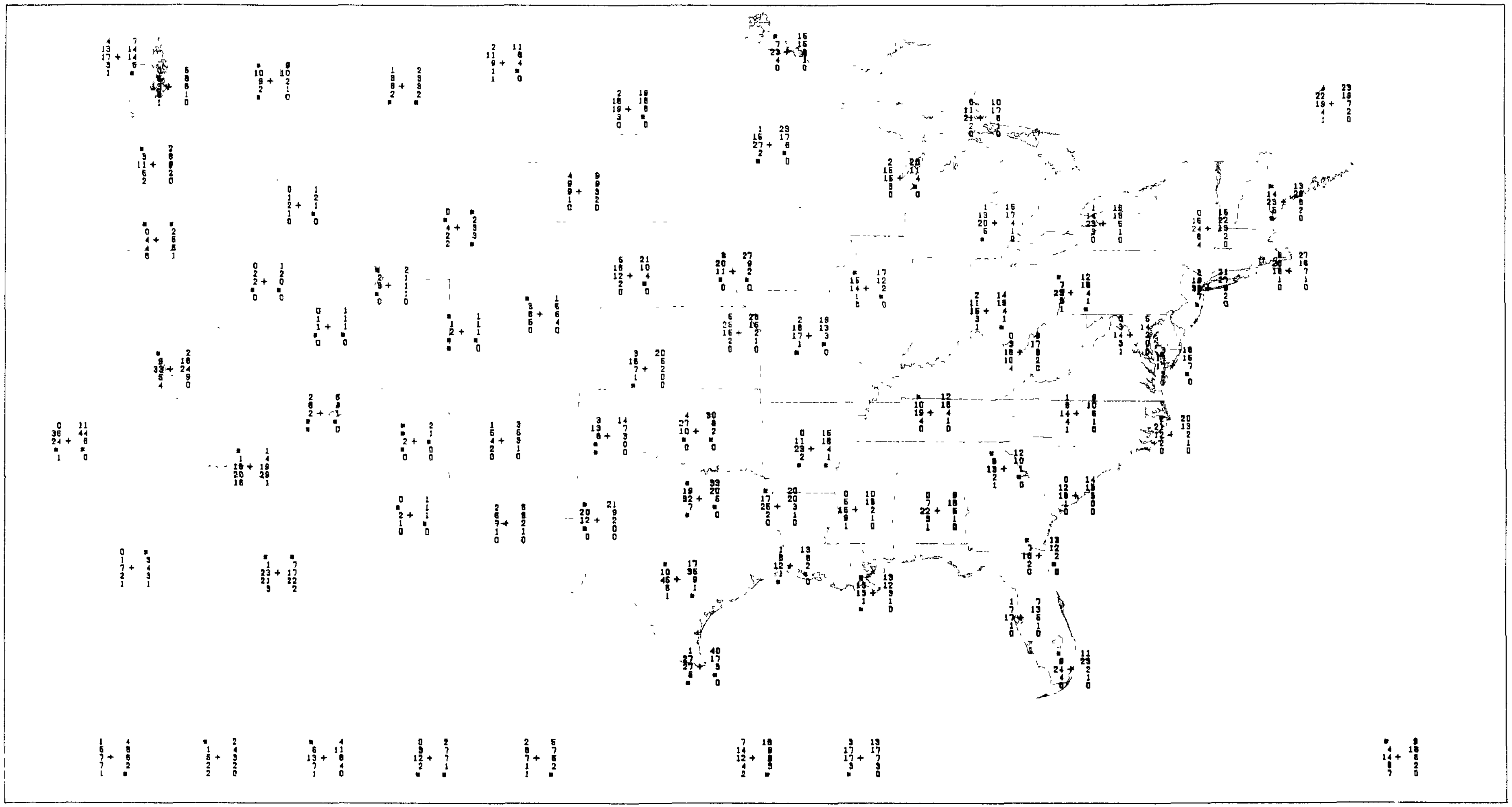

Figure 99. Percentage of spring 1115 GMT soundings with an elevated inversion base between 1-3000 m AGL and wind speeds at surface (left) and at 300 m AGL (right) in the ranges calm, 0.1-2.5, 2 6-5.0, 5.1-10 0, and >10.0 m/s (bottom to top) See Figure 2 to identify the peripheral stations

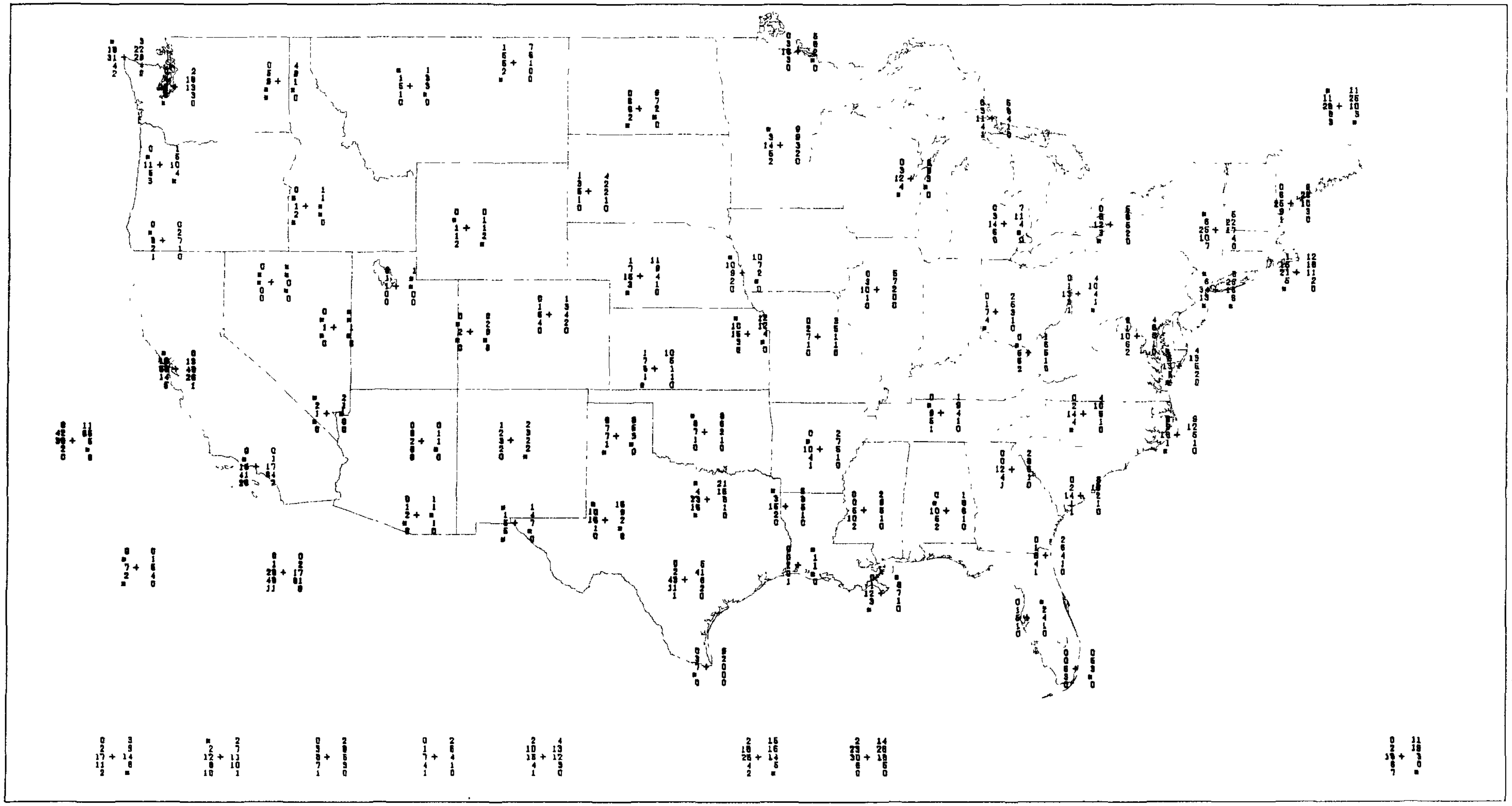

Figure 100. Percentage of summer 1115 GMT soundings with an elevated inversion base between 1-3000 m AGL and wind speeds at the surface (left) and at 300 m AGL (right) in the ranges calm, 0.1-2.5, 2 6-5.0, 5.1-10.0, and >10.0 m/s (bottom to top). See Figure 2 to identify the peripheral stations.

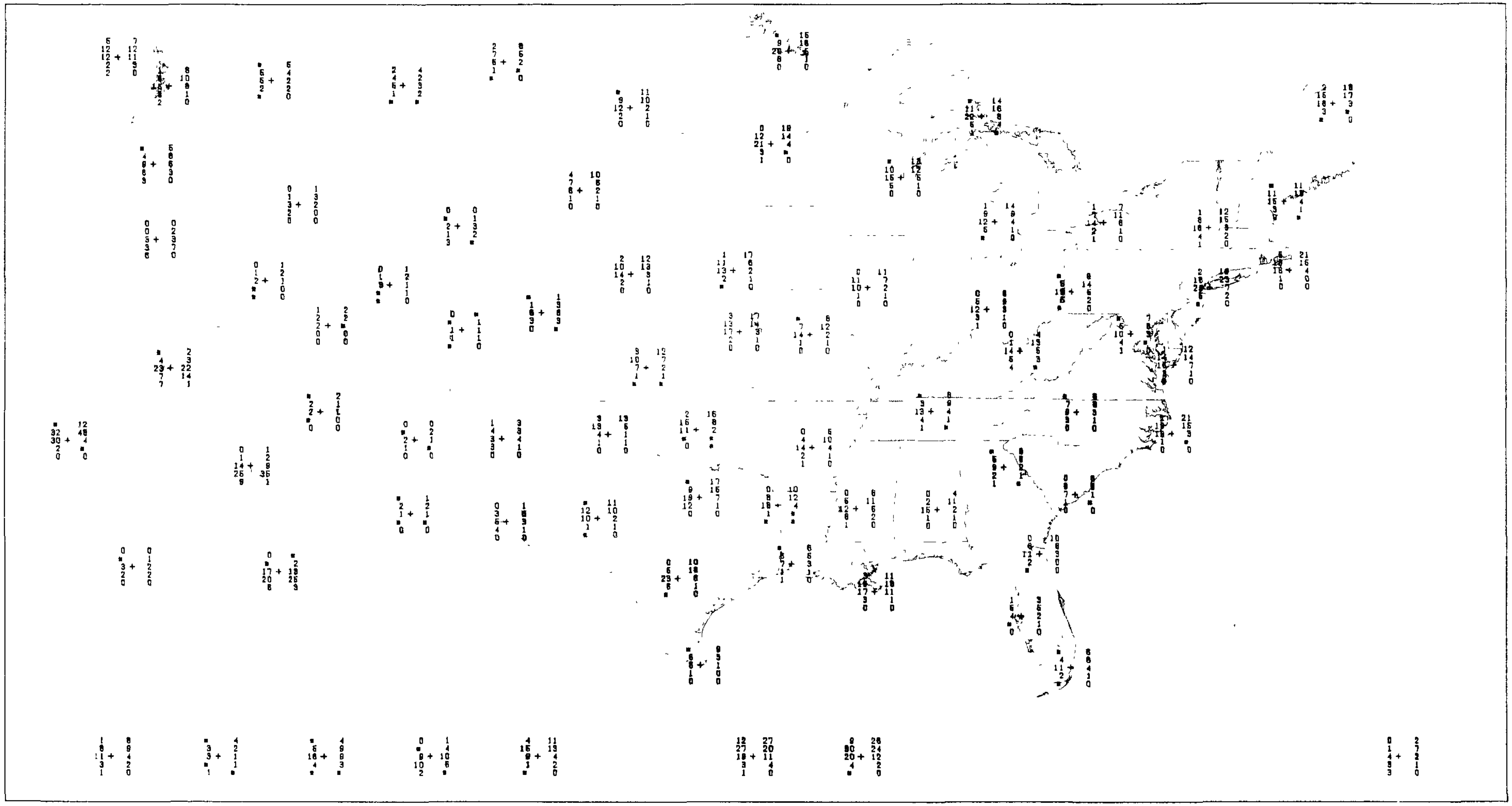

Figure 101 Percentage of autumn 1115 GMT soundings with an elevated inversion base between 1-3000 m AGL and wind speeds at the surface (left) and at 300 m AGL (right) in the ranges calm, 0.1-2.5, 2.6-5.0, 5.1-10.0, and >10.0 m/s (bottom to top). See Figure 2 to identify the peripheral stations.

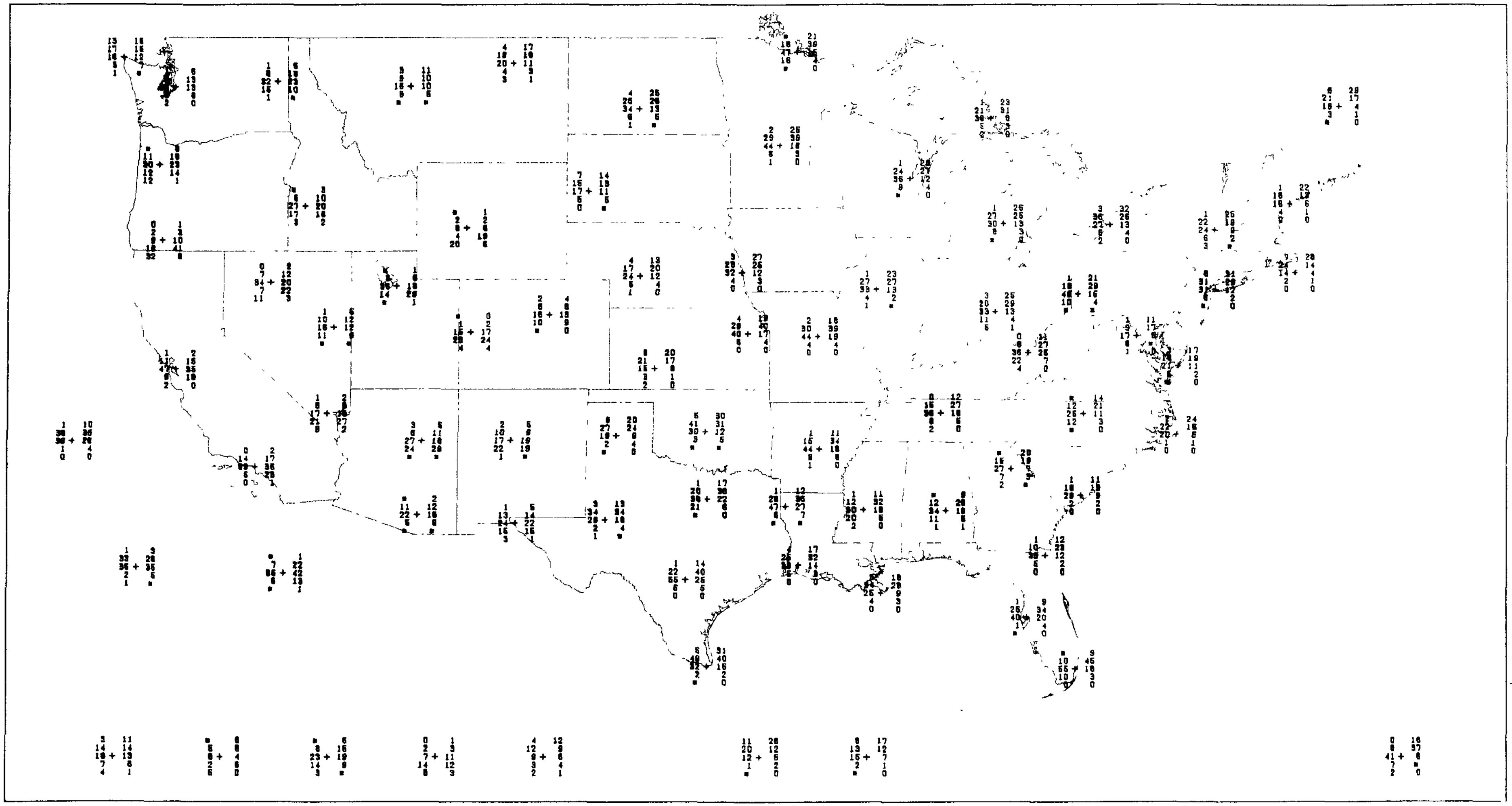

Figure 102. Percentage of winter 2315 GMT soundings with an elevated inversion base between 1-3000 m AGL and wind speeds at the surface (left) and at 300 m AGL (right) in the ranges calm, 0.1-2.5, 2.6-5.0, 5.1-10.0, and >10.0 m/s (bottom to top) See Figure 2 to identify the peripheral stations.

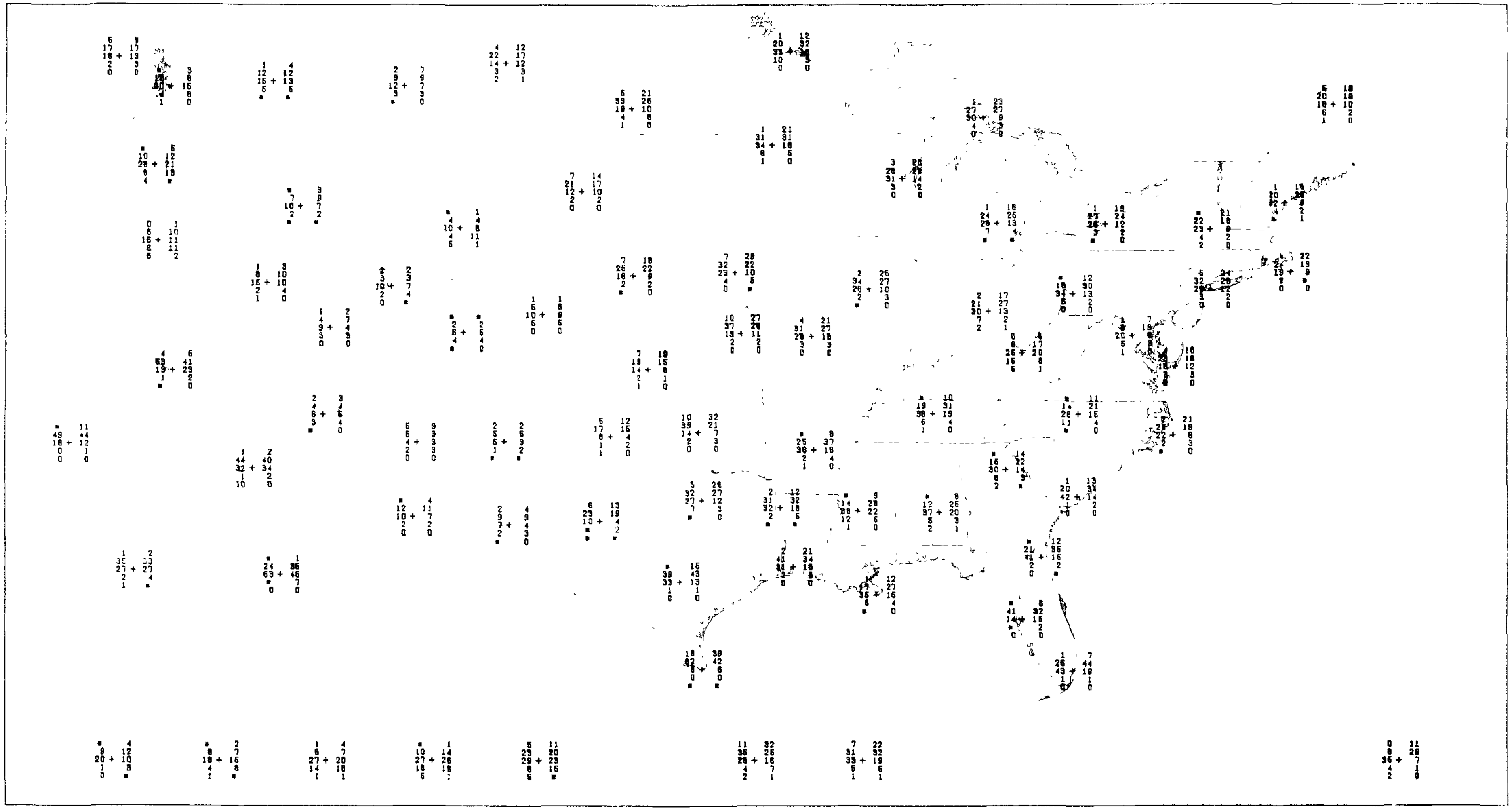

Figure 103 Percentage of spring 2315 GMT soundings with an elevated inversion base between 1-3000 m AGL and wind speeds at the surface (left) and at 300 m AGL (right) in the ranges calm, 0 1-2.5, 2 6-5.0, 5.1-10 0, and >10.0 m/s (bottom to top). See Figure 2 to identify the peripheral stations

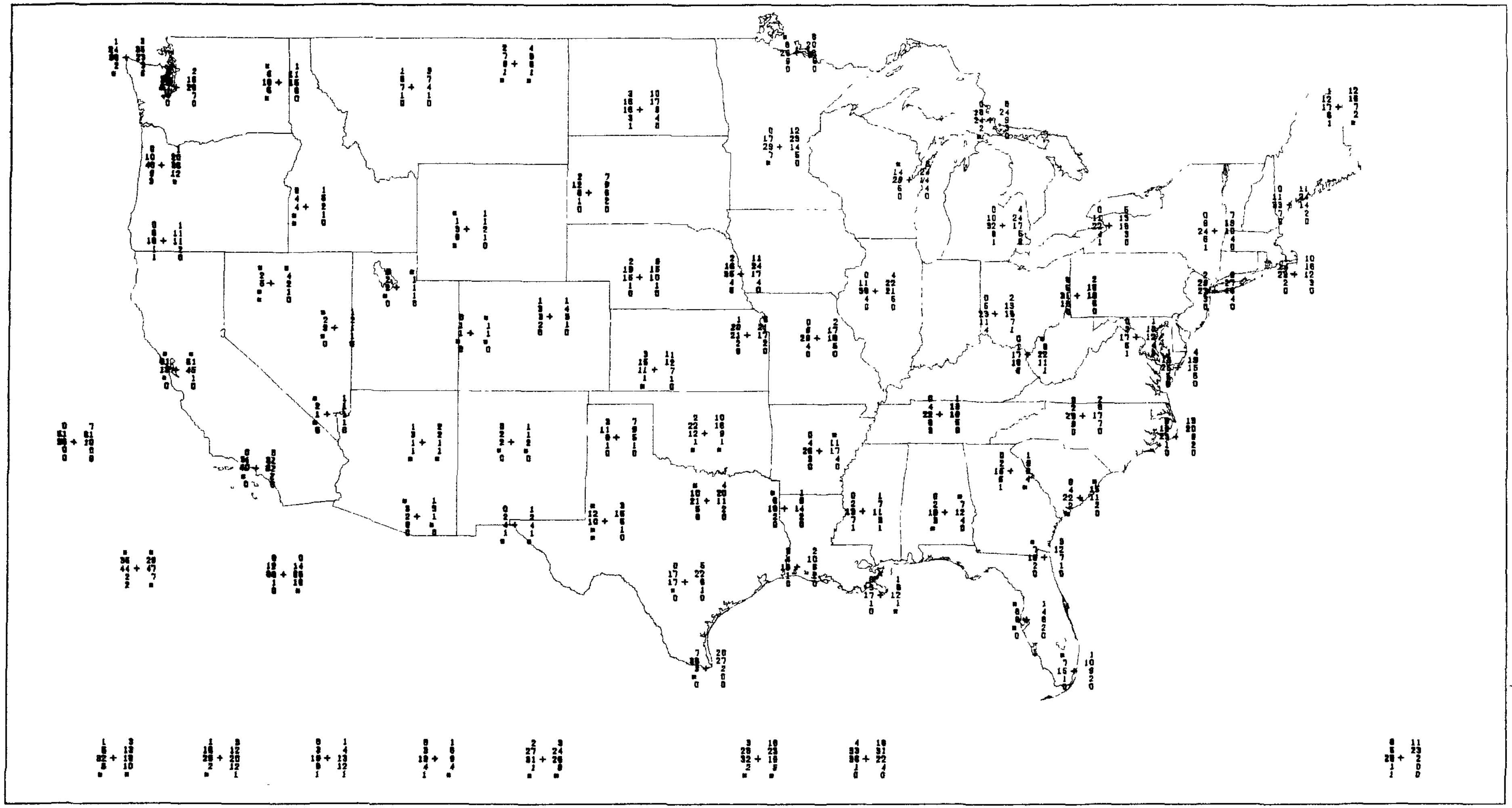

Figure 104. Percentage of summer 2315 GMT soundings with an elevated inversion base between 1-3000 m AGL and wind speeds at the surface (left) and at 300 m AGL (right) in the ranges calm, 0.1-2.5, 2.6-5.0, 5.1-10.0, and >10.0 m/s (bottom to top). See Figure 2 to identify the peripheral stations.

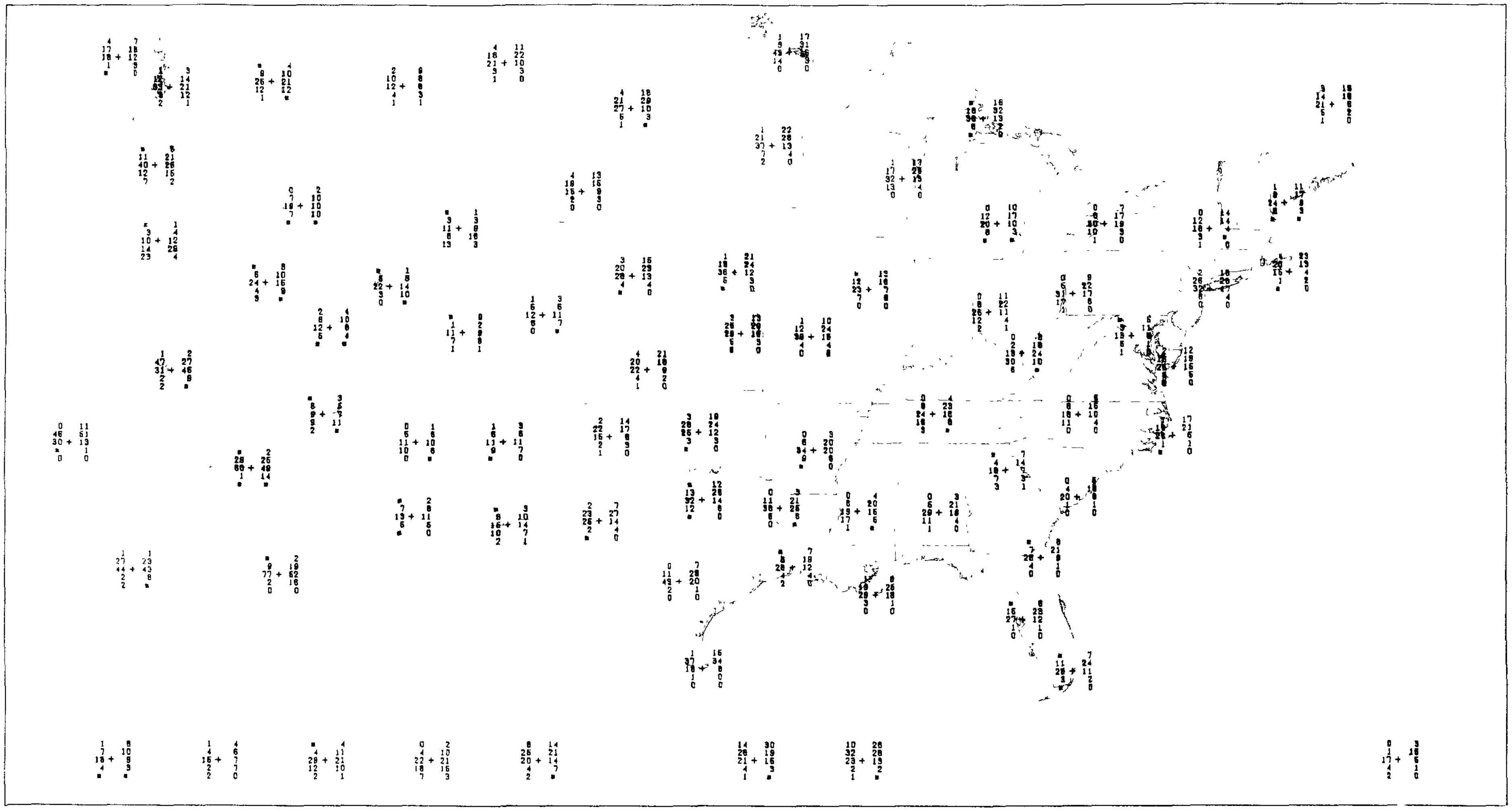

Figure 105 Percentage of autumn 2315 GMT soundings with an elevated inversion base between 1-3000 m AGL and wind speeds at the surface (left) and at 300 m AGL (right) in the ranges calm, 0.1-2.5, 2.6-5.0, 5.1-10.0, and >10.0 m/s (bottom to top). See Figure 2 to identify the peripheral stations.

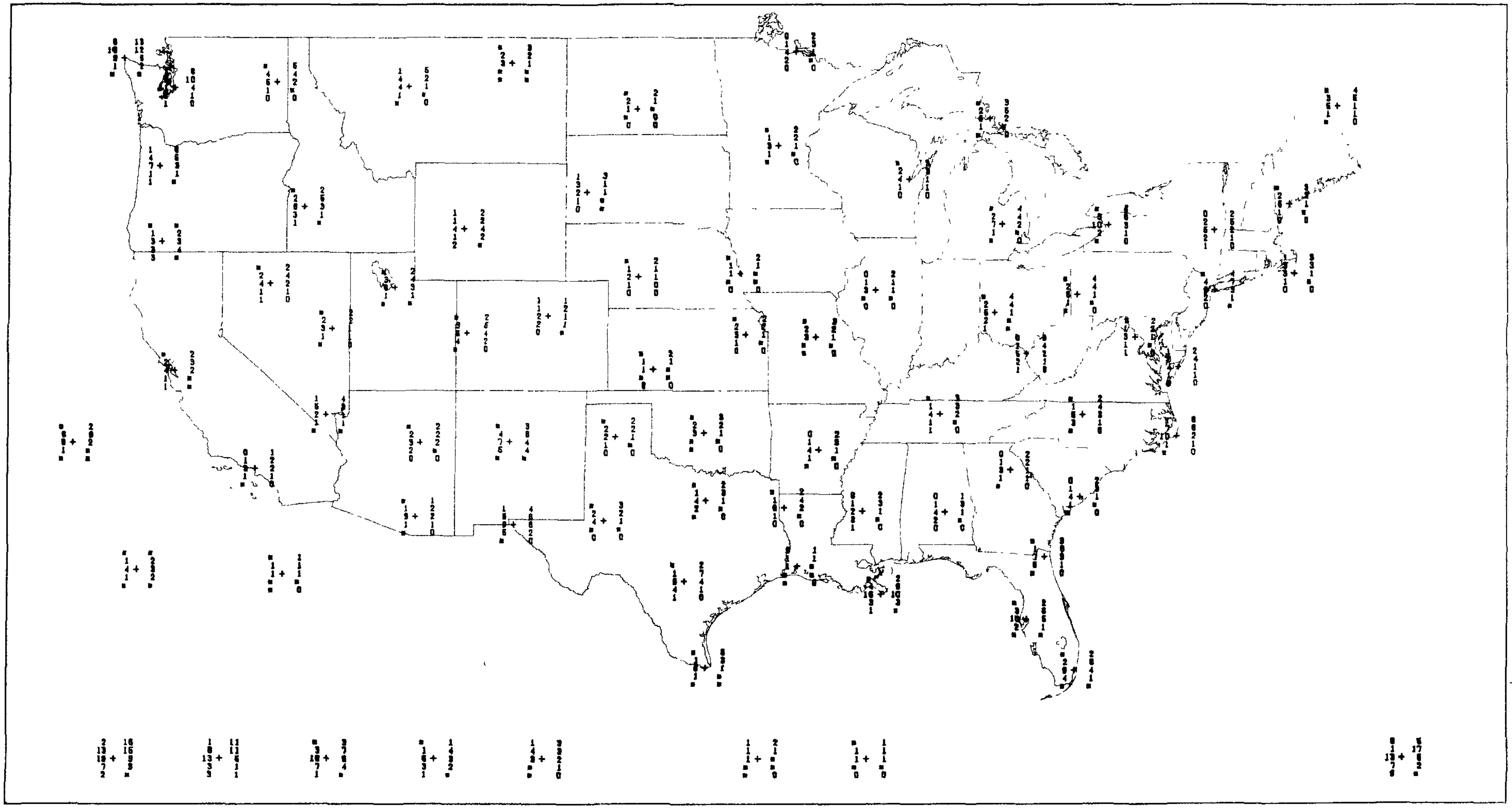

Figure 106. Percentage of all 1115 GMT soundings with no inversion below 3000 m AGL and wind speeds at the surface (left) and at 300 m AGL (right) in the ranges calm, 0.1-2.5, 2.6-5.0, 5.1-10.0, and >10.0 m/s (bottom to top). See Figure 2 to identify the peripheral stations.

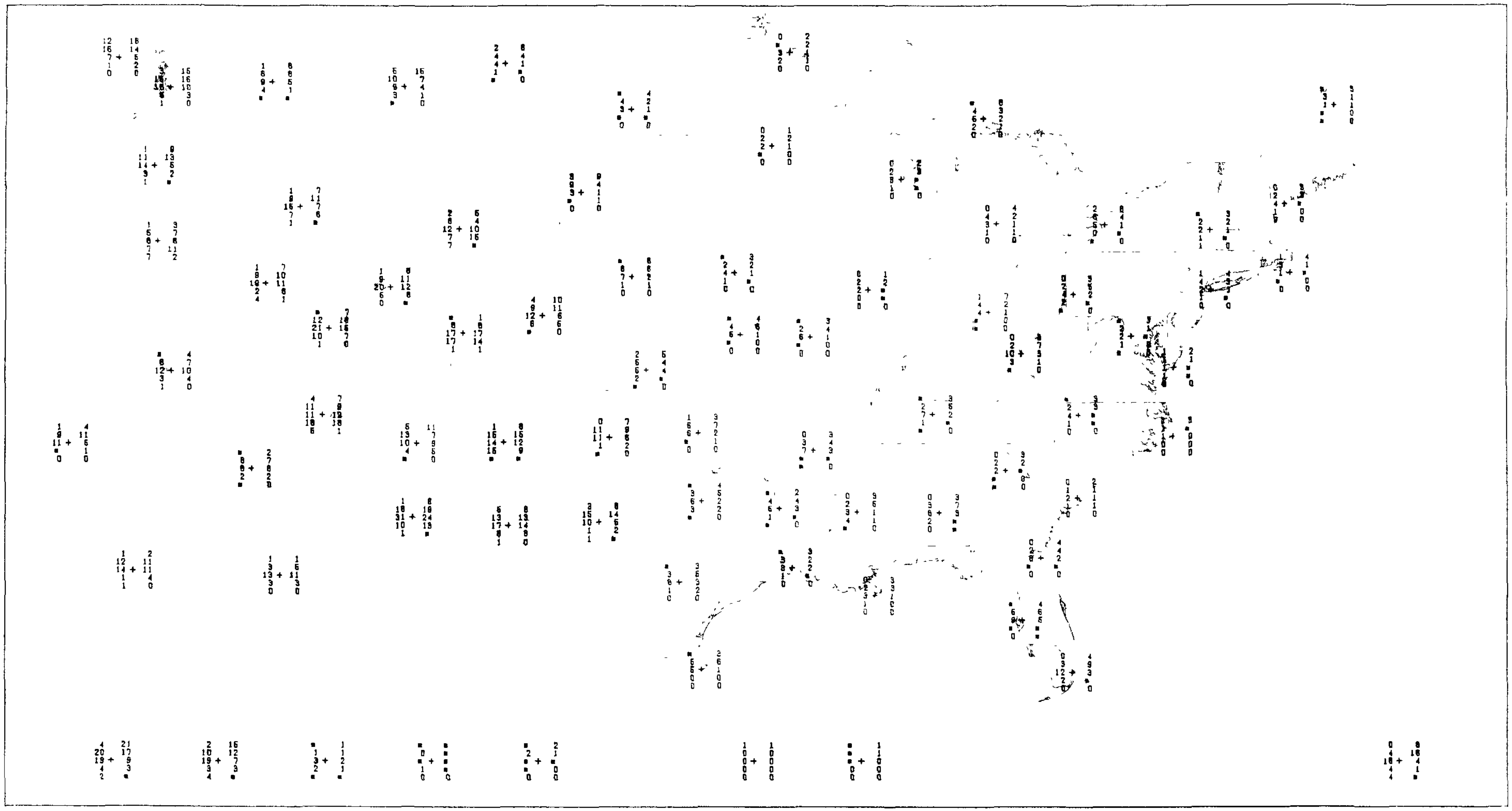

Figure 107 Percentage of winter 2315 GMT soundings with no inversion below 3000 m AGL and wind speeds at the surface (left) and at at 300 m AGL (right) in the ranges calm, 0 1-2.5, 2 6-5 0, 5 1-10 0, and >10 0 m/s (bottom to top) See Figure 2 to identify the peripheral stations

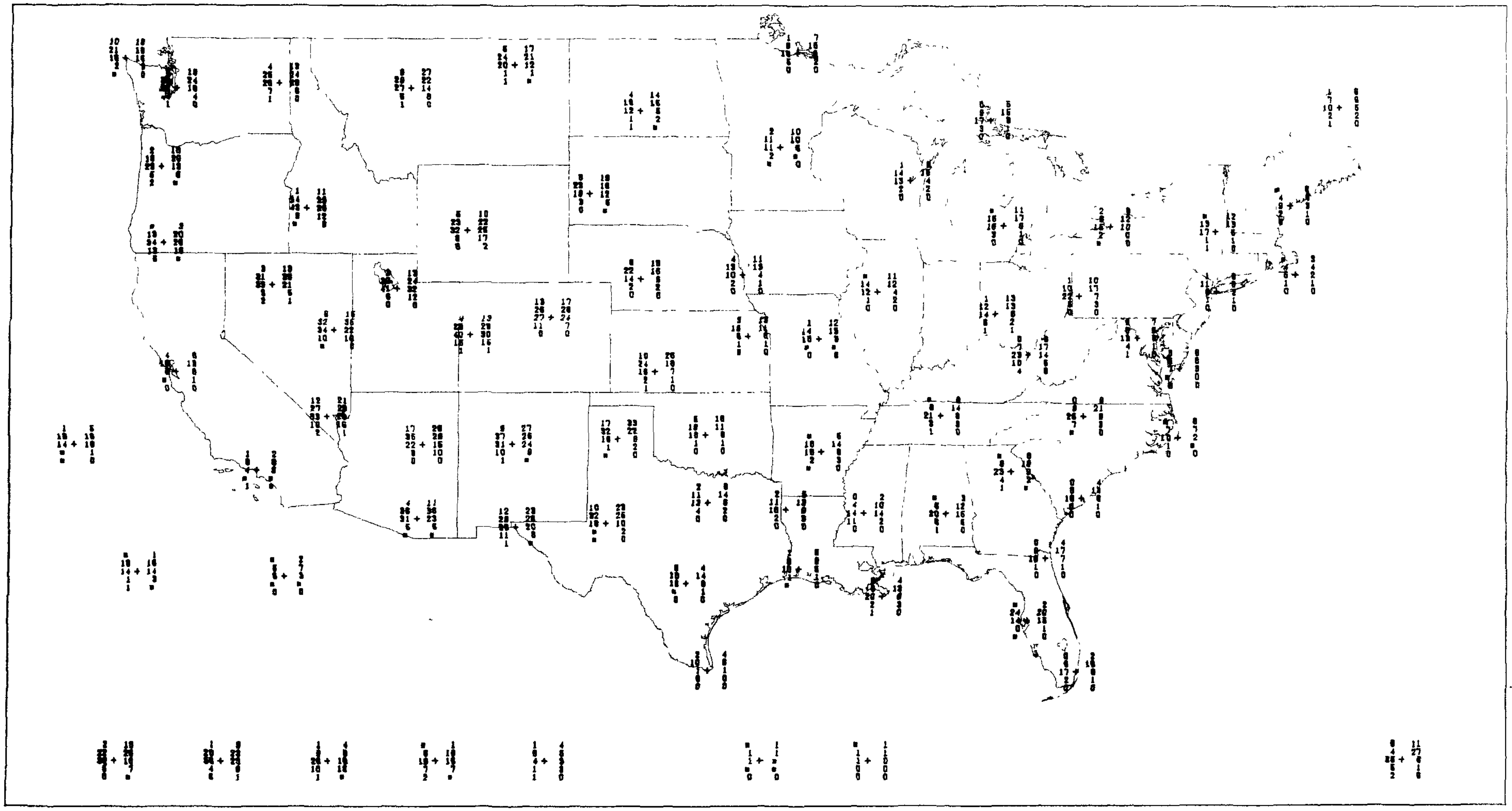

Figure 108 Percentage of spring 2315 GMT soundings with no inversion below 3000 m AGL and wind speeds at the surface (left) and at 300 m AGL (right) in the ranges calm, 0.1-2.5, 2.6-5.0, 5.1-10.0, and >10.0 m/s (bottom to top). See Figure 2 to identify the peripheral stations

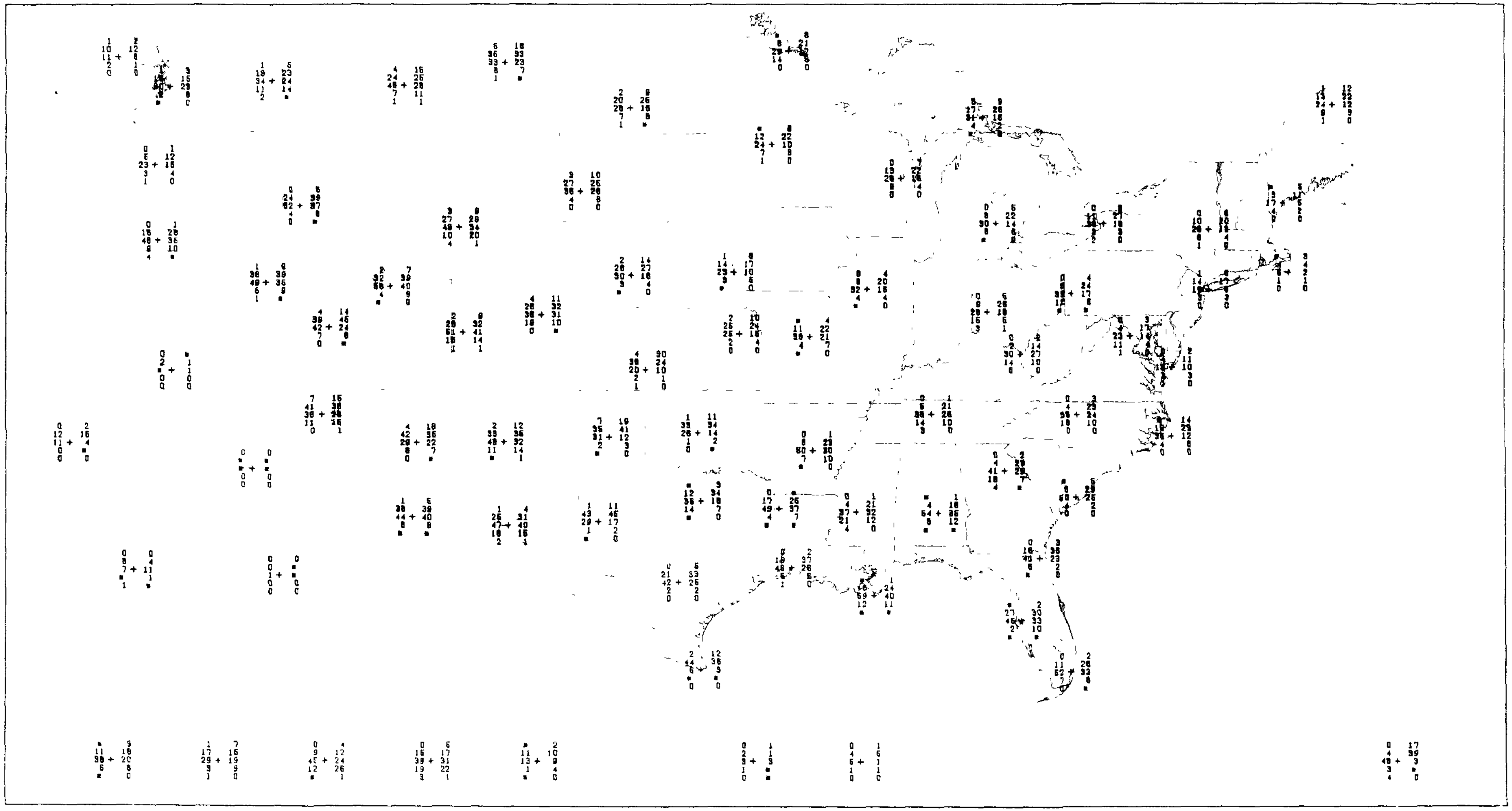

Figure 109  Percentage of summer 2315 GMT soundings with no inversion below 3000 m AGL and wind speeds at the surface (left) and at 300 m AGL (right) in the ranges calm, 0.1-2.5, 2.6-5.0, 5.1-10.0, and >10.0 m/s (bottom to top). See Figure 2 to identify peripheral stations

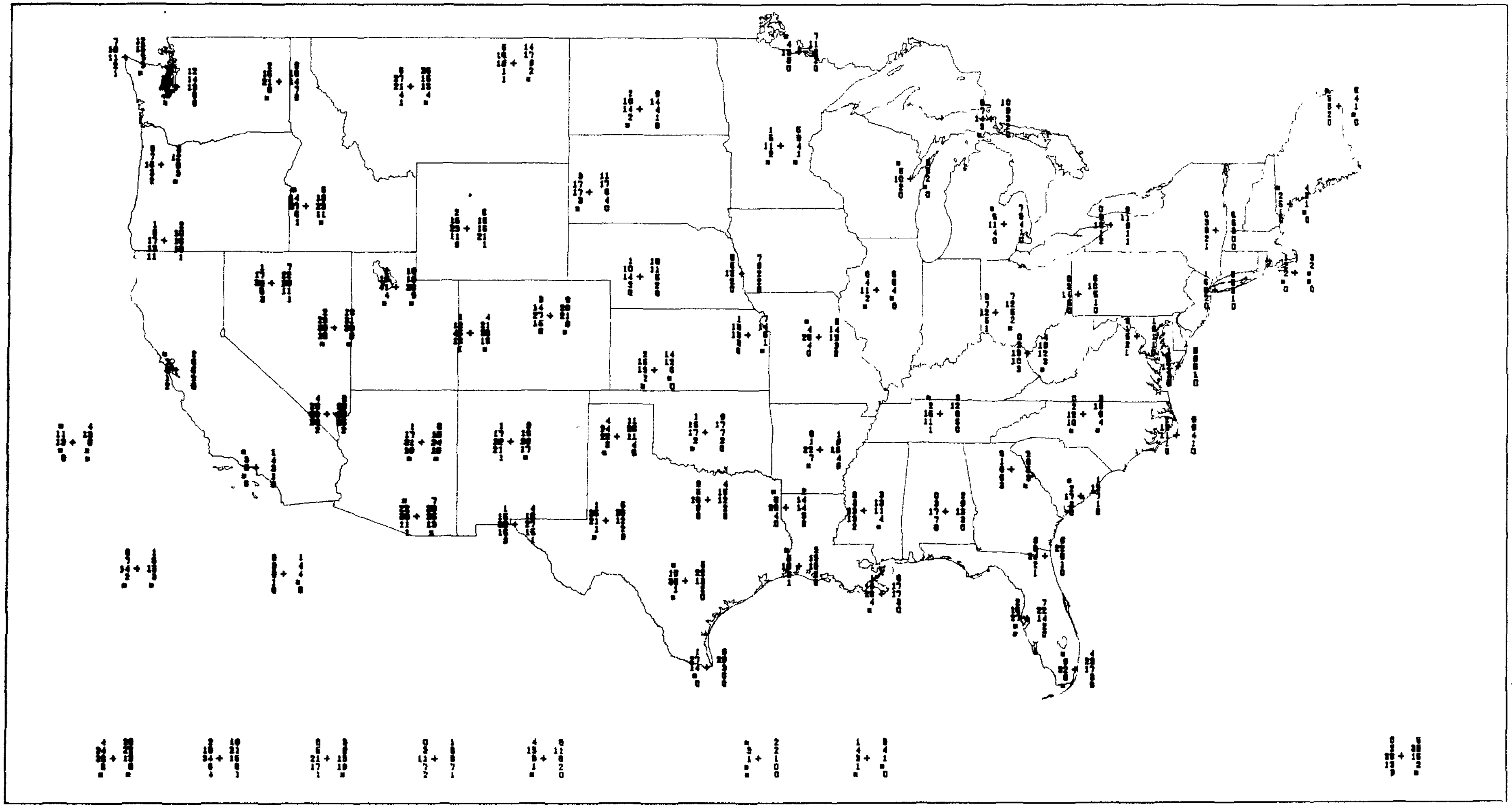

Figure 110. Percentage of autumn 2315 GMT soundings with no inversion below 3000 m AGL and wind speeds at the surface (left) and at 300 m AGL (right) in the ranges calm, 0.1-2.5, 2.6-5.0, 5.1-10.0, and >10.0 m/s (bottom to top). See Figure 2 to identify the peripheral stations.

# TECHNICAL REPORT DATA

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15. SUPPLEMENTARY NOTES

16. ABSTRACT


Summaries of atmospheric structure, based on rawinsonde measurements taken twice daily at 76 United States Weather Service stations, are presented on national maps. The data include frequencies of surface-based and elevated inversions, inversion thicknesses, and elevated inversion base-heights. Frequencies of high relative humidity are given for inversions and adjacent layers. Frequencies of wind speed categories at the surface and 300 m above are presented for surface-based, elevated, and no-inversion cases. Finally, lapse rates are characterized within and below inversions, and in specified layers through 1500 m for soundings with no inversion. Representative data are isoplethed for illustrative purposes, but many figures are without isopleths because no single variable is generally representative. Some general conclusions are: 1) inversions are virtually always present at most locations; 2) inversions are almost always greater than 100 m thick, sometimes more than 1000 m; 3) shallow inversions tend to be more intense (large $\Delta T/\Delta H$) than thick inversions; 4) wind speeds with surface-based inversions are generally slower at the surface than at 300 m and the most common surface speed-class is 2.6-5.0 m/sec. The data presented in this report should be of considerable interest to those concerned with the atmospheric boundary layer.


17. KEY WORDS AND DOCUMENT ANALYSIS

| a. DESCRIPTORS | b. IDENTIFIERS/OPEN ENDED TERMS | c. COSATI Field/Group |
|---|---|---|
| * Climatology<br>* Meteorological charts<br>* Wind velocity<br>* Temperature inversions<br>* Humidity<br>Boundary layer | Rawinsonde measurements | 04B<br>08B<br>20D |

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