AD657801

AFCRL-67-0435
AUGUST 1967
AIR FORCE SURVEYS IN GEOPHYSICS, NO. 196

AIR FORCE CAMBRIDGE RESEARCH LABORATORIES
L. G. HANSCOM FIELD, BEDFORD, MASSACHUSETTS

Clear Lines-of-Sight from Aircraft

EUGENE A. BERTONI

OFFICE OF AEROSPACE RESEARCH
United States Air Force

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AEROSPACE INSTRUMENTATION LABORATORY   PROJECT 8624

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Abstract

An in-flight observation program to collect observations of the presence, or absence, of clear lines-of-sight at several angles in the vertical plane has been completed. Approximately 72,000 observations were collected over a period of about 15 months. Observations were taken by flight crews of the Air Force, Navy, and Pan American Airways. Data were obtained over most of the Northern Hemisphere, except the area from 30°E to 110°E.

All observations taken within a 10° latitude-longitude sector were grouped together by altitude and season. The relative frequency of a clear line-of-sight is plotted in the appropriate area on maps for various lines-of-sight. The number of observations on which the relative frequency is based is shown in parentheses.

The relative frequencies are intended to serve as estimates of the probabilities of clear lines-of-sight. These estimates should be considered as a first approximation since, (a) the observations were taken in a very subjective manner, (b) the estimates are based only on about one season of data, and (c) cloud variability may be quite large within some 10° sectors.

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1. INTRODUCTION

In an attempt to provide consultation on the impact of cloudiness on the design of optical and infrared ground based and airborne detection and tracking systems, it became apparent that cloud data compiled from standard surface weather observations are not very applicable in obtaining desired estimates. Lund (1965, 1966) and McCabe (1965) provide statistical models for estimating the probability of a clear line-of-sight using sunshine and cloud cover observations. This paper describes and presents data from an in-flight observation program covering much of the Northern Hemisphere, initiated to collect observations of the presence, or absence, of clear lines-of-sight from aircraft at several different angles above and below the horizon.

2. DATA COLLECTION

The most economical and practical method of obtaining line-of-sight data was the employment of USAF aircraft and crews on routinely flown missions over frequently flown routes in the Northern Hemisphere. The USAF Military Airlift Command, Strategic Air Command, and Weather Reconnaissance Squadrons provided

(Received for publication 14 July 1967)

the bulk of the observations. Pan American World Airways, Inc. participated on a noninterference, best effort, no cost to the government basis. The U.S. Naval Ice Reconnaissance Unit also contributed to the program.

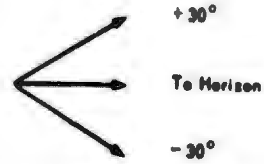
The type of observation obtained was the yes-no (check-off) type, that is, can blue sky at 90° above the horizon be seen? yes (clear) or no (not clear)? Can the ground (ocean) at 90° below the horizon be seen? yes (clear) or no (not clear)? Since a great many observers with little or no meteorological training would be involved, this type of observation was selected as it does not allow very much subjectivity.

All observations were taken in the vertical plane at five selected angles of vision and generally in the direction the aircraft was traveling. The five lines-of-sight were (a) 90° below the horizon (ground at -90°), (b) 30° below the horizon (ground at -30°), (c) horizon directly ahead of aircraft, (d) 30° above the horizon (blue sky at + 30°), and (e) 90° above the horizon (blue sky at + 90°). During cruise these observations were made once an hour, GMT, or in conjunction with standard (RECCO, AIREPS, or COMBAR) meteorological observations which are very nearly hourly. During climb and descent, observations were taken at 1000; 2500; 5000; 10,000; 20,000; and 30,000 ft if time permitted and the observations could be taken safely. Figure 1 is a copy of the data collection form used by participants. Data collection began in April 1965 with all participating units active by September 1965 and was terminated in October 1966.

Approximately 72,000 observations were obtained, all over the Northern Hemisphere from 20°E westward through 0° to 110°E longitude and from the equator to 80°N latitude. This area was divided into 10° latitude-longitude sectors. Few observations were obtained between 30° and 110°E longitude.

Approximately 27,100 observations were taken during the winter season (December, January, February); 14,100 during spring (March, April, May); 13,400 during summer (June, July, August); and 17,600 during fall (September, October, November). Probabilities of a clear line-of-sight were computed for each 10° latitude-longitude sector, for each angle of vision, each season, and the following layers of altitude: below 1800 ft, 1801 to 3600 ft, 3601 to 7400 ft, 7401 to 14,999 ft, 15,000 to 24,999 ft, 25,000 to 34,999 ft, 35,000 to 44,999 ft, and above 45,000 ft. Probabilities were not computed for sectors having less than 10 observations per season. No distinction is made between daytime and nighttime observations, direction of travel of the aircraft, or location of aircraft within the sector. These probabilities are presented by season in Appendices A, B, C, and D.

INSTRUCTIONS: All observations should be taken in the vertical plane in the direction the aircraft is heading. Take cruise observations at regular observing/reporting time. Use the guide at right to determine angles of sighting at horizon, + 30° and - 30°. Next, take the sky overhead and ground below observation. Check appropriate column on form below after logging time and position. Then check 1 of 3 predominant obstructions to vision, if applicable.



CHECK ONE COLUMN ONLY IN RECORD BELOW

CLEAR (CLR) - SKY, GROUND OR HORIZON VISIBLE AT FIRST QUICK GLANCE.

NOT CLEAR (NOT CLR) - SKY, GROUND OR HORIZON NOT VISIBLE AT FIRST QUICK GLANCE.

MAIL COMPLETED FORM EACH MONTH TO:
AFCRL (CREW)
L. G. HANSCOM FIELD
BEDFORD, MASSACHUSETTS 01731

LINE OF SIGHT OBSERVATIONS

DEPART: *(City, State, Country)*	CIG	VIS	TYPE AIRCRAFT
ARRIVE: *(City, State, Country)*	CIG	VIS	FLT NO/TRACK
OBSERVER	DATE (GMT)	ORGANIZATION	

HOUR (GMT)	LAT	LONG	ALTITUDE (MSL)		HORIZON		-30°		+30°		SKY OVERHEAD		GROUND BELOW		PREDOMINANT OBSTRUCTION		
					CLR	NOT CLR	CLR	NOT CLR	CLR	NOT CLR	CLR	NOT CLR	CLR	NOT CLR	CLDS	PCIP	HAZE
			CLIMB	1000													
				2500													
				5000													
				10000													
				20000													
				30000													
			CRUISE														
			DESCENT	30000													
				20000													
				10000													
				5000													
				2500													
				1000													

AFCRL FORM FEB 68 0-57

Figure 1. Line-of-Sight Observation Form

3. ANALYSIS

More than 7200 observations were taken during the winter season from aircraft flying between 25,000 and 35,000 ft. This is the largest number of observations collected for any season and layer. Figures 2a, b, c, d, and e depict an analysis of the estimated probabilities (relative frequencies) for this layer. These are the only data of sufficient density to permit large scale map analysis.

Figure 2a is an analysis of the observations taken at the -90° viewing angle during the winter season. It reveals that the highest probabilities of a clear line-of-sight straight down are over land areas with probability decreasing as ocean areas are approached. In mid-United States and Canada the probability of seeing right under the aircraft is greater than 50 percent, on the east coast approximately 20 percent, and on the west coast approximately 30 percent. Areas of poor air-to-surface visibility cover much of the Atlantic and Pacific Oceans.

A comparison between Figure 2a and Landsberg's (Berry et al, 1945) mean cloudiness in percentage of sky cover for the month of January shows good general agreement. Areas of poor air to surface visibility, that is, Gulf of Alaska, Pacific north of Japan, and from the east coast of the United States across the Atlantic to Great Britain, generally coincided with areas of high percentage of mean cloudiness. In the mid-United States, Canada, and part of Mexico where the probability of a clear line-of-sight is highest, as seen in Figure 2a, Landsberg's chart compares favorably showing less than 50 percent mean cloud cover.

Surprisingly, Figure 2b, an analysis of the observations taken at the -30° viewing angle, is very similar to Figure 2a except in the Pacific Ocean along approximately 170°W longitude where the pilots report seeing the ocean ahead of them at 30° below horizon much more frequently than seeing the ocean directly below them, a reversal of the expected results. In scattered and broken cloudiness the vertical extent of clouds should offer greater obstruction than a straight down line-of-sight which could be blocked only by the plan view of each cloud. Undercasts would, of course, tend to eliminate this difference. No explanation is offered for this anomalous result.

Figure 2c depicts the probability of observing a clear line-of-sight from the aircraft to the horizon. A clear horizon is defined as one where the distant line along which the earth (ocean) and sky appear to meet is distinct; that is, not obscured by clouds or fog (haze). In general there is only a 30 to 50 percent chance of seeing the horizon in much of the belt between 30 and 40°N latitude. The probability increases to about 70 percent at both higher and lower latitudes.

Figures 2d and 2e show that, from altitudes of 25,000 to 35,000 ft the probability of seeing blue sky is greater than 70 percent. However, this still leaves a 20- to 30-percent probability of not being able to detect and track an incoming aerospace vehicle, a probability of no small concern.

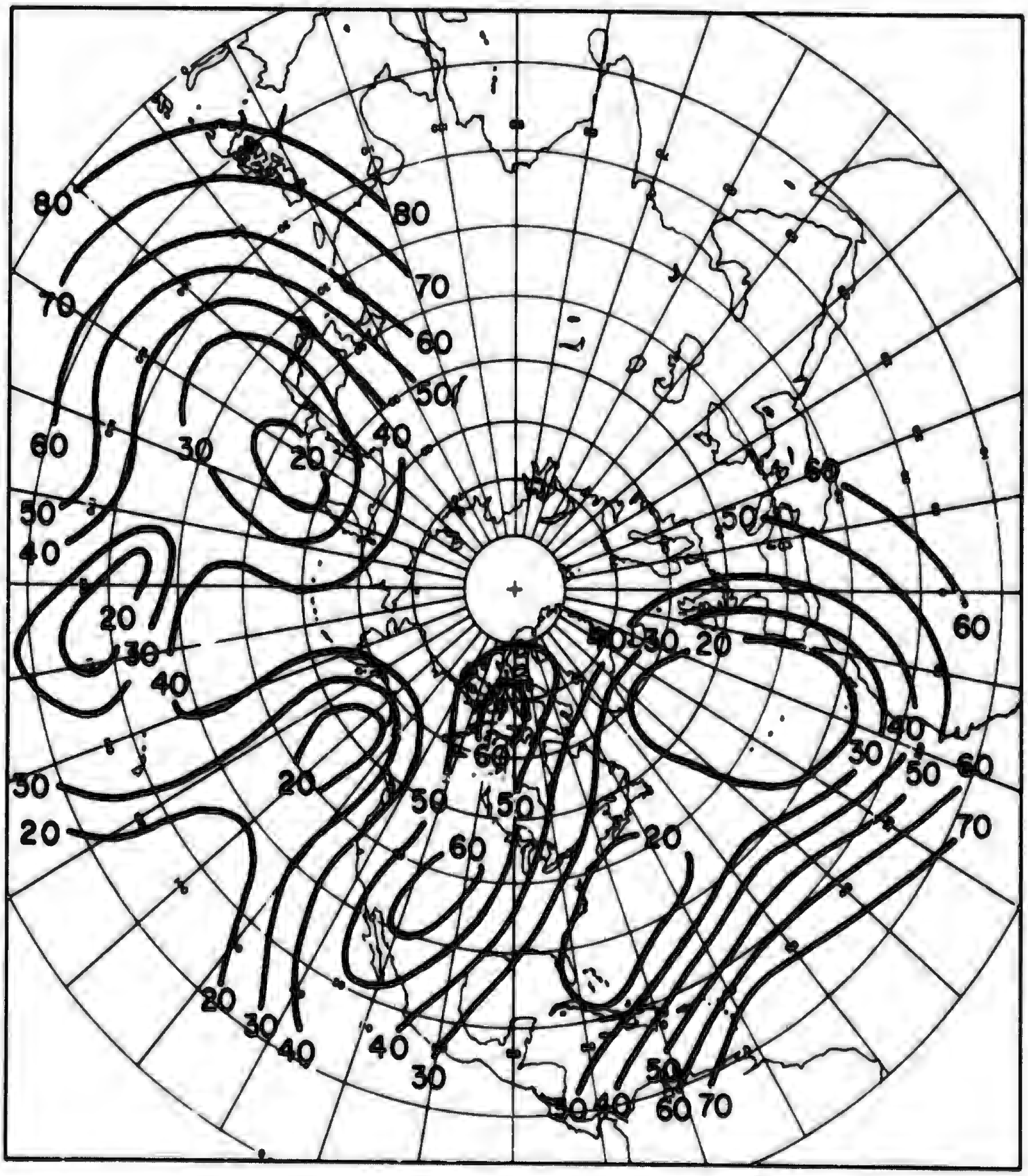


Figure 2a. Probability of Clear Lines-of-Sight from 25,000 to 35,000 ft at an Angle of 90° Below the Horizon in Winter

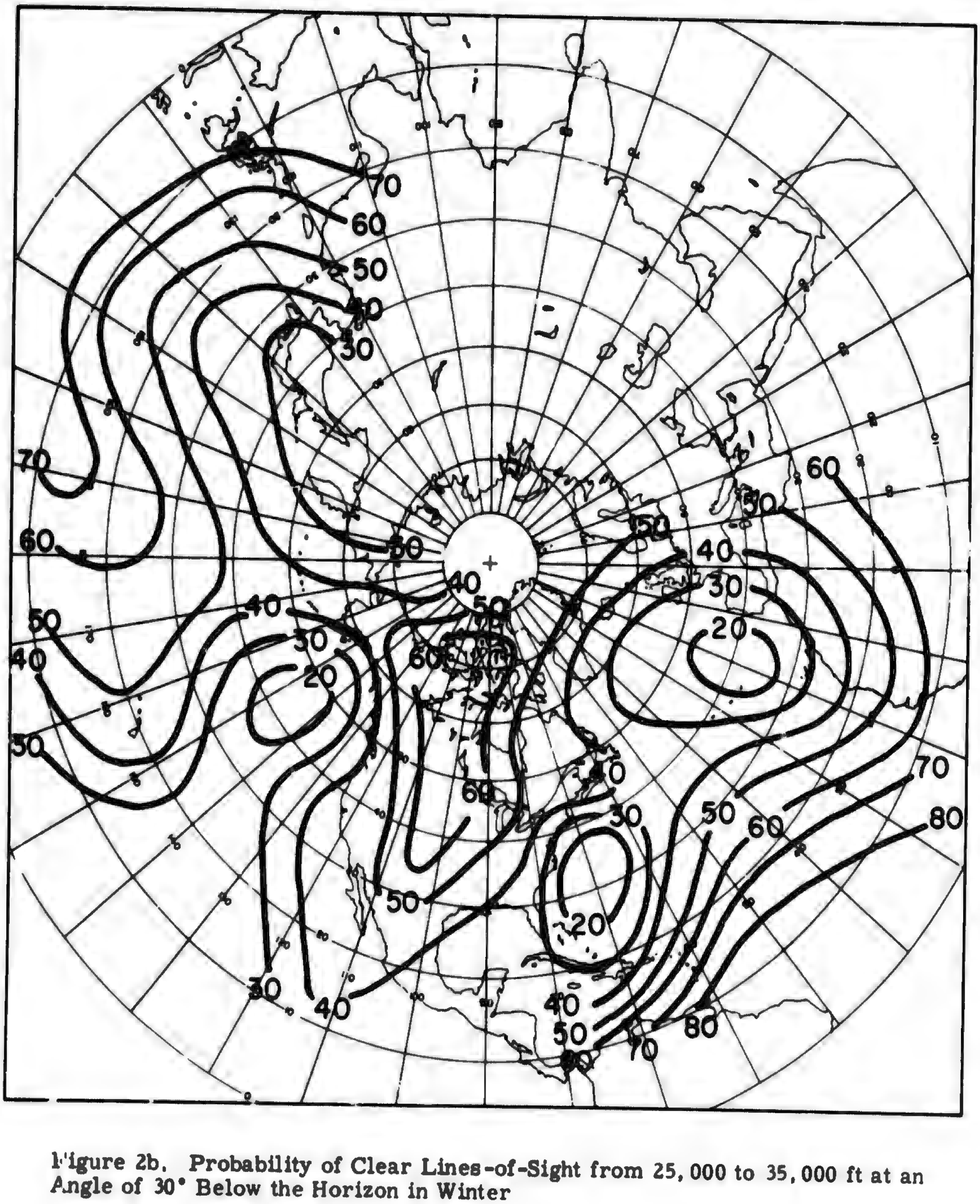


Figure 2b. Probability of Clear Lines-of-Sight from 25,000 to 35,000 ft at an Angle of 30° Below the Horizon in Winter

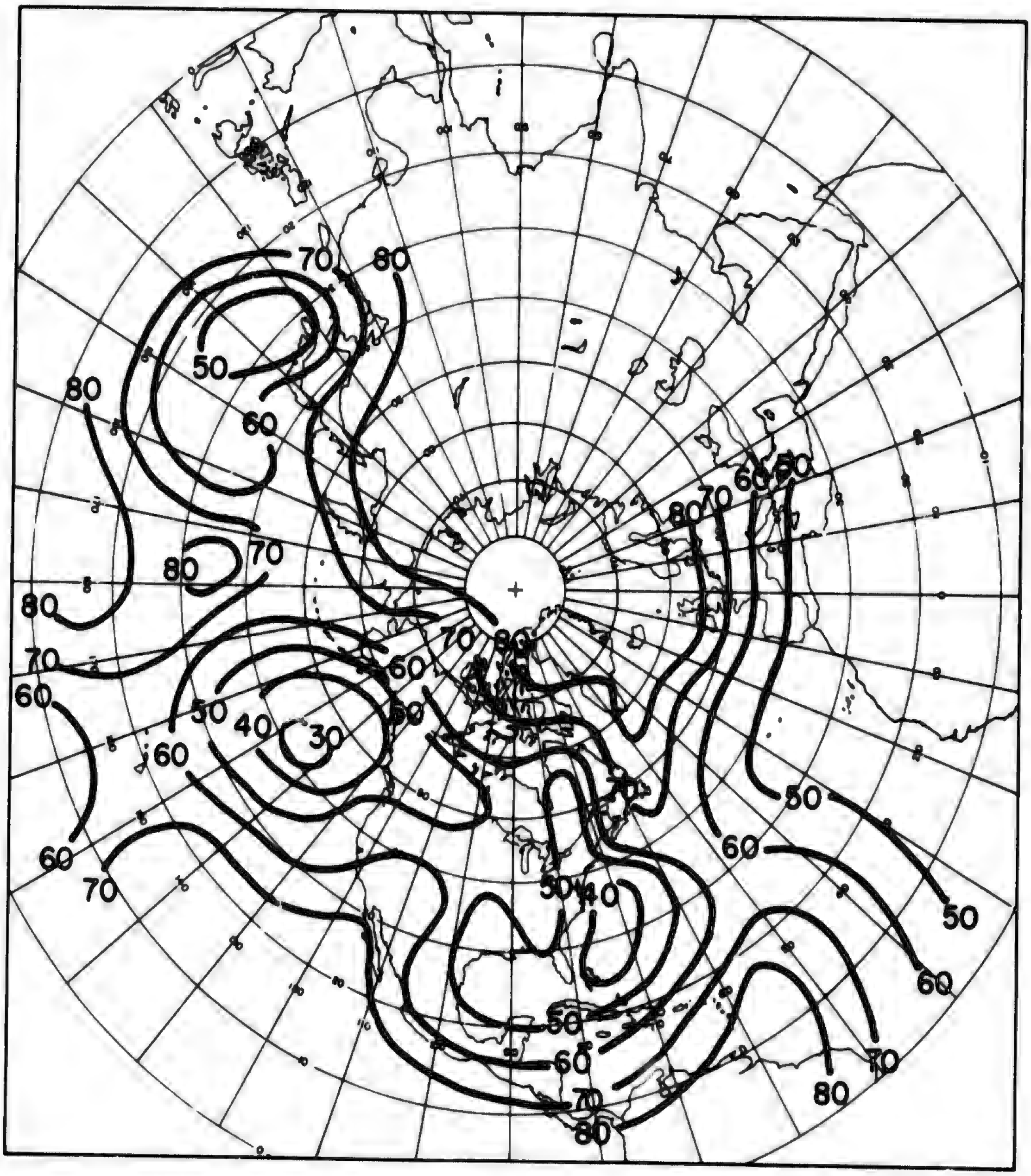


Figure 2c. Probability of Clear Lines-of-Sight from 25,000 to 35,000 ft at the Horizon Directly in Front of Aircraft in Winter

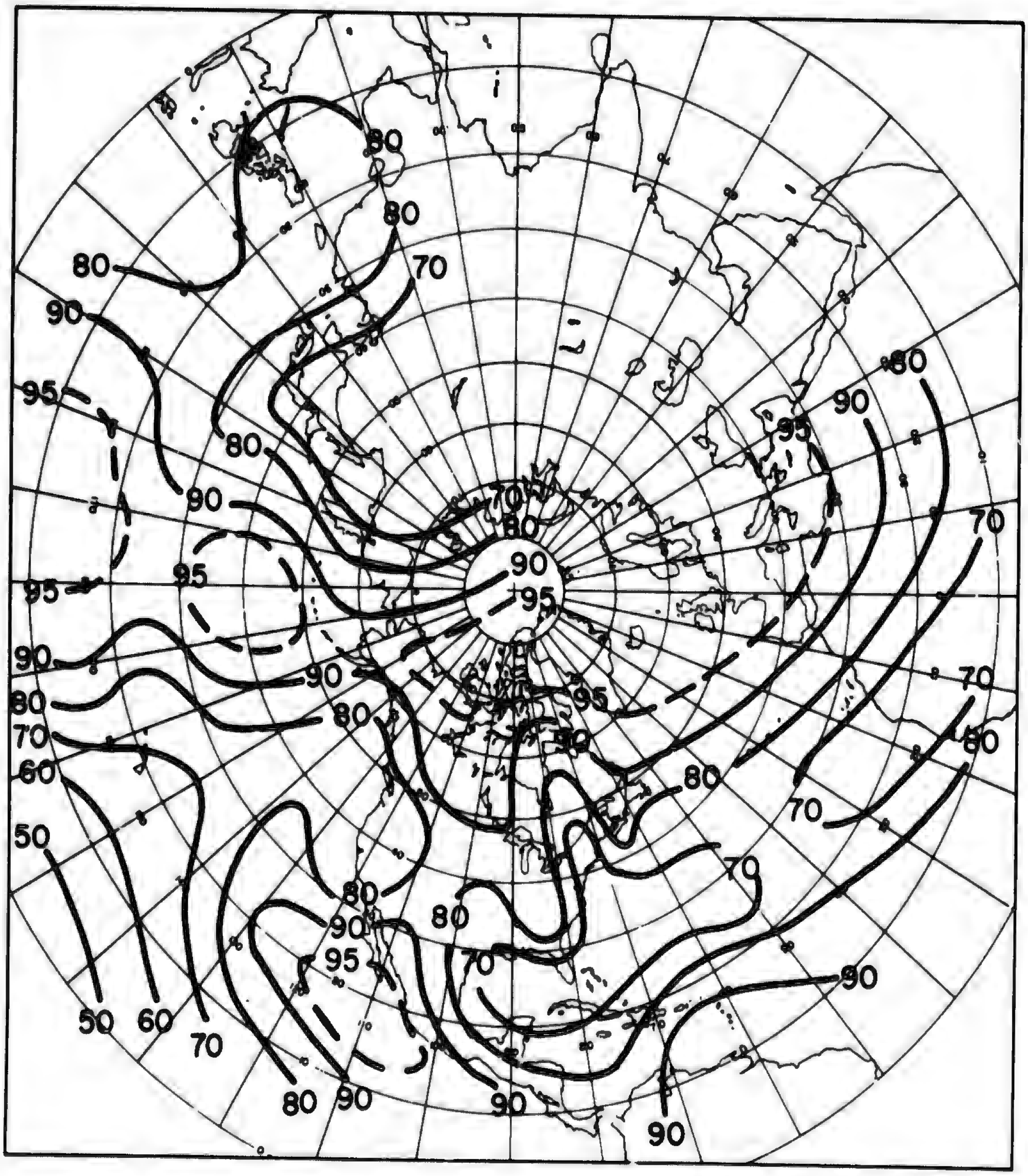


Figure 2d. Probability of Clear Lines-of-Sight from 25,000 to 35,000 ft at an Angle of 30° Above the Horizon in Winter

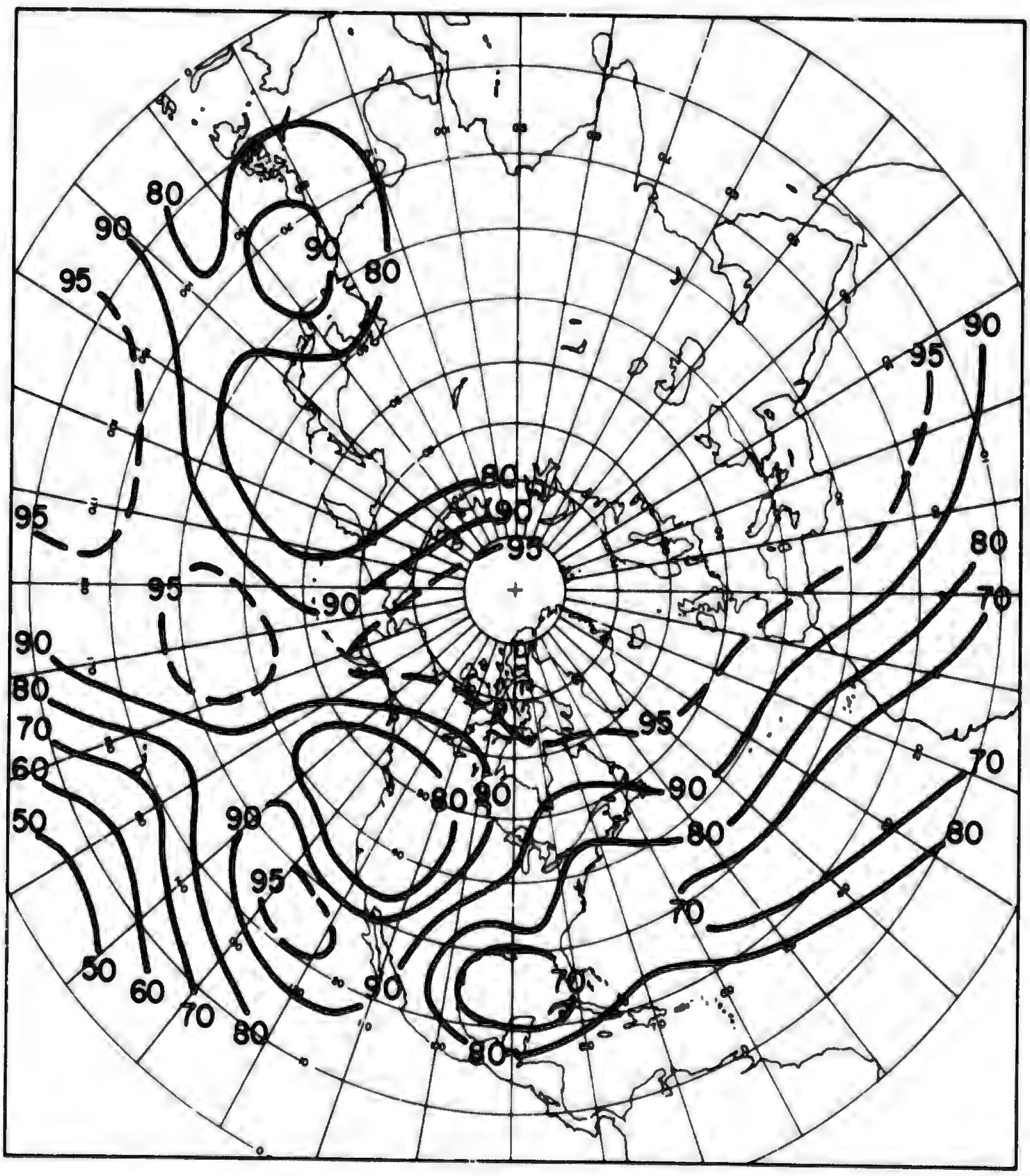


Figure 2e. Probability of Clear Lines-of-Sight from 25,000 to 35,000 ft at an Angle of 90° Above the Horizon in Winter

Another analysis, Figure 3, illustrates the probability of a clear line-of-sight along the 40°N latitude circle for the five angles in the 25,000 to 35,000 ft layer. As stated, probability of seeing the ground at -90° should be greater than at -30° because when looking down at an angle less than -90° the observer's visibility would be obstructed not only by plan view of clouds but by the sides of clouds as well. Also, an actual line-of-sight is considerably longer at -30°. Figure 3 does not bear this out. This can only be explained by the assumption that the observer is encompassing a larger field of vision when observing at an angle of -30° than when viewing directly below the aircraft.

As expected, when viewing the sky at +30° and +90°, the probability of seeing blue sky is best at +90°. From these altitudes (between 25,000 and 35,000 ft) the probability of a clear line-of-sight, looking at 30° or more above the horizon, ranges from 70 to 95 percent in the winter with some pronounced areas of good overhead visibility. A distinct horizon is seen, with few exceptions, more than 50 percent of the time along the 40° latitude circle in the winter.

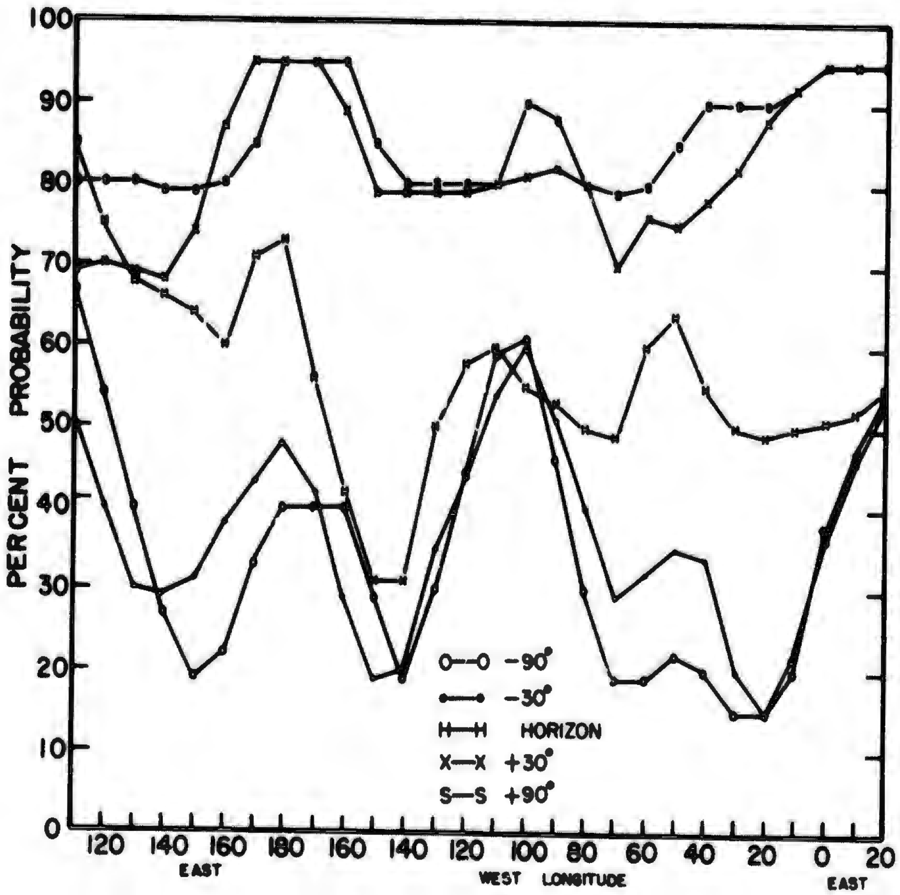


Figure 3. Probability of Clear Lines-of-Sight from 25,000 to 35,000 ft at Angles of -90°, -30°, Horizon, +30°, and +90° at the 40°N Latitude Circle in Winter

Figure 4 (a, b, c, d) depicts the collection of all observations within the sector between 30 to 40°N and 120 to 130°W (San Francisco area) for each season. Figure 4a represents the analysis of about 2000 observations during winter in this sector and shows a gradual decrease in the probability of seeing the horizon from 66 percent at 10,000 ft to 50 percent at 40,000 ft. From 30,000 ft the sky overhead cannot be seen 21 percent of the time and from 40,000 ft 13 percent of the time. At 30,000 ft the ground below at -30° and -90° cannot be seen 52 and 56 percent of the time, respectively.

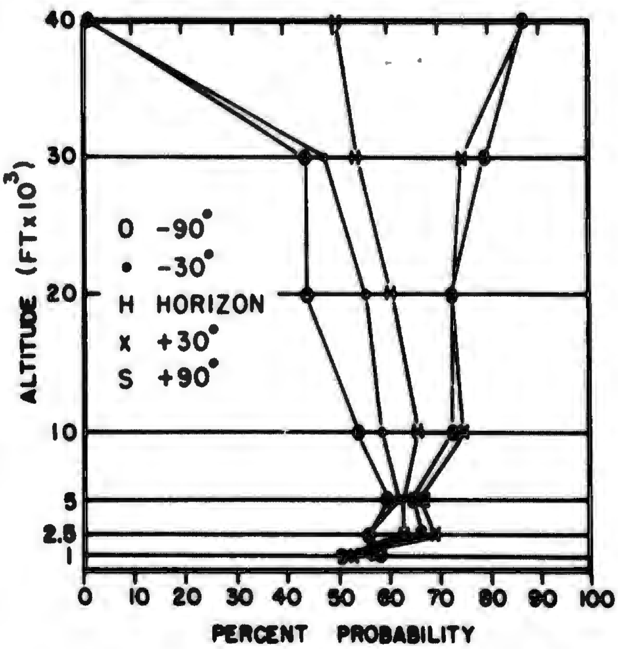


Figure 4a. Probability of Clear Lines-of-Sight in Sector 30 to 40°N and 120 to 130°W for Winter Season

An analysis of spring, for the San Francisco area, based on nearly 1100 observations, is provided in Figure 4b.

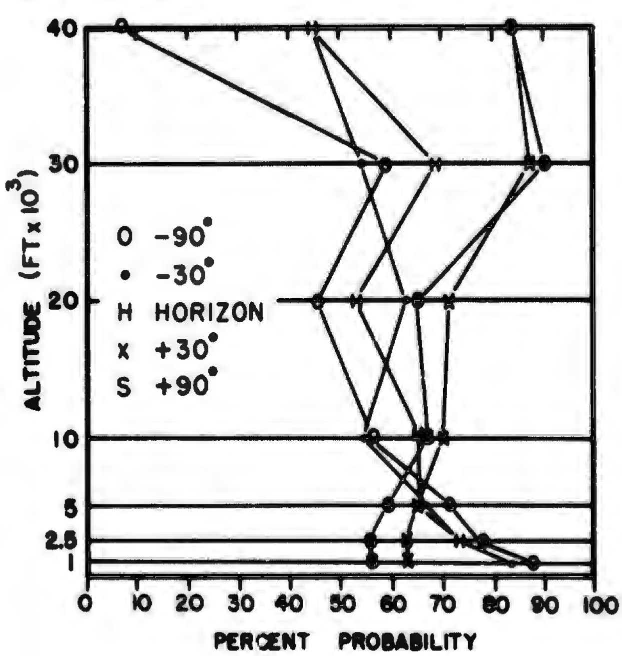


Figure 4b. Probability of Clear Lines-of-Sight in Sector 30 to 40°N and 120 to 130°W for Spring Season

The probability of seeing the horizon varies considerably, from 66 percent at 10,000 ft to 53 percent at 20,000 ft, to 69 percent at 30,000 ft, to 44 percent at 40,000 ft. That blue sky can be seen above the aircraft, at +30° and +90° with a higher probability at 30,000 ft than at 40,000 ft, is some indication of inconsistencies in the data. This is undoubtedly the result of the subjective type of observation and small sample of data.

Figure 4c depicts an analysis of the summer season. Generally the probability of seeing the sky at +30° and +90° is about 88 percent above 5000 ft. At 10,000 ft

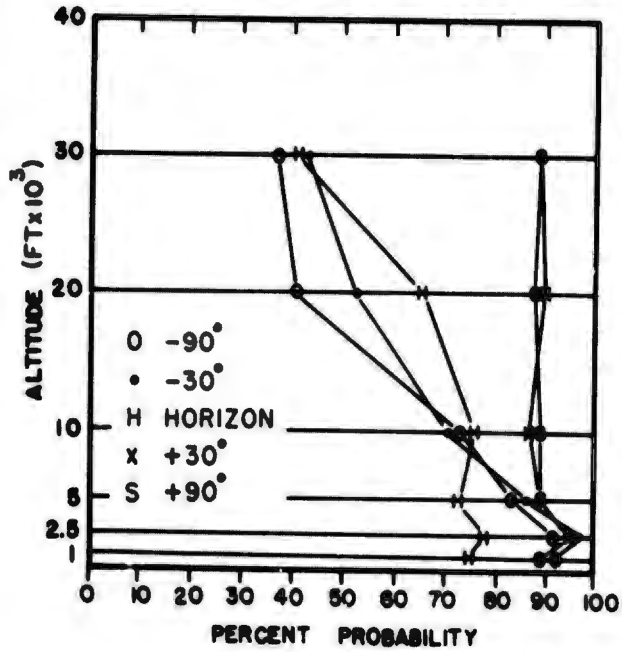


Figure 4c. Probability of Clear Lines-of-Sight in Sector 30 to 40°N and 120 to 130°W for Summer Season

and lower the horizon is seen more than 73 percent of the time, while at 20,000 ft it is seen only 66 percent of the time and at 30,000 ft 41 percent. Only 300 observations were available for this illustration.

Figure 4d, fall, in the San Francisco sector, shows an increase with altitude, in the probability of seeing the horizon from 51 percent at 5,000 ft to 70 percent at 30,000 ft, a complete reversal of the altitude trend in other seasons. At 30,000 ft the ground below at -90° is visible 25 percent of the time. Blue sky above at +90° is visible 85 percent of the time from 30,000 ft. Nearly 800 observations were used in the analysis.

Figure 5 provides a summary of all 72,000 observations. The curves are not intended to be representative of any given season or location but were drawn to describe how probabilities vary with altitude and how they relate to each other. Some interesting results obtained from this graph are (a) from an altitude of 40,000 ft the sky directly overhead cannot be seen five percent of the time, and (b) the ability to see the horizon varies slightly from 50 percent at 12,000 ft to 58 percent at 40,000 ft.

Why the earth's surface can be seen with a higher probability, above 20,000 ft, at an

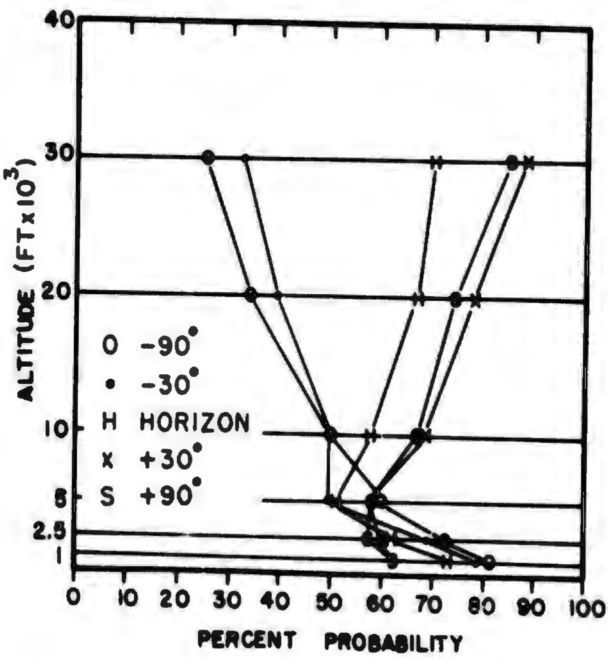


Figure 4d. Probability of Clear Lines-of-Sight in Sector 30 to 40°N and 120 to 130°W for Fall Season

angle 30° below the horizon than when looking straight down is still unexplained.

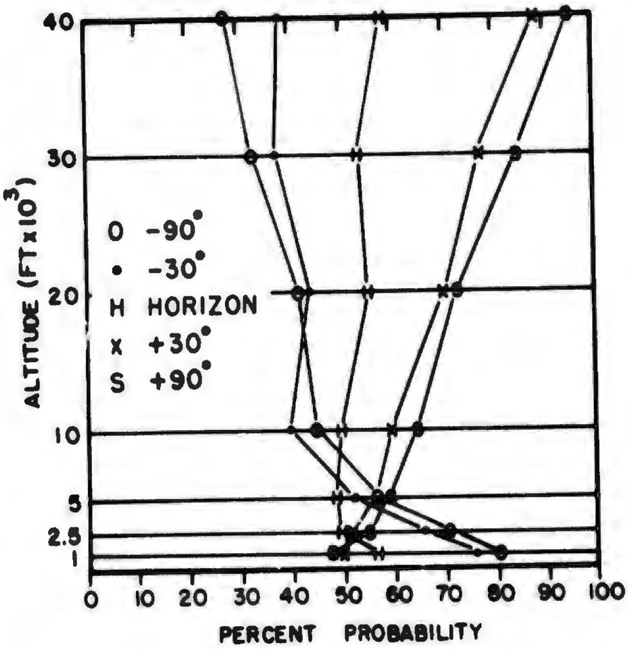


Figure 5. Probability of Clear Lines-of-Sight over Northern Hemisphere for All Seasons Combined (72,000 observations)

4. COMPARISON

Figure 6 provides a comparison between actual frequencies of clear lines-of-sight to the ground in the 30 to 40°N, 70 to 80°W sector provided by these aircraft observations and analogous, estimated frequencies for Washington, D.C. during summer, derived from surface cloud and sunshine observations by McCabe (1965). His relationship of sunshine, cloud cover, and sun angle for this location and season, indicates an estimate of the probability of a cloud-free line-of-sight of about 87 percent, looking straight up from the surface to an altitude of 40,000 ft. However, the airborne observers (AFCRL curve) at 40,000 ft, report they can see the ground below at -90°, only 26 percent of the time. The AWS -30° curve depicts an estimate of the probability of a cloud-free line-of-sight to various altitudes at an angle of 30° above the horizon (same as -30° for an airborne observer) to all layers up to 40,000 ft. It indicates clear lines from the surface to 40,000 ft of 68 percent, while the airborne observer reports he can

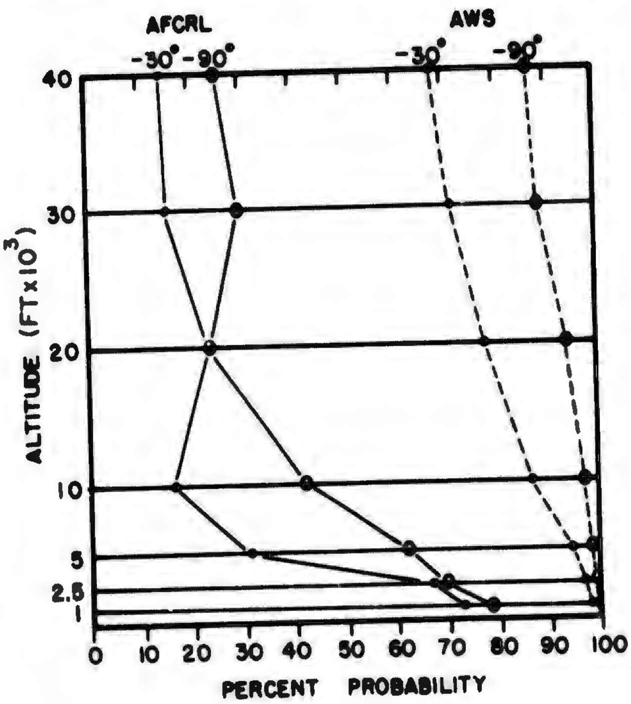


Figure 6. Comparison (Washington, D.C. in Summer) of AFCRL Experimental Data and AWS Derived Frequencies

only see the ground 15 percent of the time from that altitude and angle. These differences are astonishingly great.

Some of this difference may be explained by Lund (1966) who states: "Since the sunshine recorder does not detect 'thin' clouds, the probability of a clear line-of-sight, as defined in this paper, exceeds the probability of a cloud-free line-of-sight by an amount equal to the probability of 'thin' clouds, roughly 6 to 20 percent at the stations under study." More may be explained by the fact that smoke, haze, and ground fog are not detected by the sunshine recorder, yet their presence can be a serious obstruction to seeing the ground or other airborne objects from an aircraft.

U.S. Weather Bureau (1951) statistics show that the average cloudiness over Washington, D.C., during summer, is 5/10. Clear days (3/10 or less clouds) were reported 35 percent of the time. These statistics, as summarized from standard surface observations, suggest a much more optimistic picture of unobstructed lines-of-sight than provided by observations of the ground by an airborne observer.

A total of 300 aircraft observations were available for this illustration: 43 at 1000 ft; 37 at 2500 ft; 59 at 5000 ft; 65 at 10,000 ft; 21 at 20,000 ft; 50 at 30,000 ft; and 27 at 40,000 ft. Because such a small sample can be unrepresentative, it was compared with all 72,000 observations (Figure 5) to establish further confidence in these unexpected results, much lower probability of clear lines-of-sight than expected. The -90° and -30° curves in Figure 5 seem to support the AFCRL -90° and -30° curves in Figure 6, although obstructions to air-to-ground visibility over the mid-Atlantic coast (Figure 6) in the summer appear somewhat greater than the annual Northern Hemisphere average provided by the Weather Bureau.

5. SUMMARY AND CONCLUSIONS

The relative frequencies of clear lines-of-sight plotted on the maps in the appendices of this paper are based on more than 72,000 in-flight observations. Nevertheless, the representativeness of these estimates as true long term probabilities is open to question. The observations were taken by many different observers, from a wide variety of aircraft, at all times of the day and night, at all seasons of the year, from points scattered over most of the Northern Hemisphere. The data were summarized by season, altitude, angle of vision, and 10° latitude-longitude sectors. This necessary subdivision of the data has often led to estimates of probabilities based upon small samples of data. There is also a question of the representativeness of the 1965-66 observations for long term climatology.

Despite these shortcomings, the observations are unique and the probability estimates provide a first approximation of the true seeing conditions from a cockpit. Hopefully better estimates will be obtained through future endeavors of this type.

Some pertinent information obtained from these data are:

(a) Highest probabilities in winter, of a clear line-of-sight looking at the surface from 25,000 to 35,000 ft are over land areas with probability decreasing as ocean areas are approached.

(b) In general there is a 20- to 30-percent chance of not seeing blue sky from altitudes of 25,000 to 35,000 ft in winter.

(c) A distinct horizon is seen, with few exceptions, more than 50 percent of the time along the 40° latitude circle in winter from 25,000 to 35,000 ft.

(d) Fall, in the San Francisco sector, shows an increase with altitude in the probability of seeing the horizon from 51 percent at 5000 ft to 70 percent at 40,000 ft, a complete reversal of the altitude trend from other seasons.

(e) If the small sample of aircraft observations, used in Figure 6, is representative of the true relationship between probabilities deduced from standard surface weather observations and the actual probability of air crews to see the ground, estimates of clear lines-of-sight from the air, based upon standard surface weather observations, are very greatly inflated and will lead to badly underdesigned visual and infrared detection and tracking systems.

(f) A check of statistics of clear days, as summarized from standard surface observations, reveals that they provide a much more optimistic picture than that provided by observations of the ground by an aircraft observer as indicated by these 72,000 observations. Since, on a clear day there should be no obstruction to lines-of-sight, it appears that what is a clear day to a ground observer is not a clear day to an airborne observer.

Acknowledgments

The author is grateful to Mr. Iver A. Lund, Air Force Cambridge Research Laboratories, for his direction, guidance, and assistance throughout this entire program; Lt. Col. L.L. DeVries, Air Weather Service, who acted as liaison between AFCRL and U.S. Air Force participants; Capt. Louis P. McNicoll, 53rd Weather Reconnaissance Squadron for his suggestions in designing the observation form; Lt. William S. Dehn, U.S. Naval Oceanographic Office, Ice Reconnaissance Unit, for his cooperation and participation in this program; to Pan American World Airways, Inc., for their most generous contributions toward this effort, particularly Mr. L.R. Ulrich, Superintendent of Meteorology; and finally to Mr. Norman Sissenwine, Project Scientist for P-8624, Atmospheric Variability, under which this research was performed, who conceived and encouraged this effort in its entirety, and provided many ideas on the formulation of results.

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Lund, I.A. (1965) Estimating the probability of clear lines-of-sight from sunshine and cloud cover observations, J. Appl. Meteor. 4:714-722.

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McCabe, J.T. (1965) Estimating Mean Cloud and Climatological Probability of Cloud-Free Lines-of-Sight, Technical Report 186, Environmental Technical Applications Center, USAF, 26 pp.

U.S. Department of Commerce, Weather Bureau (1951) Sunshine and Cloudiness at Selected Stations in the United States, Alaska, Hawaii, and Puerto Rico, Technical Paper No. 12, 16 pp.

Appendix A

Winter Estimates of Probability of a Clear Line-of-Sight

In this ' ppendix are given Northern Hemisphere maps of estimates of the probability of a clear line-of-sight for winter (December, January, February) at five selected angles of vision: (a) ground at 90 degrees below the horizon (-90°); (b) ground at 30 degrees below the horizon (-30°); (c) horizon; (d) sky at 30 degrees above the horizon (+30°); (e) sky at 90 degrees above the horizon (+90°), and for eight altitude layers: below 1800 ft; 1801 to 3600 ft; 3601 to 7400 ft; 7401 to 14,999 ft; 15,000 to 24,999 ft; 25,000 to 34,999 ft; 35,000 to 44,999 ft; and above 45,000 ft. The Northern Hemisphere is divided into 10° latitude-longitude sectors. The values given in these sectors are estimates of the probability of a clear line-of-sight. Values in parentheses indicate the number of observations taken in that sector. Probabilities were not computed for sectors that reported less than 10 observations.

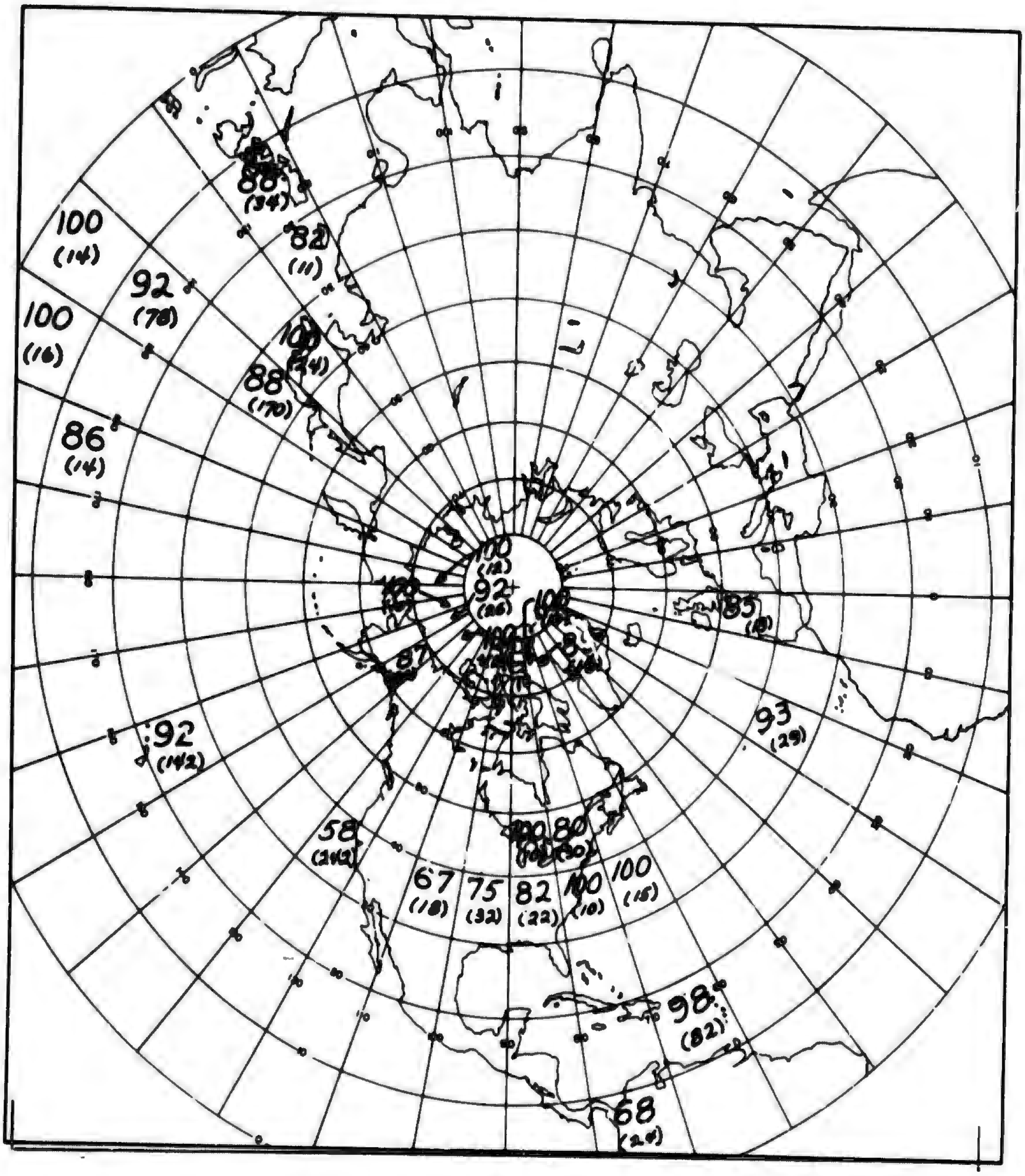

Figure A1. Estimates of the Probability of Seeing the Ground Directly Below the Aircraft (-90°) from Altitudes up to 1800 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

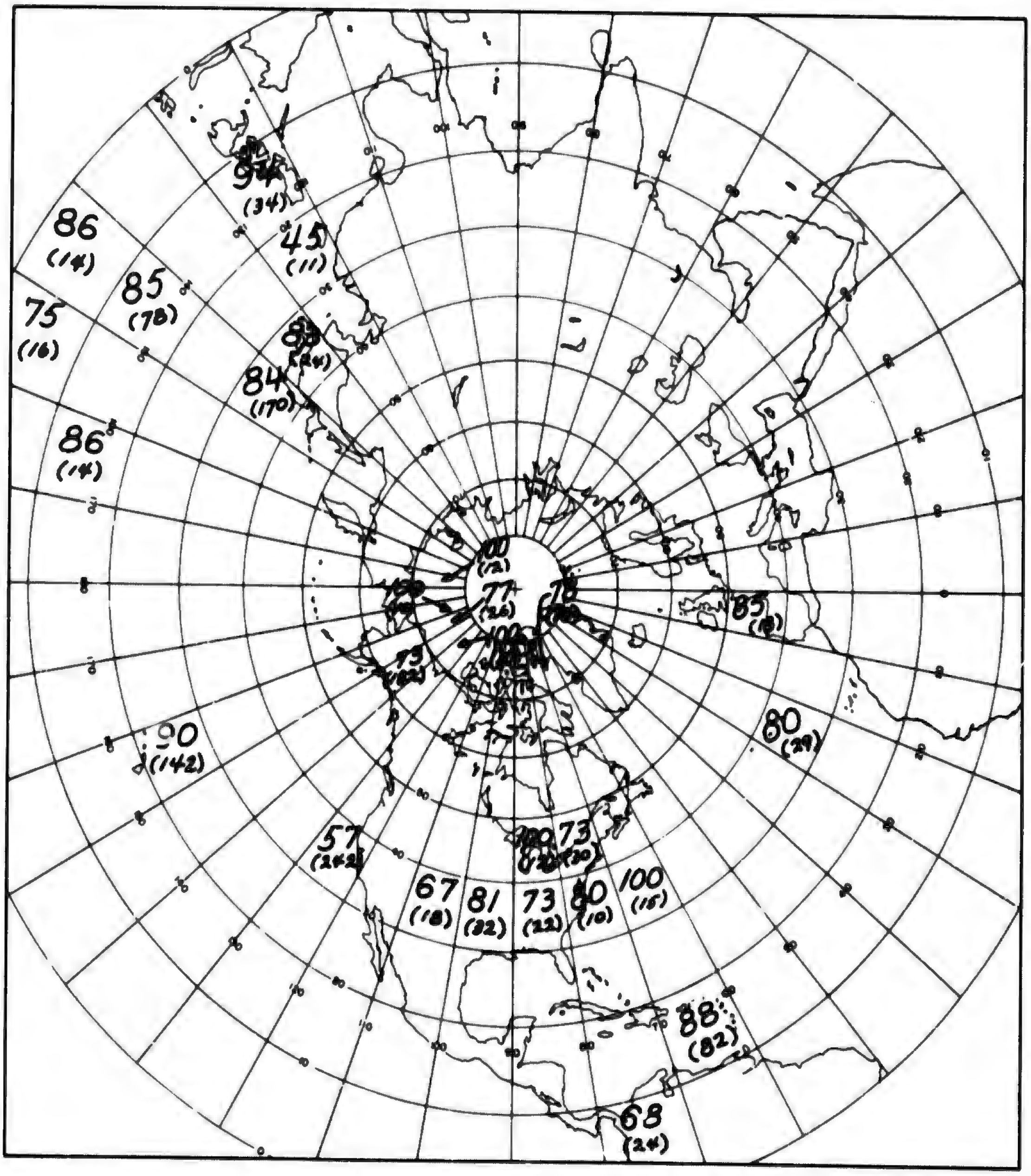

Figure A2. Estimates of the Probability of Seeing the Ground at 30° Below the Horizon (-30°) from Altitudes up to 1800 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

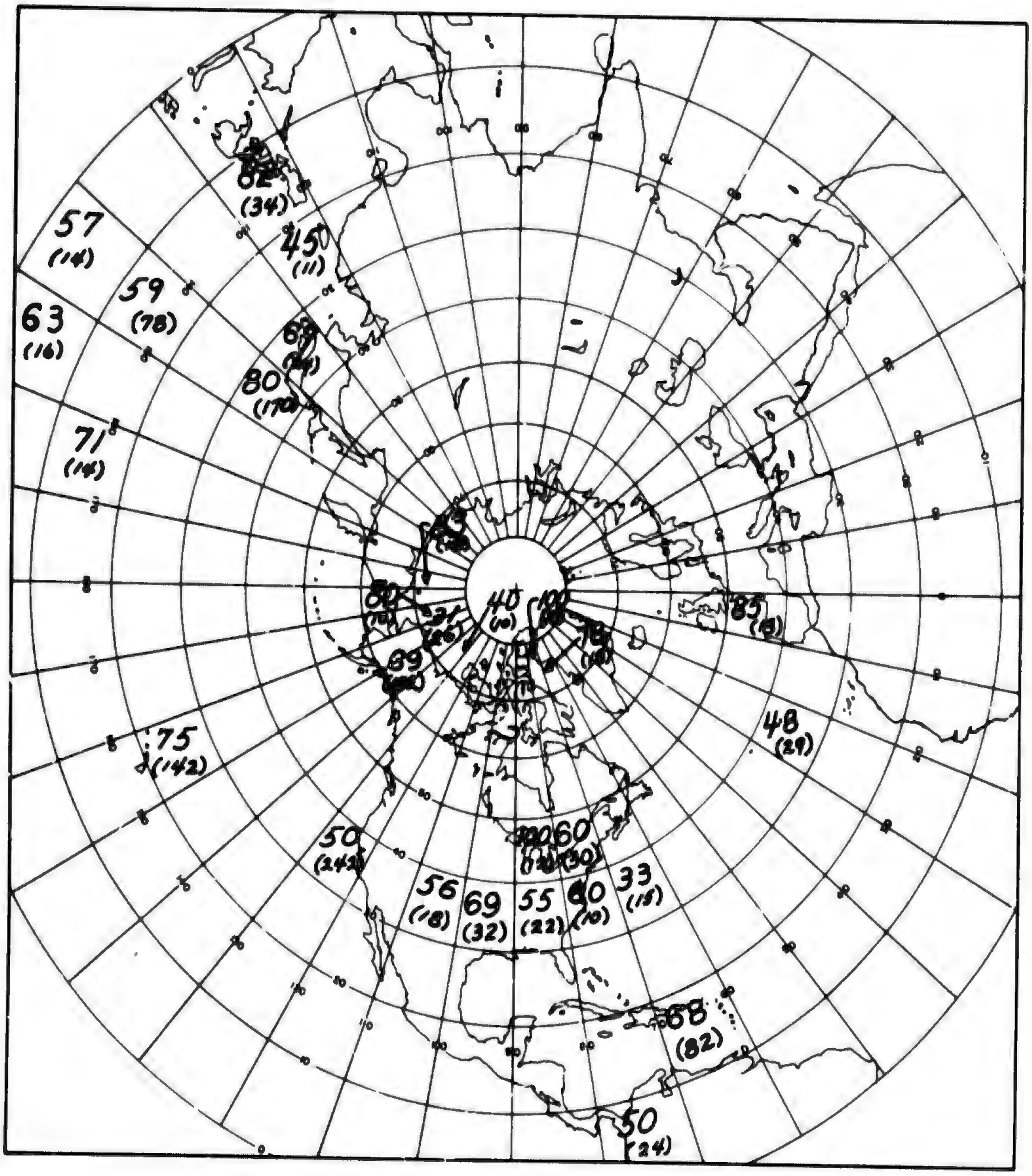

Figure A3. Estimates of the Probability of Seeing the Horizon from Altitudes up to 1800 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

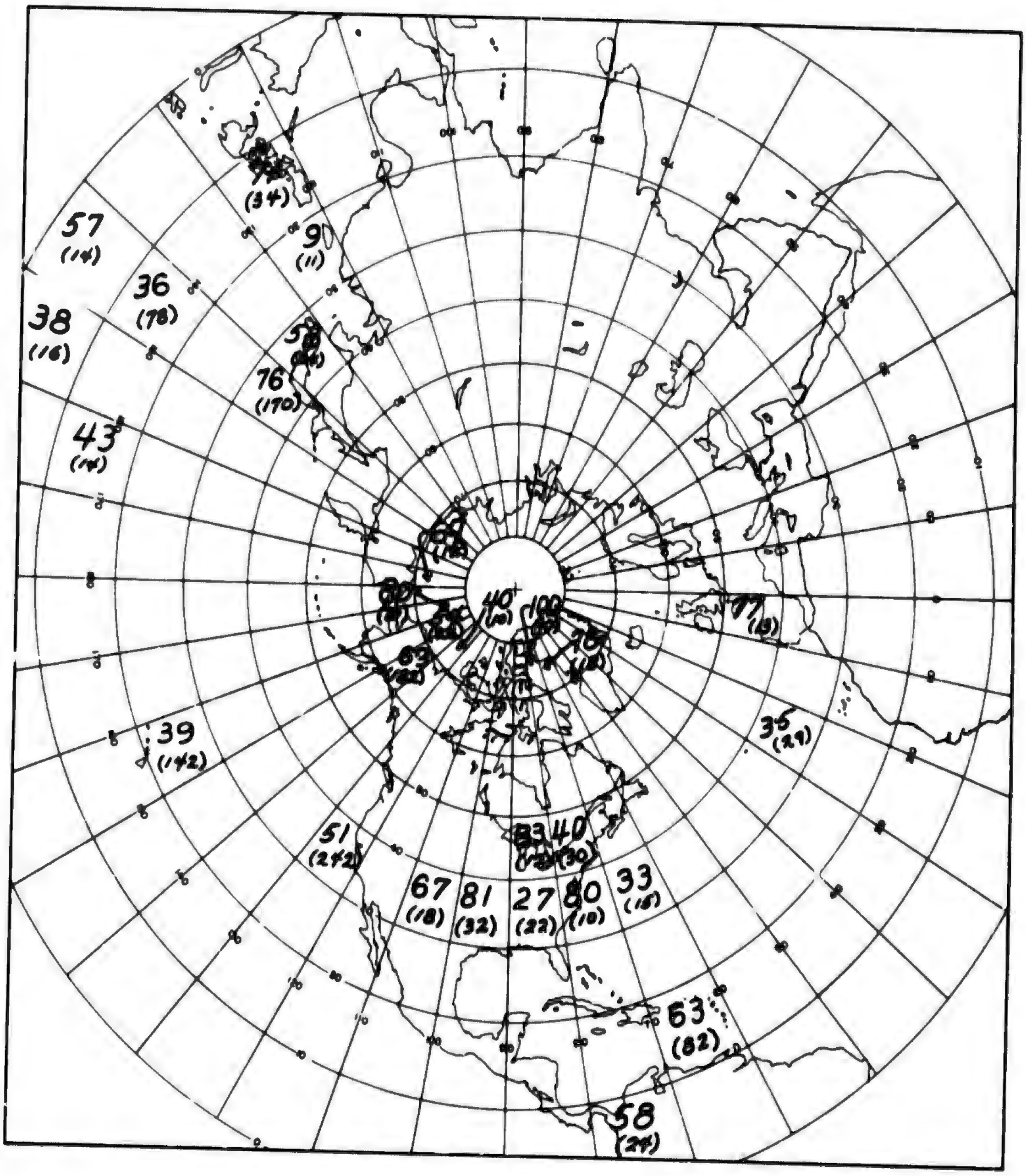

Figure A4. Estimates of the Probability of Seeing Blue Sky at 30° Above the Horizon (+30°) from Altitudes up to 1800 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

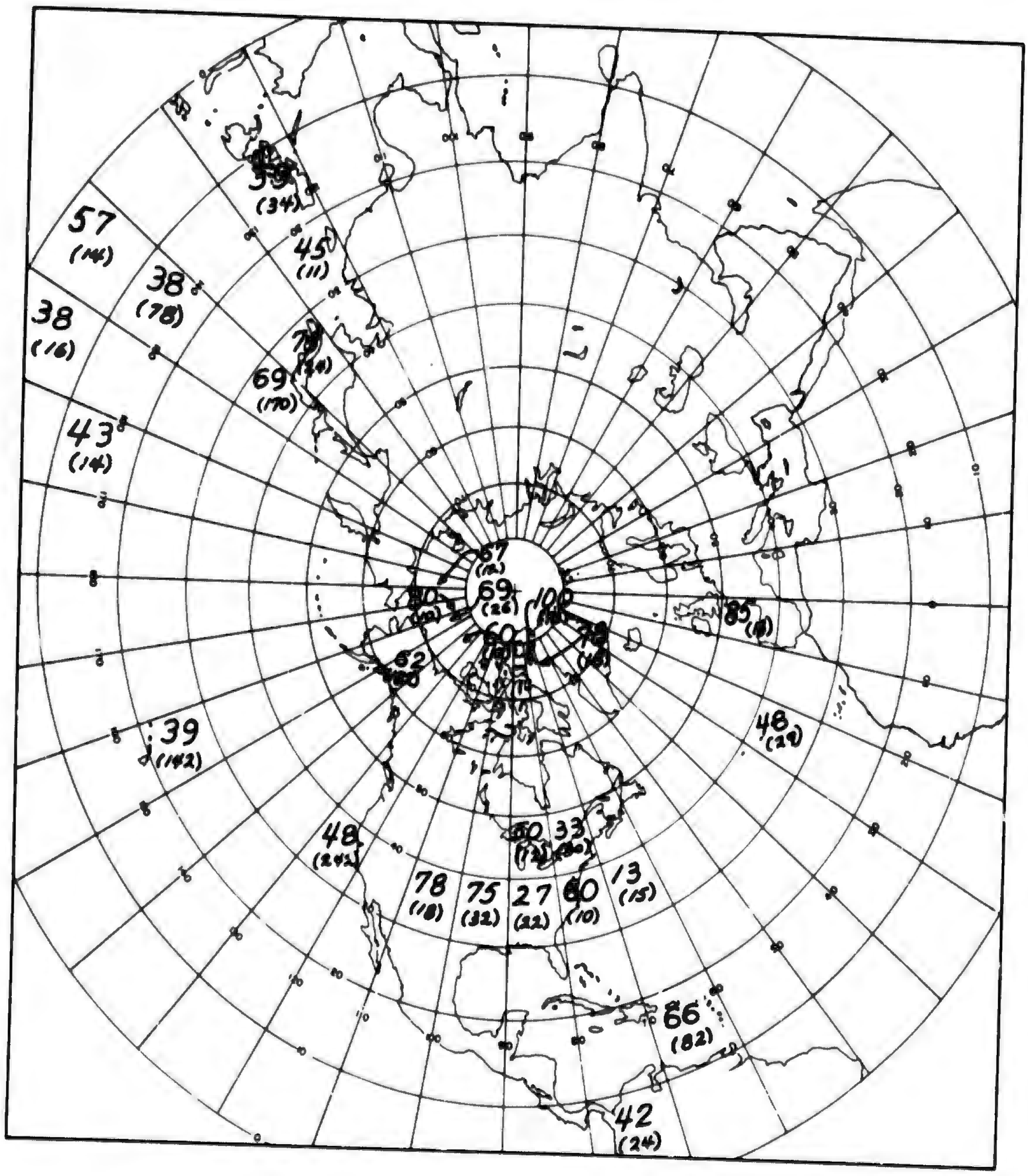

Figure A5. Estimates of the Probability of Seeing Blue Sky at 90° Above the Horizon (+90°) from Altitudes up to 1800 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

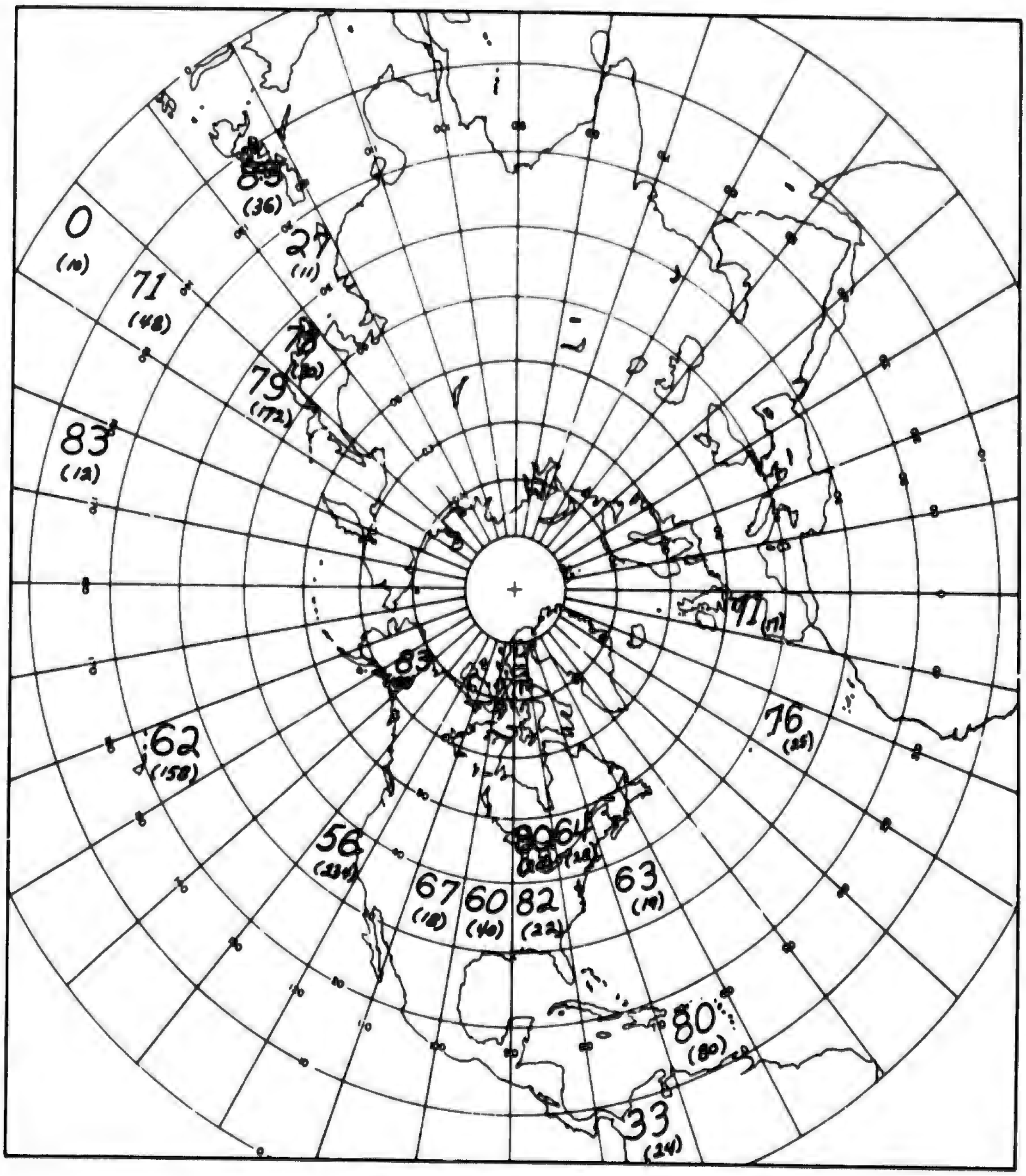

Figure A6. Estimates of the Probability of Seeing the Ground Directly Below the Aircraft (-90°) from Altitudes of 1801 to 3600 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

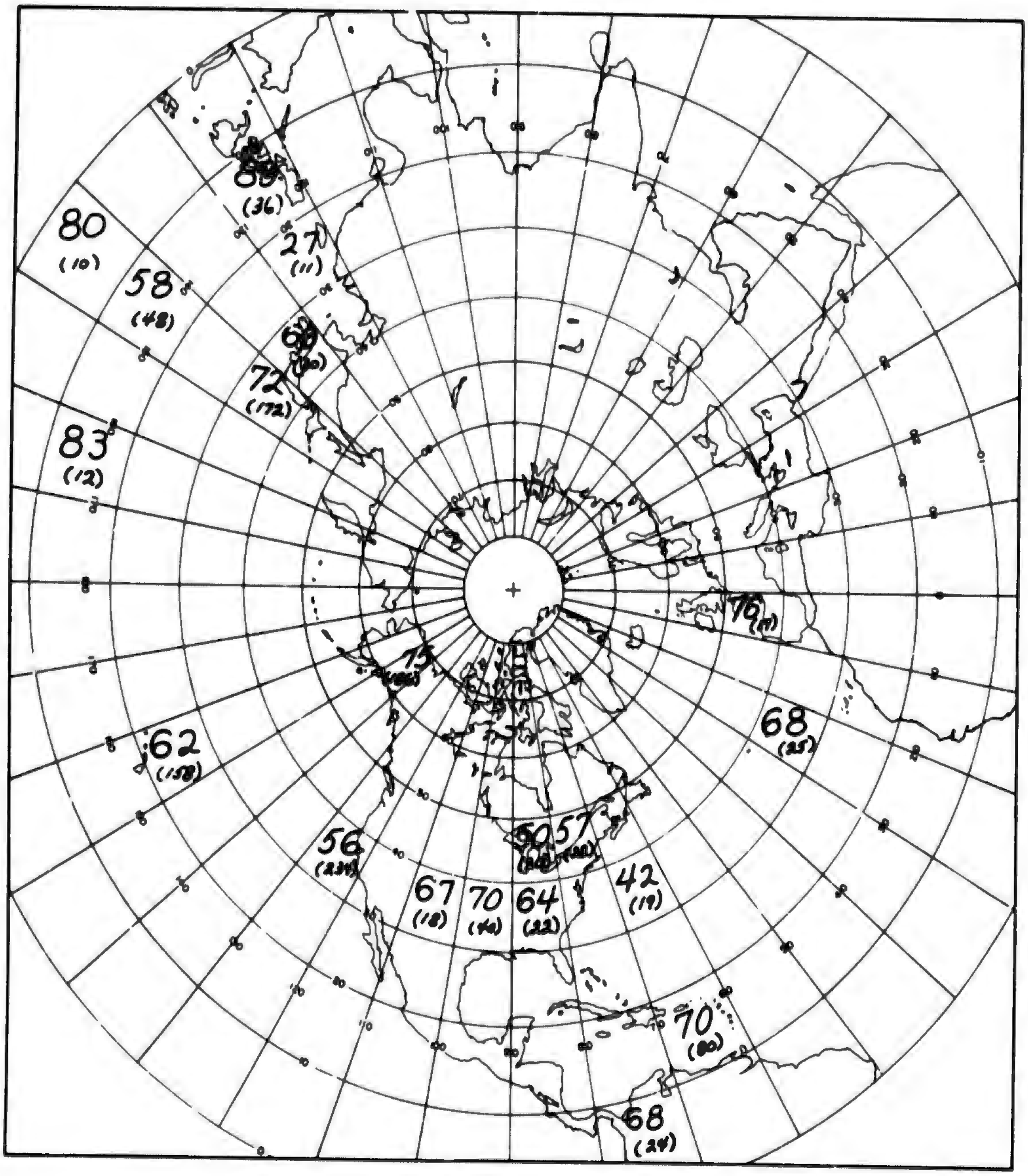

Figure A7. Estimates of the Probability of Seeing the Ground at 30° Below the Horizon (-30°) from Altitudes of 1801 to 3600 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

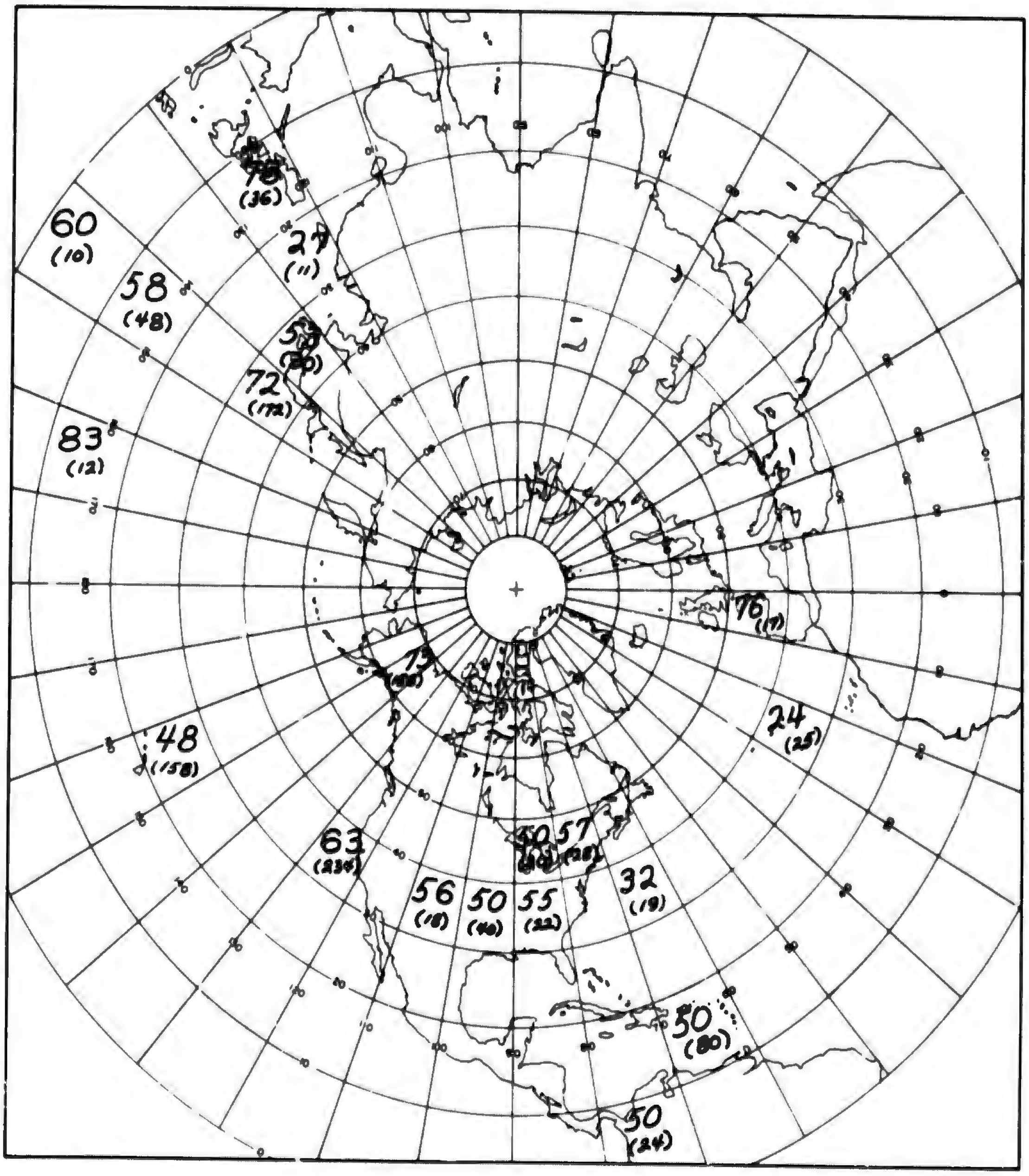

Figure A8. Estimates of the Probability of Seeing the Horizon from Altitudes of 1801 to 3600 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

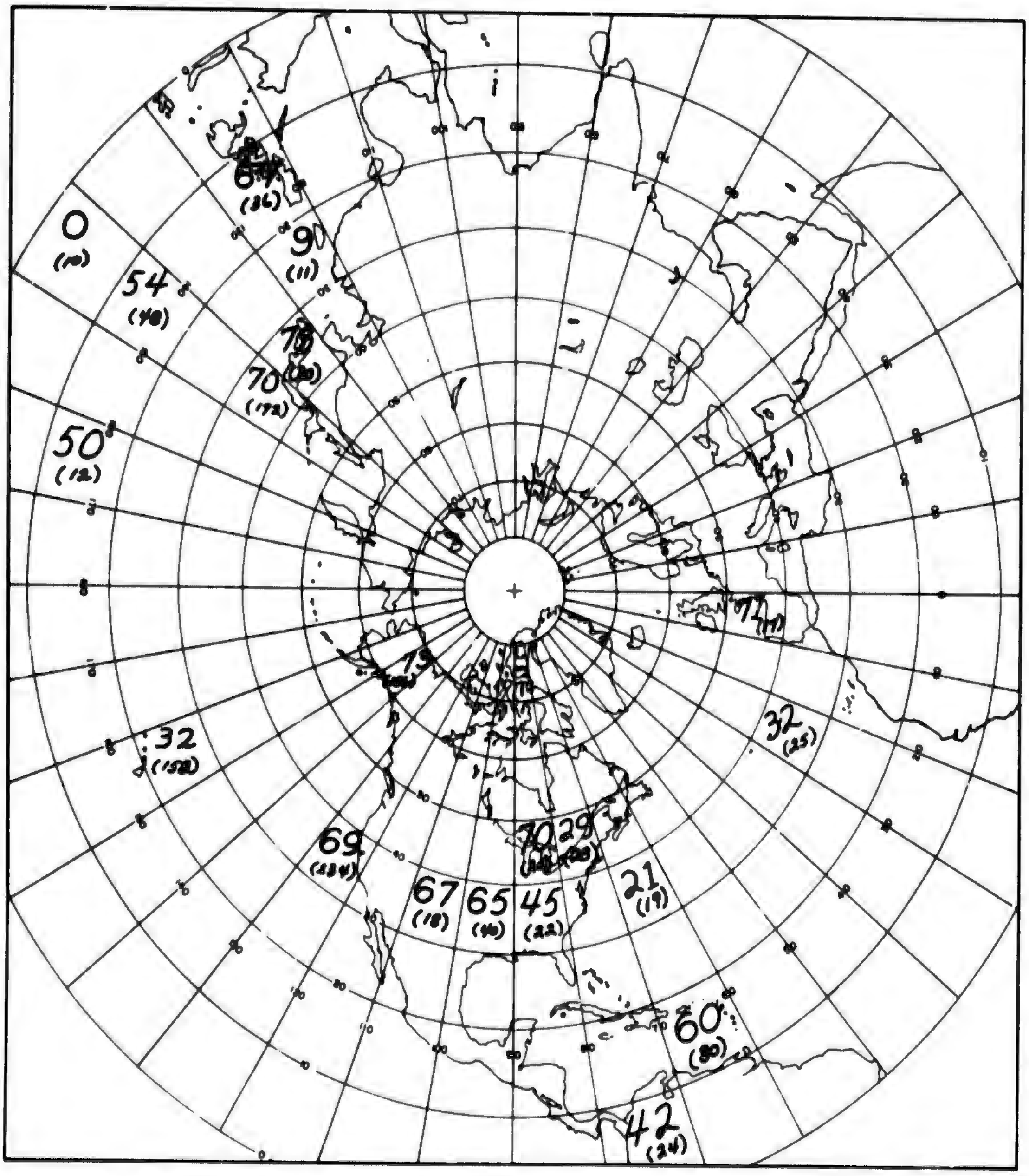

Figure A9. Estimates of the Probability of Seeing Blue Sky at 30° Above the Horizon (+30°) from Altitudes of 1801 to 3600 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

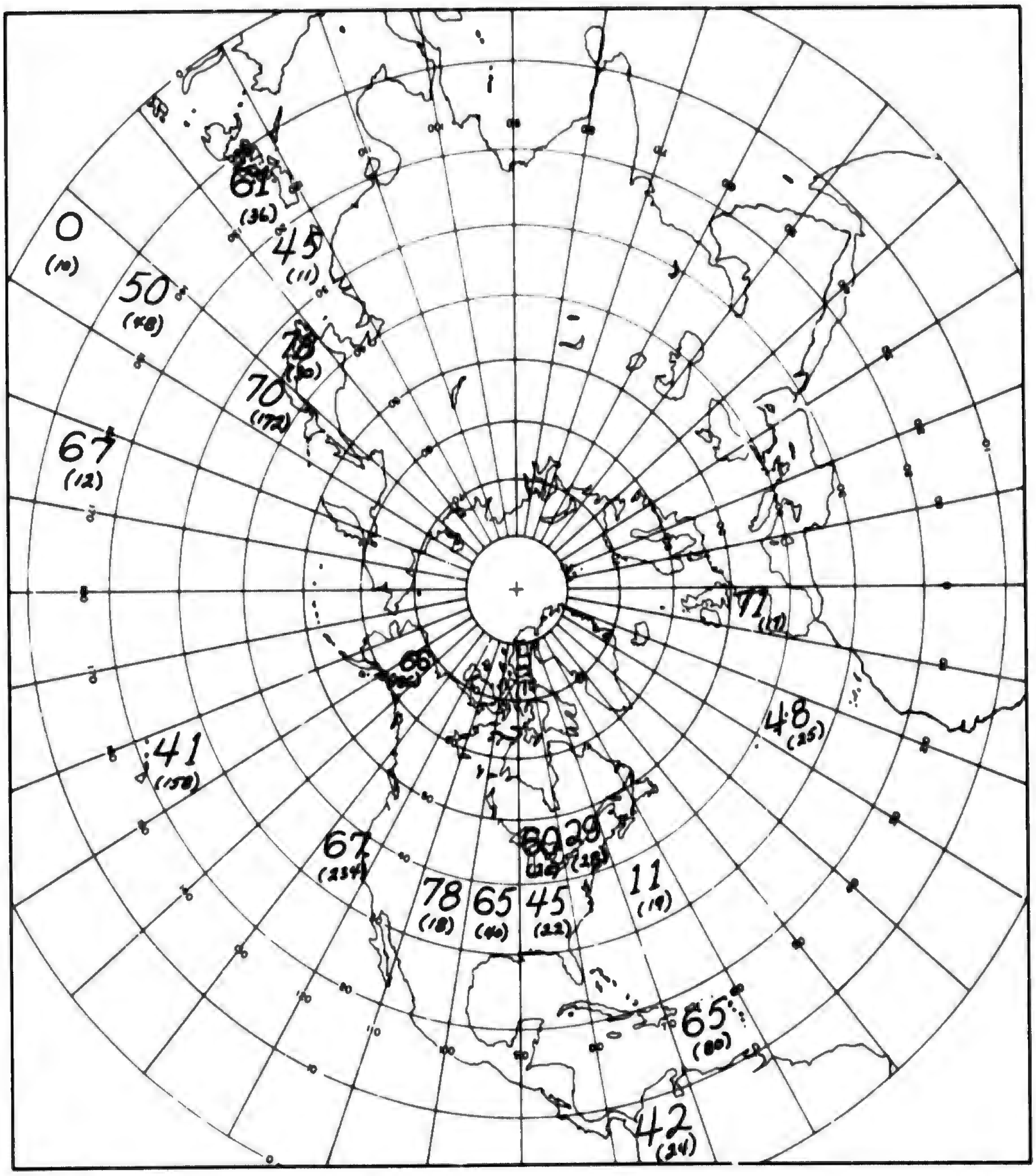

Figure A10. Estimates of the Probability of Seeing Blue Sky at 90° Above the Horizon (+ 90°) from Altitudes of 1801 to 3600 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

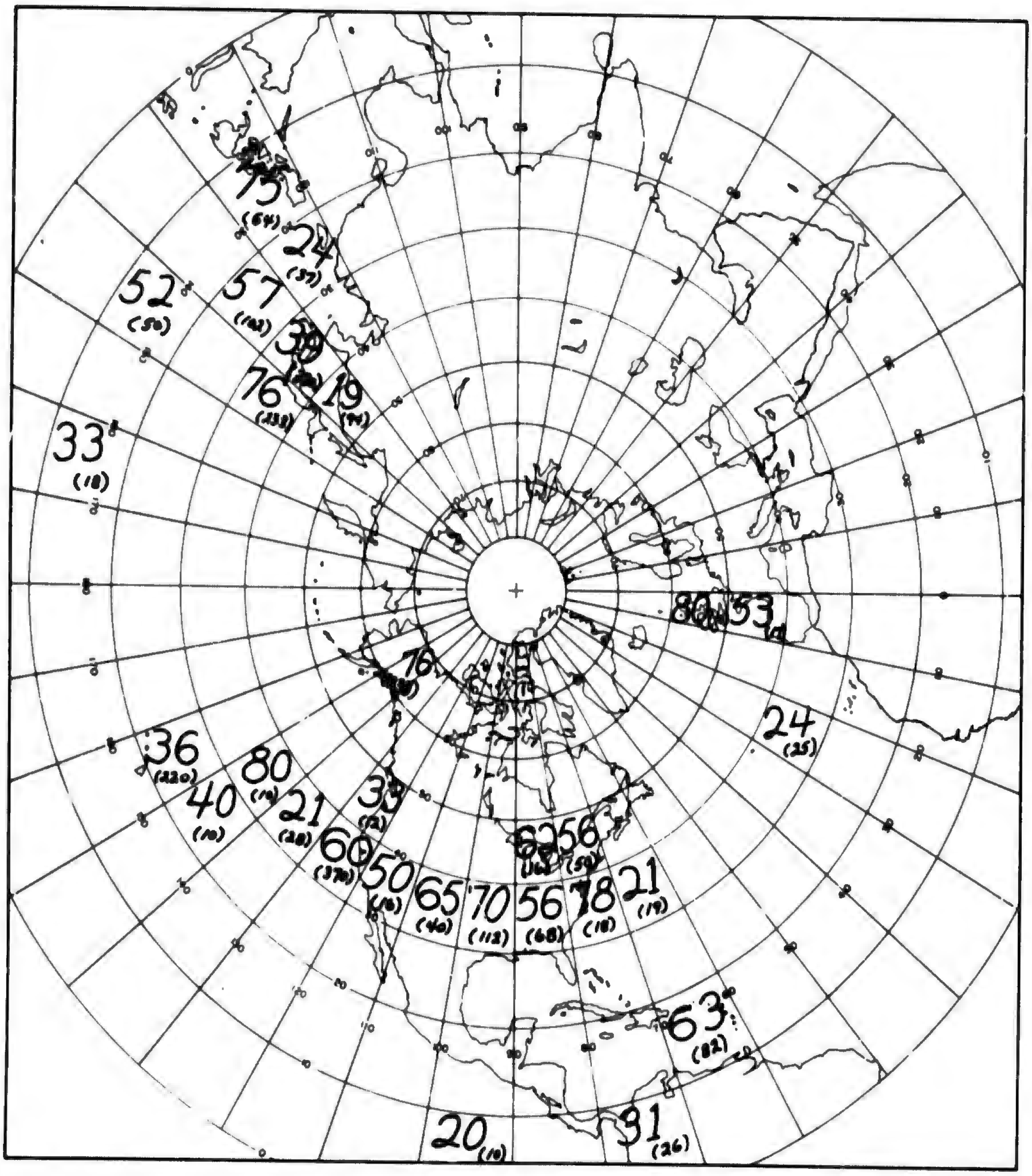

Figure A11. Estimates of the Probability of Seeing the Ground Directly Below the Aircraft (-90°) from Altitudes of 3601 to 7400 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

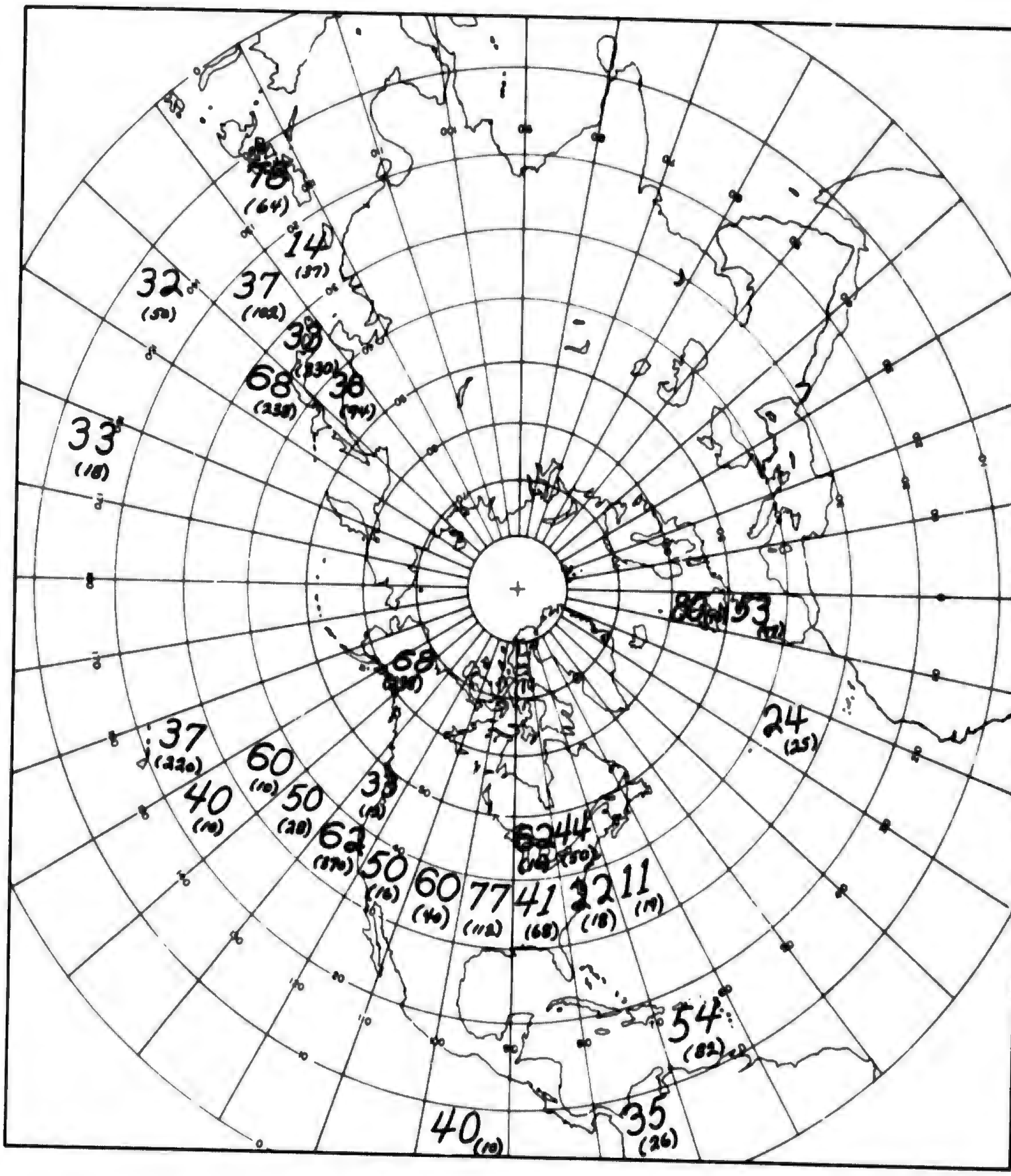

Figure A12. Estimates of the Probability of Seeing the Ground at 30° Below the Horizon (-30°) from Altitudes of 3601 to 7400 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

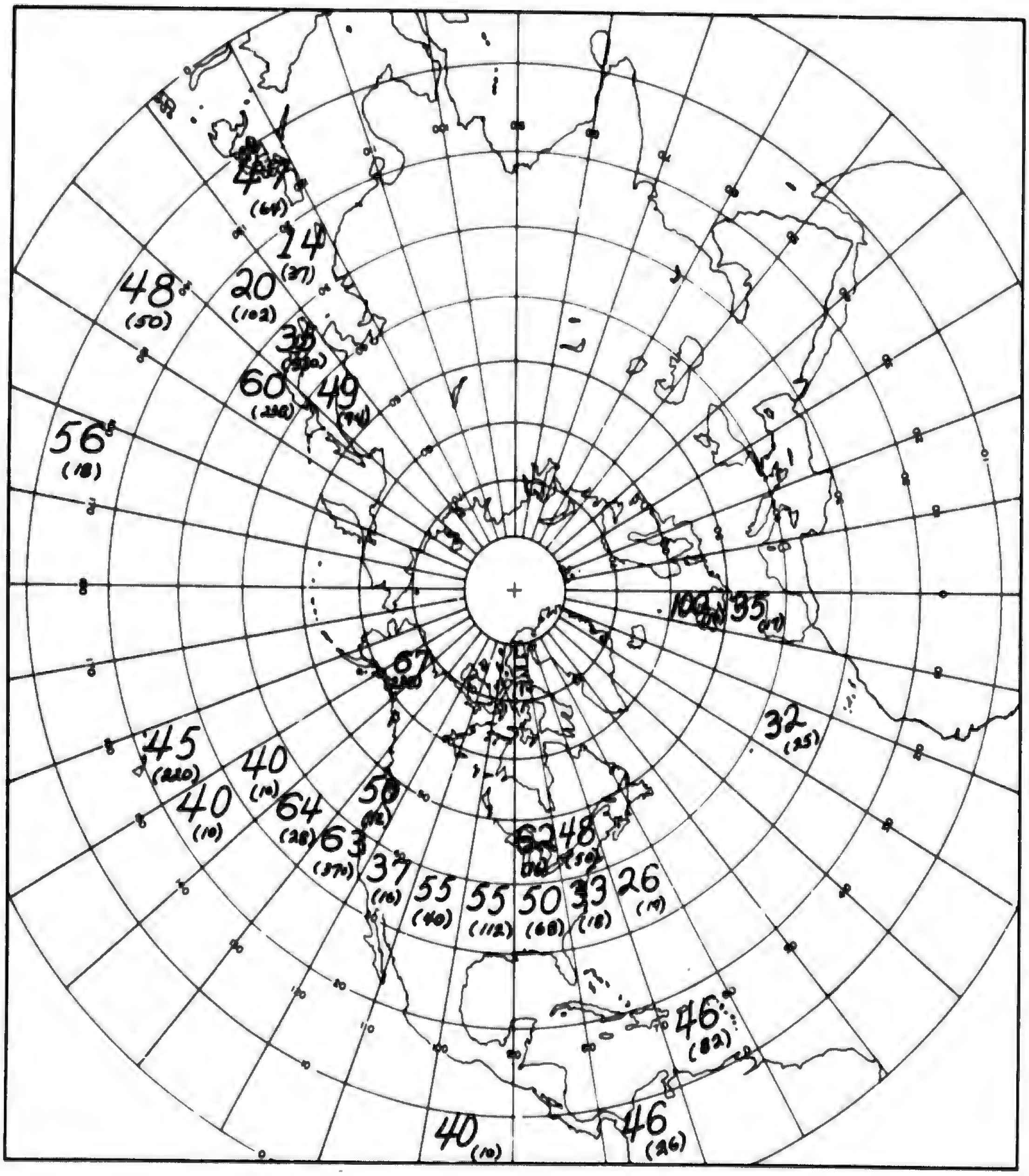

Figure A13. Estimates of the Probability of Seeing the Horizon from Altitudes of 3601 to 7400 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

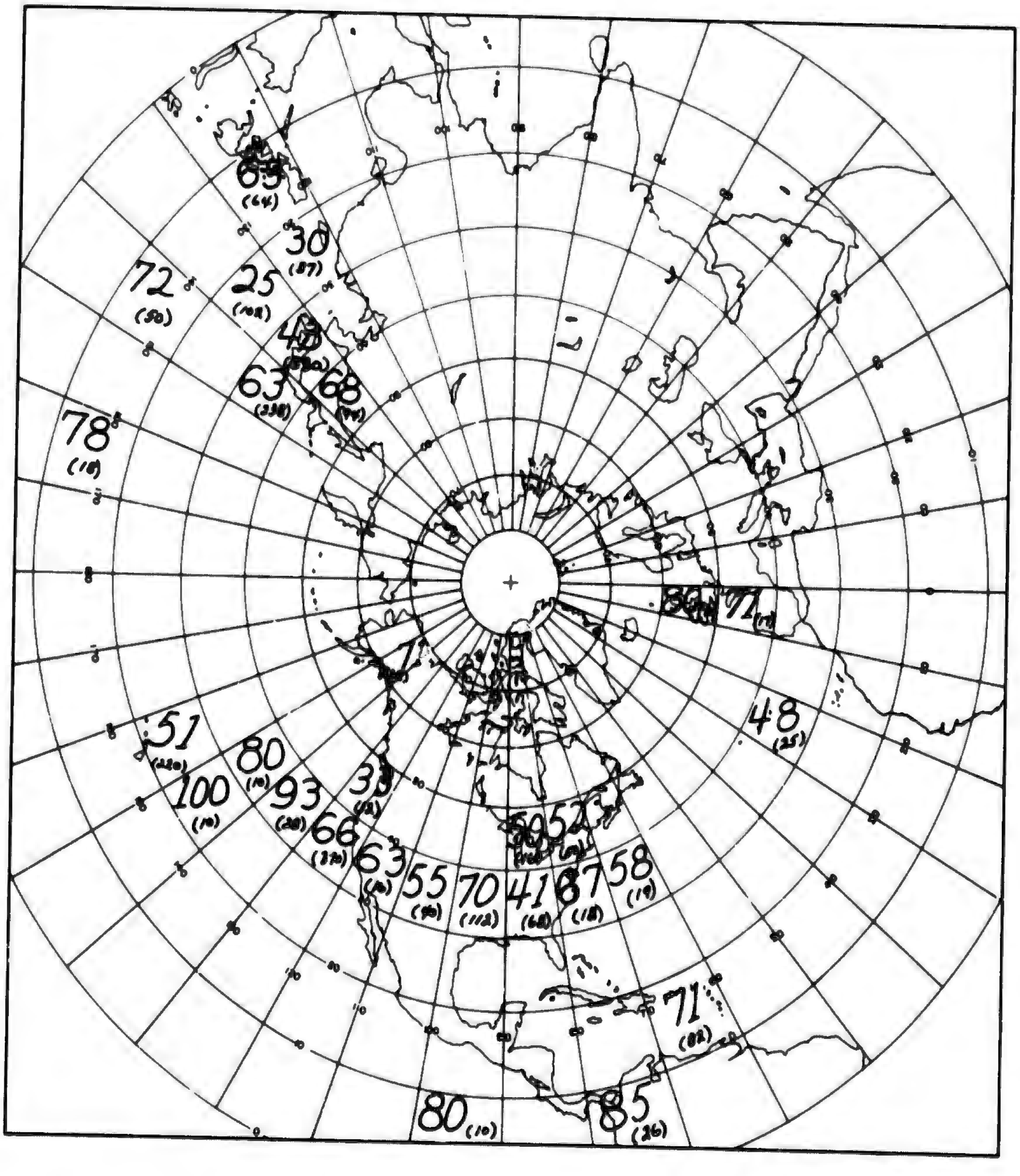

Figure A14. Estimates of the Probability of Seeing Blue Sky at 30° Above the Horizon (+ 30°) from Altitudes of 3601 to 7400 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

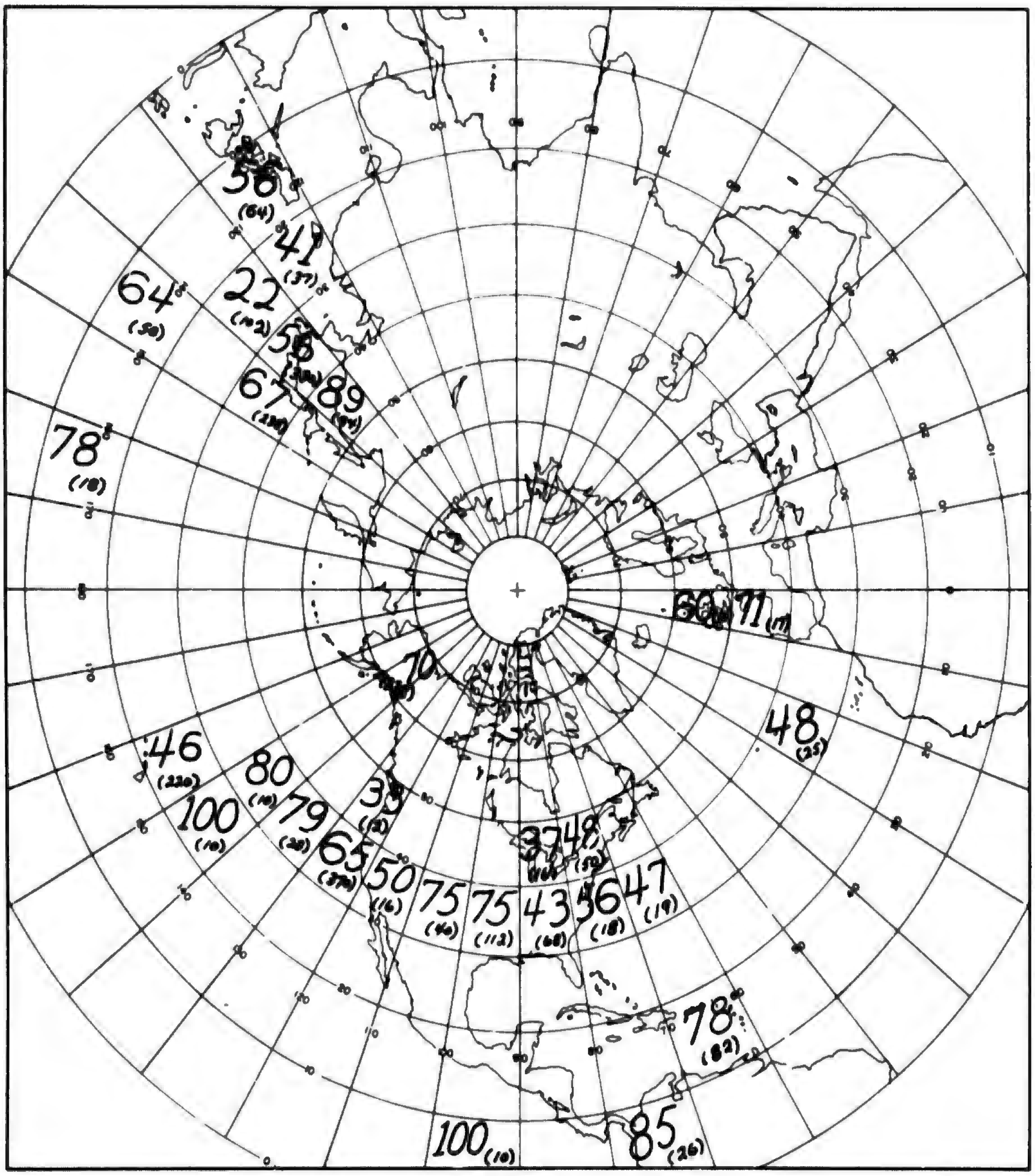

Figure A15. Estimates of the Probability of Seeing Blue Sky at 90° Above the Horizon (+ 90°) from Altitudes of 3601 to 7400 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

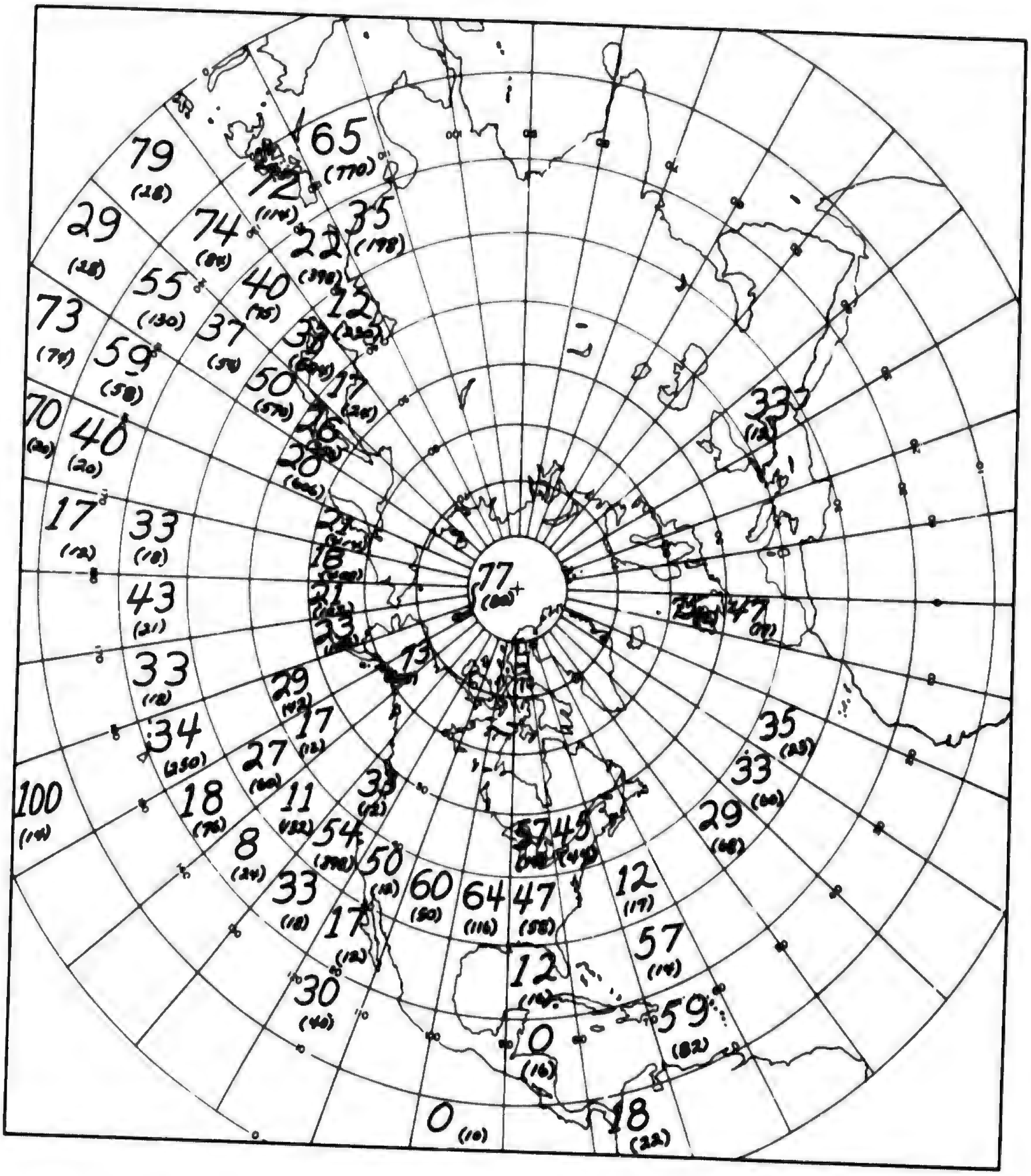

Figure A16. Estimates of the Probability of Seeing the Ground Directly Below the Aircraft (-90°) from Altitudes of 7401 to 14,999 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

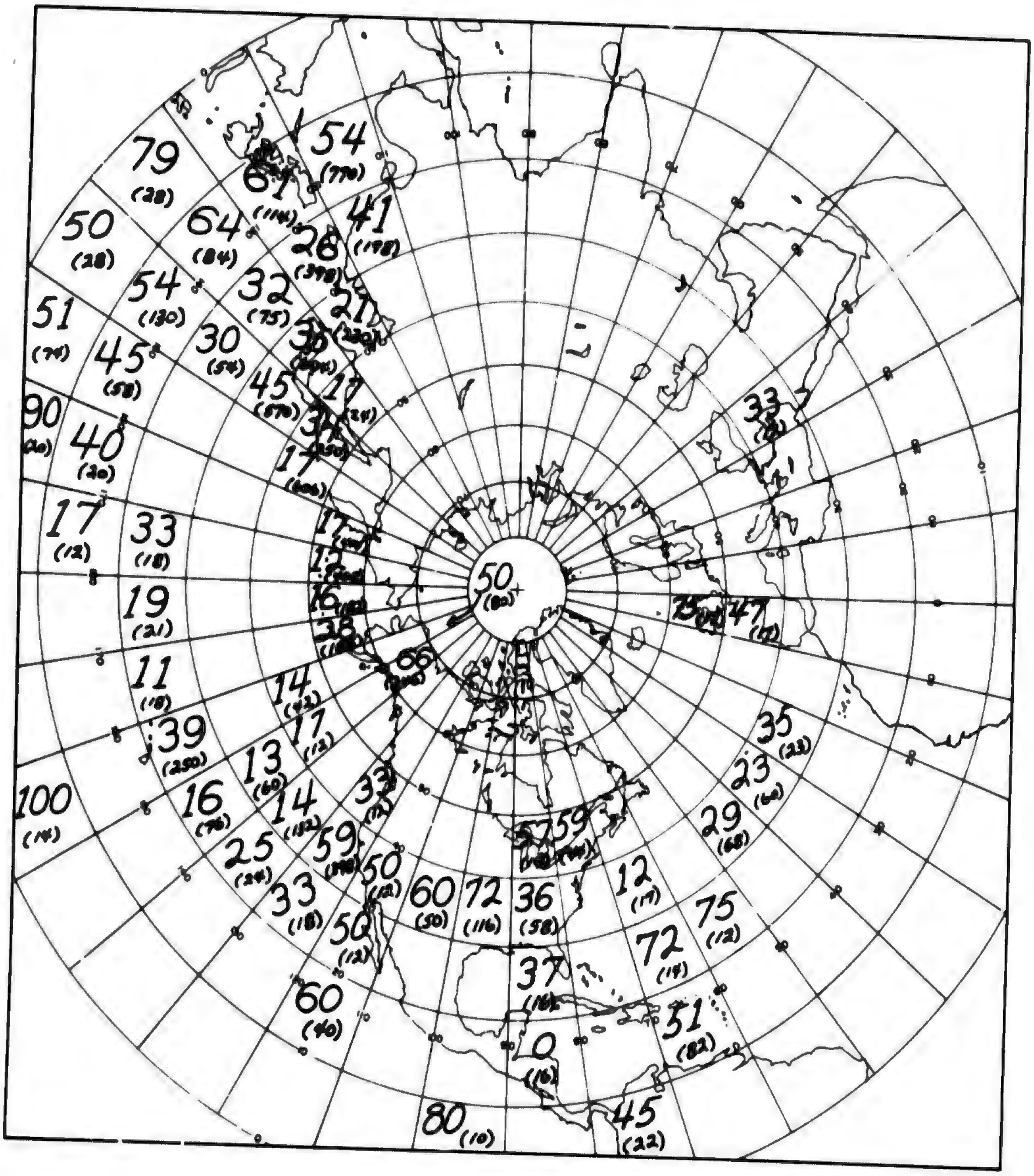

Figure A17. Estimates of the Probability of Seeing the Ground at 30° Below the Horizon (-30°) from Altitudes of 7401 to 14,999 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

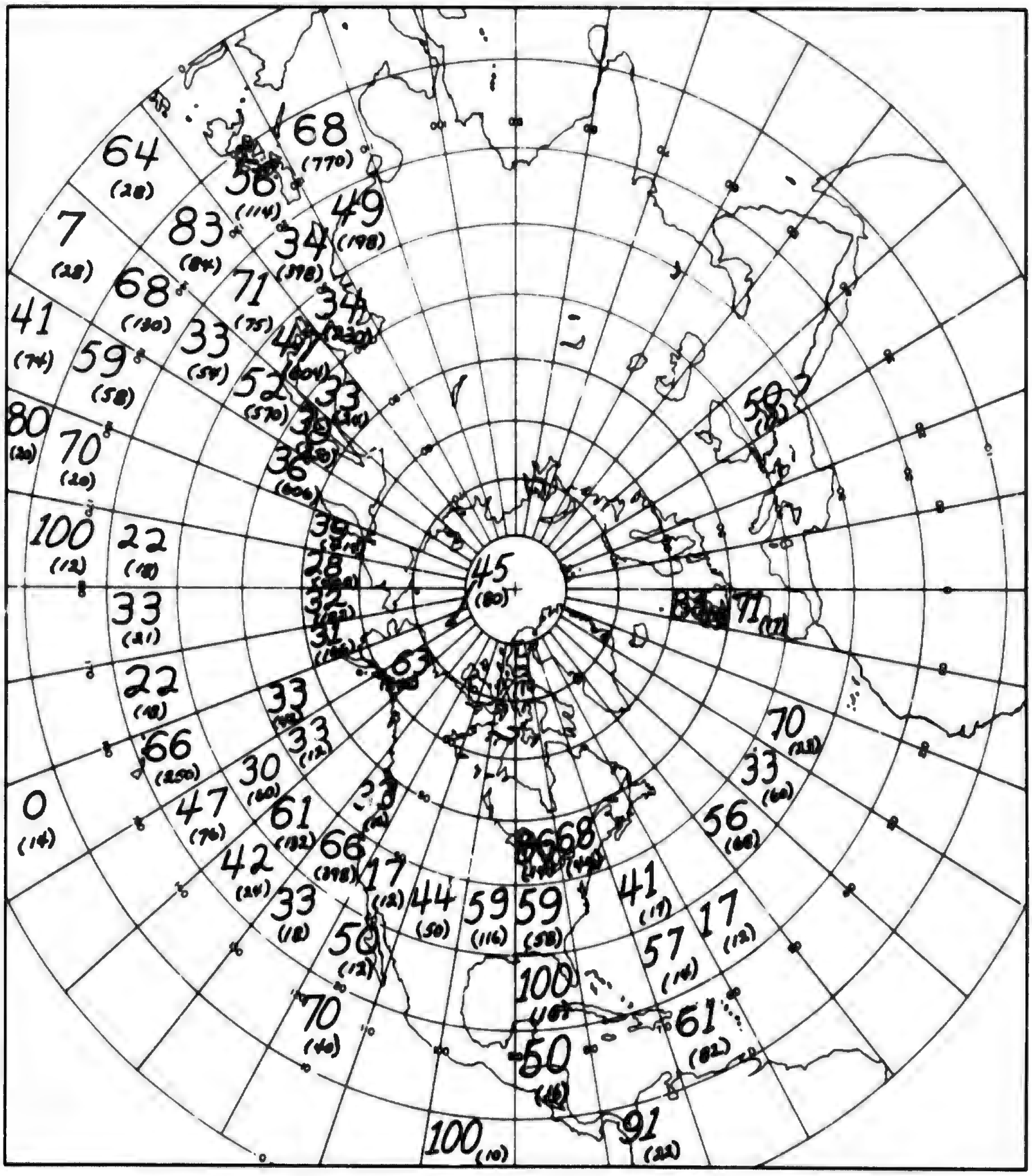

Figure A18. Estimates of the Probability of Seeing the Horizon from Altitudes of 7401 to 14,999 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

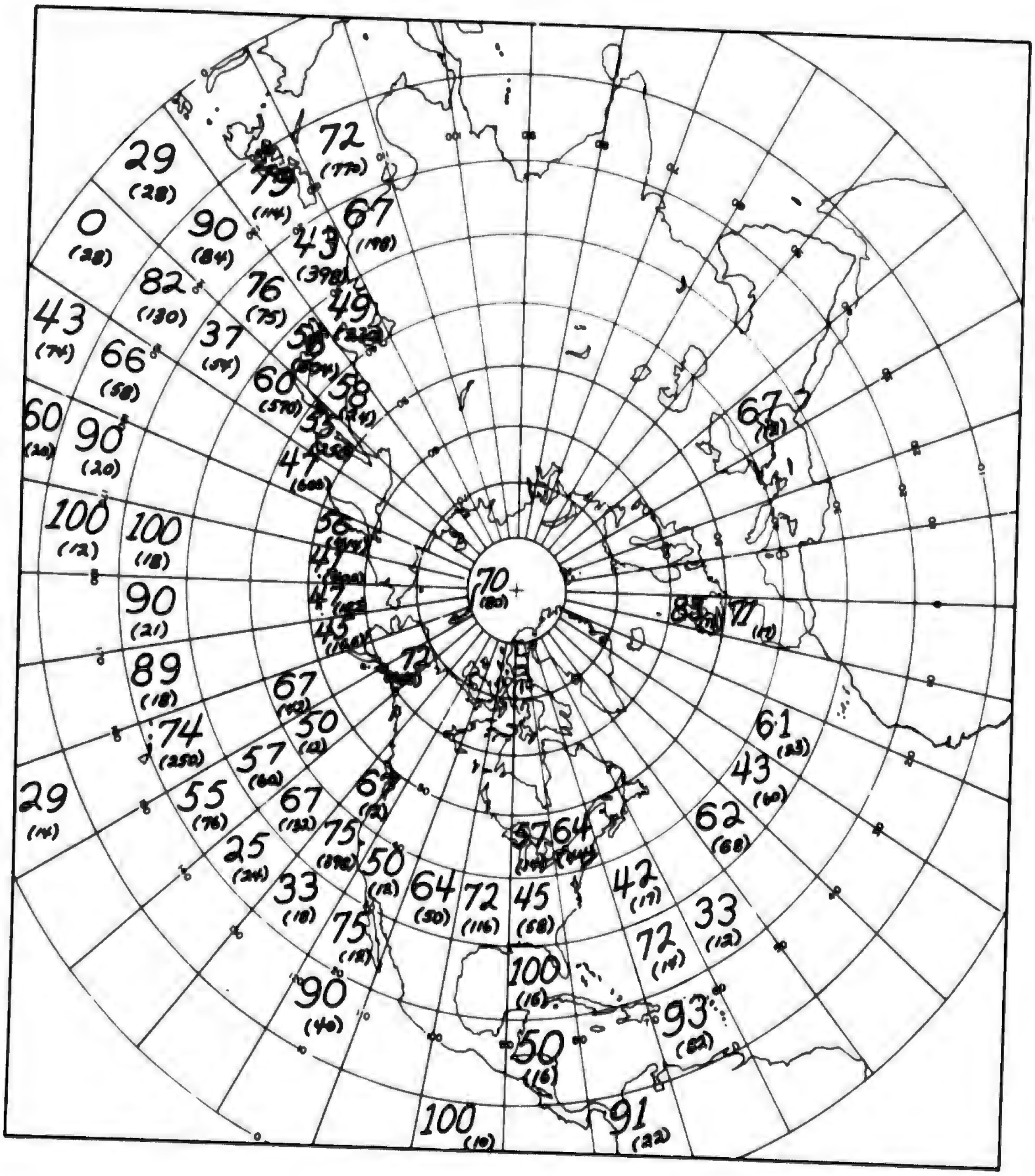

Figure A19. Estimates of the Probability of Seeing Blue Sky at 30° Above the Horizon (+ 30°) from Altitudes of 7401 to 14,999 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

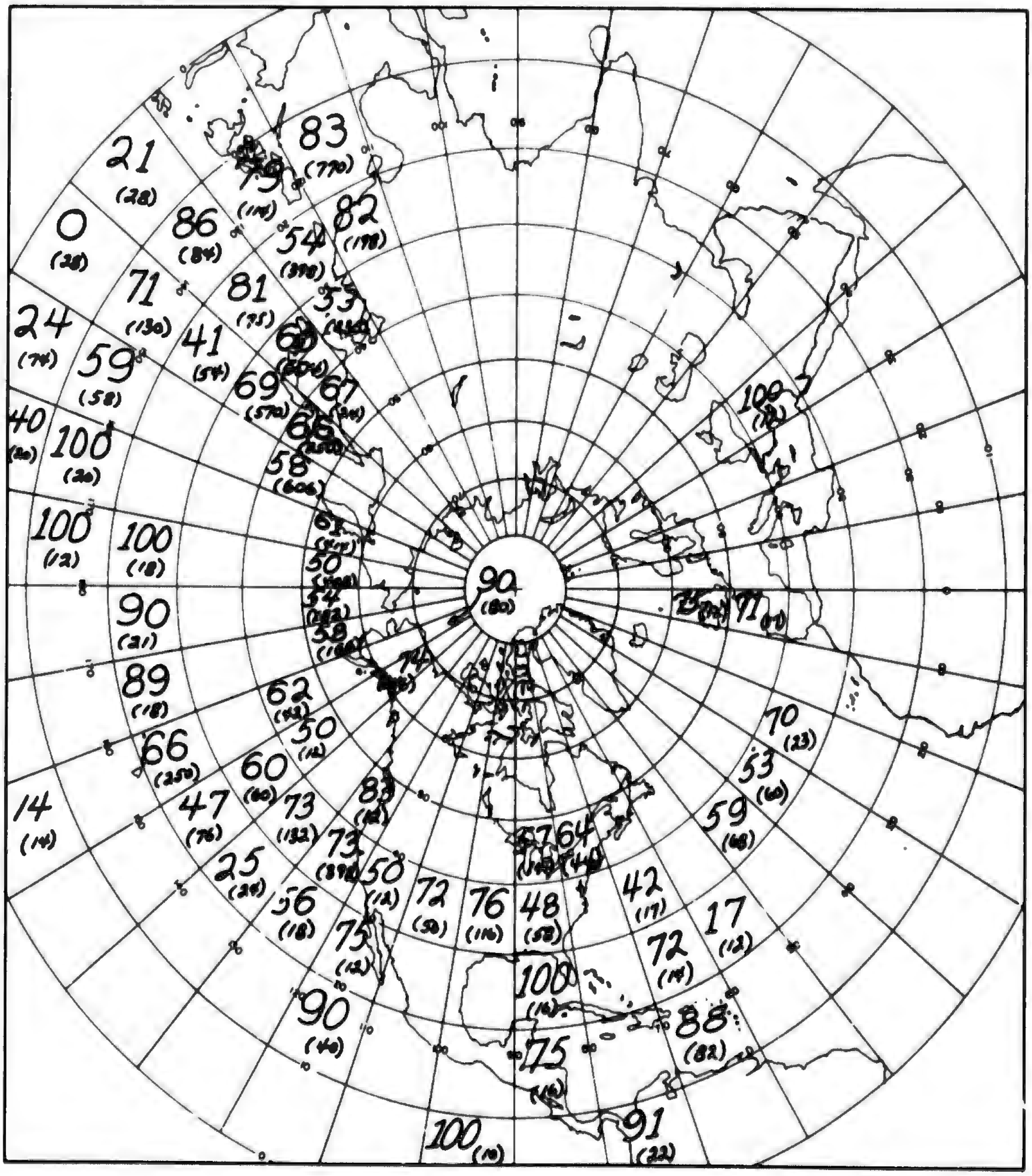

Figure A20. Estimates of the Probability of Seeing Blue Sky at 90° Above the Horizon (+ 90°) from Altitudes of 7401 to 14,999 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

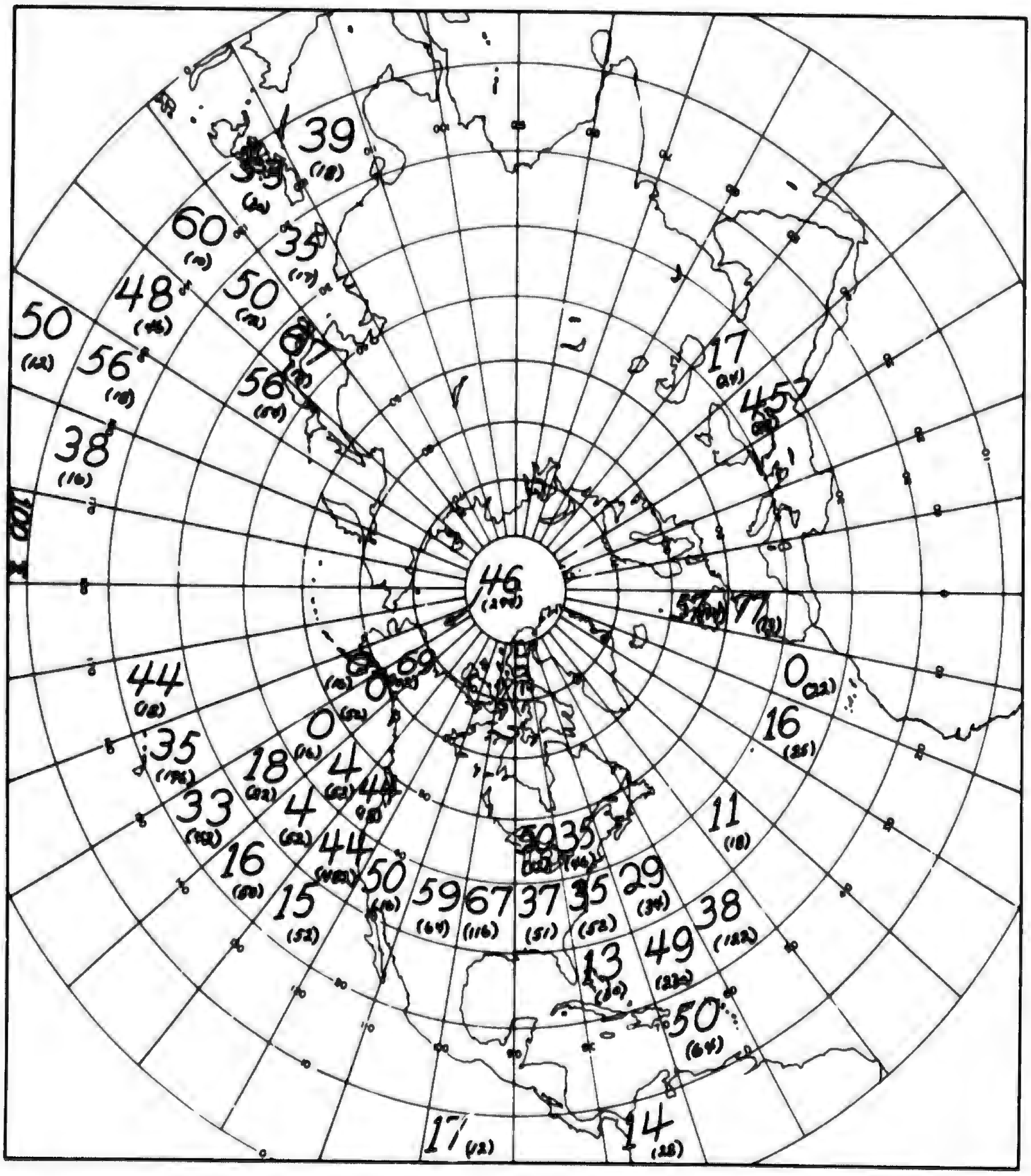

Figure A21. Estimates of the Probability of Seeing the Ground Directly Below the Aircraft (-90°) from Altitudes of 15,000 to 24,999 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

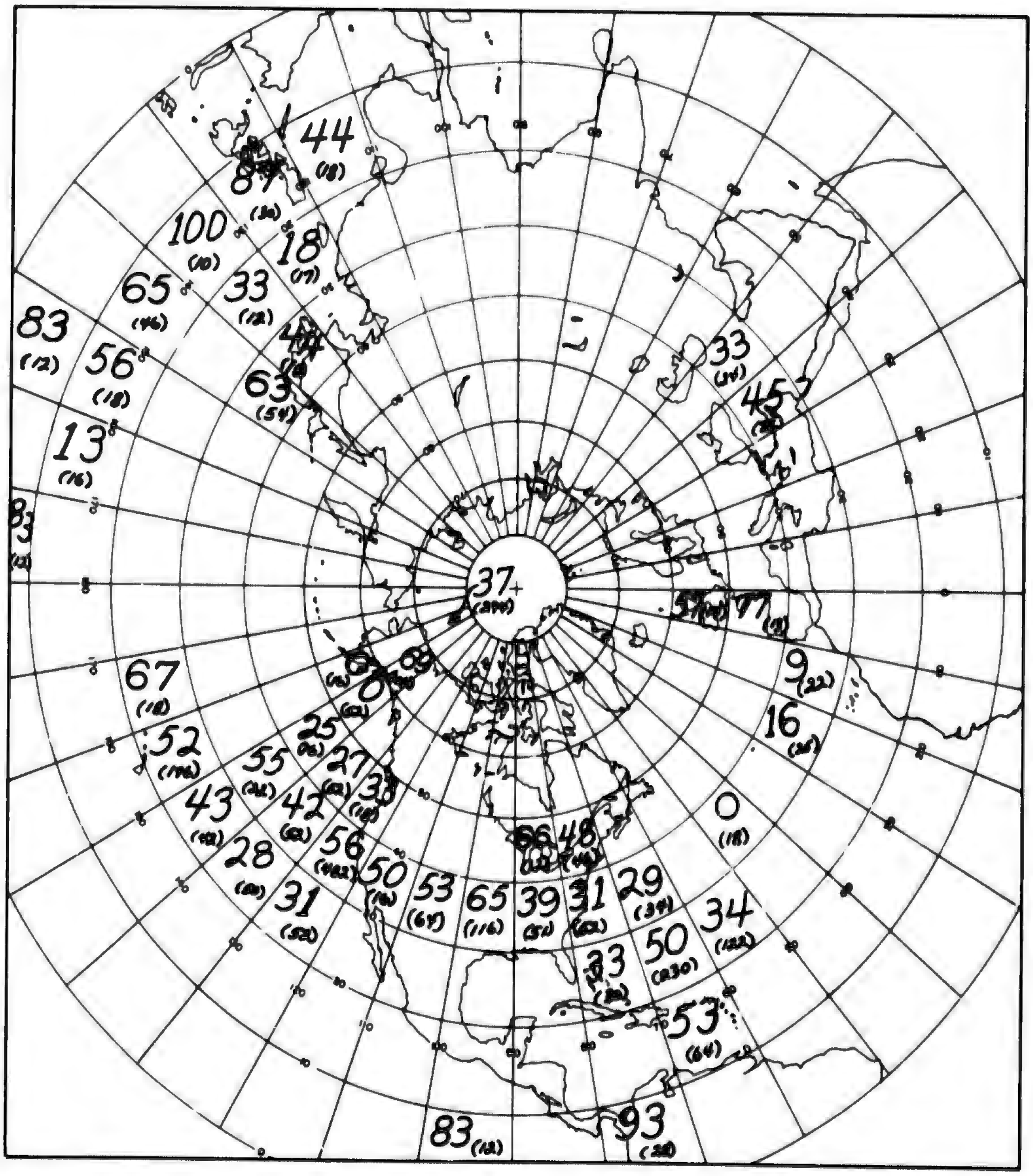

Figure A22. Estimates of the Probability of Seeing the Ground at 30° Below the Horizon (-30°) from Altitudes of 15,000 to 24,999 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

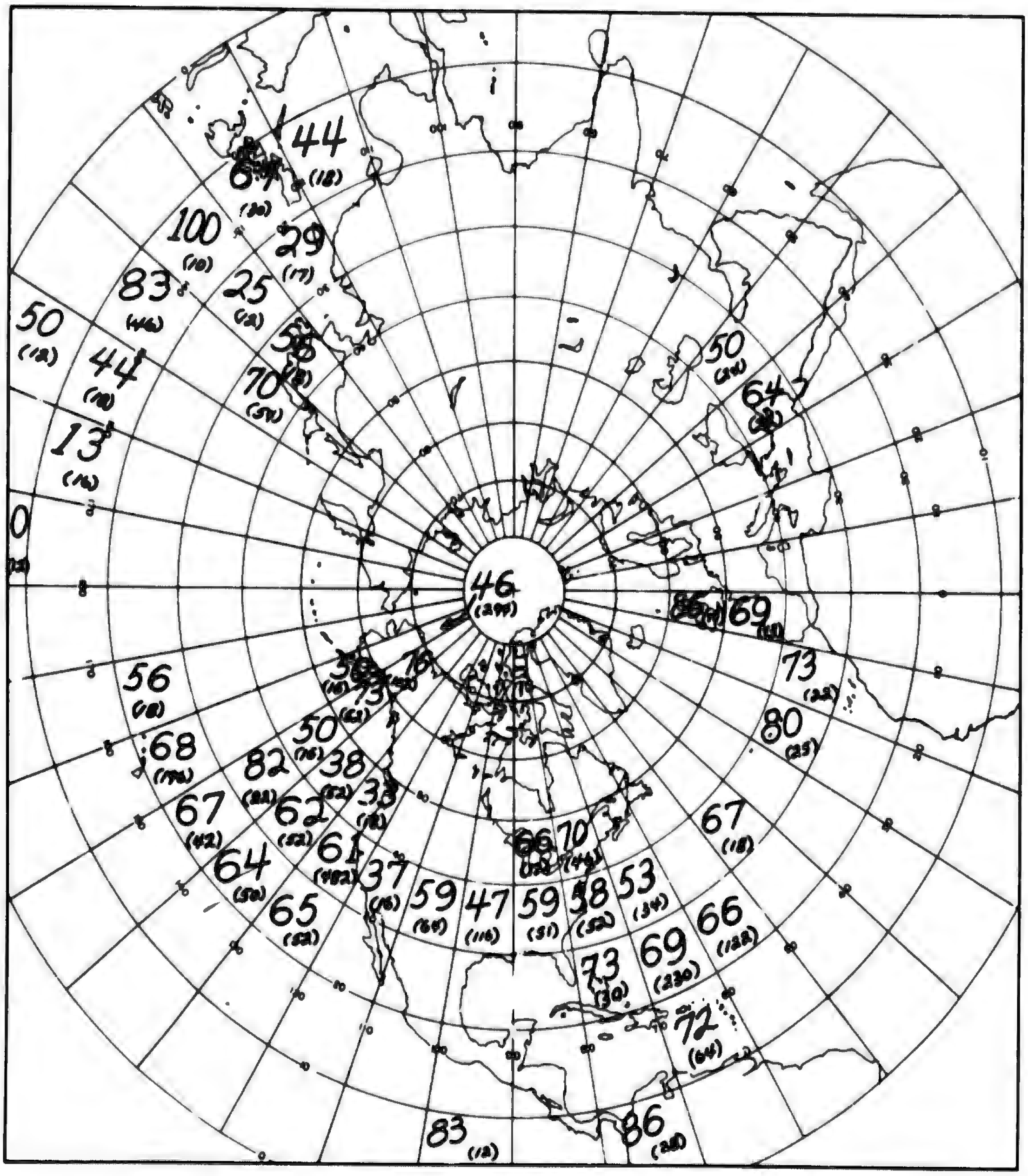

Figure A23. Estimates of the Probability of Seeing the Horizon from Altitudes of 15,000 to 24,999 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

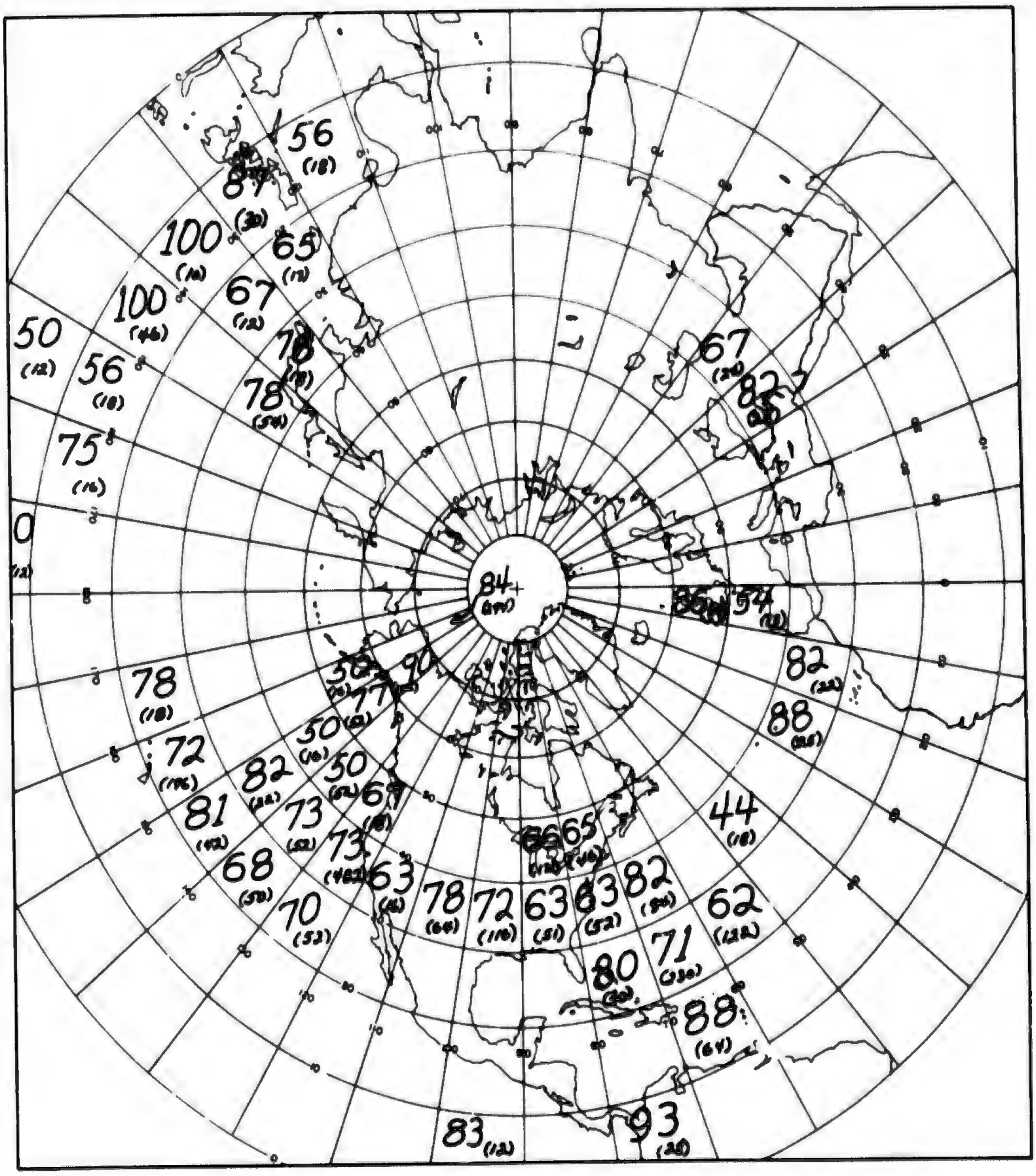

Figure A24. Estimates of the Probability of Seeing Blue Sky at 30° Above the Horizon (+ 30°) from Altitudes of 15,000 to 24,999 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

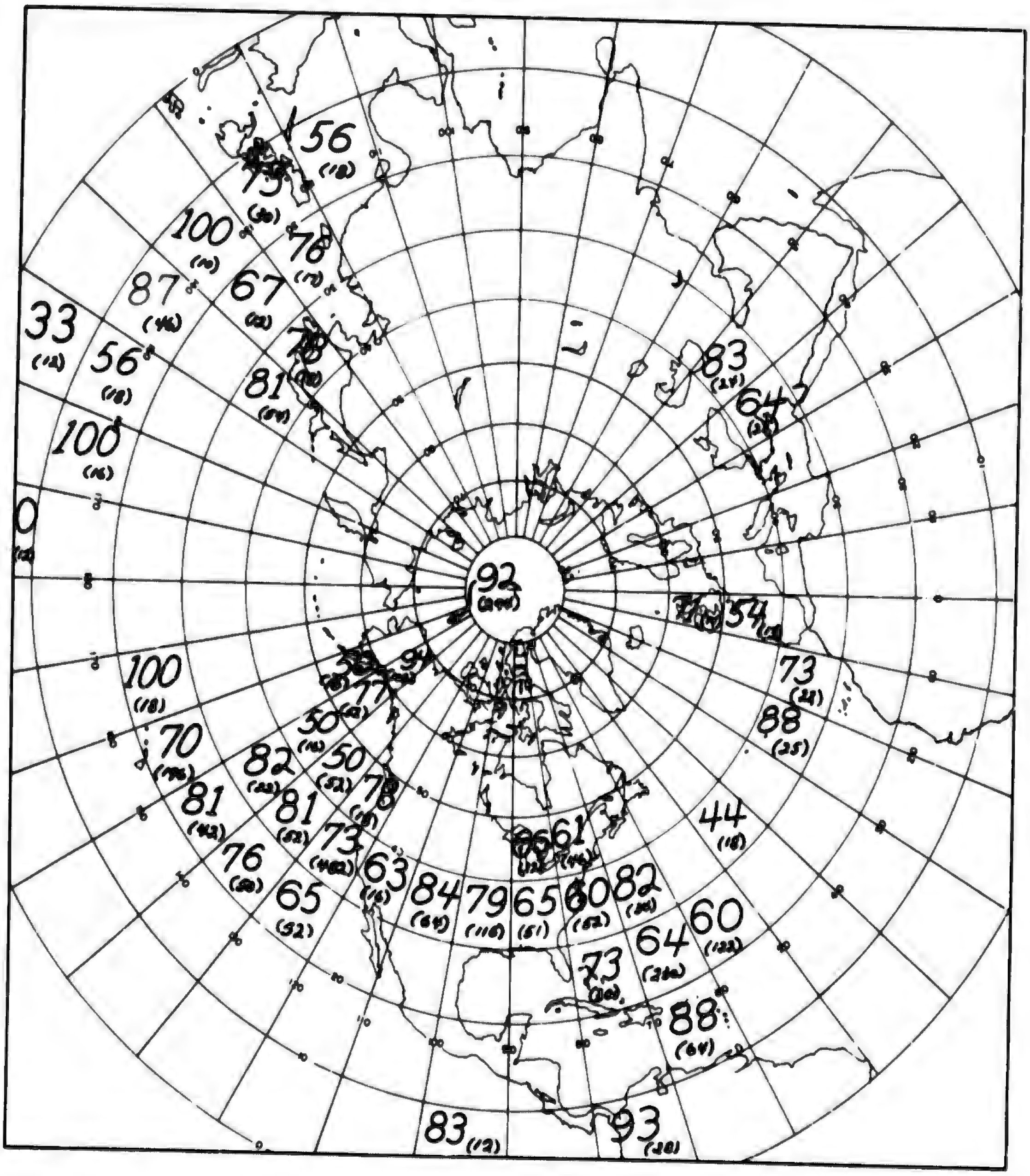

Figure A25. Estimates of the Probability of Seeing Blue Sky at 90° Above the Horizon (+ 90°) from Altitudes of 15,000 to 24,999 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

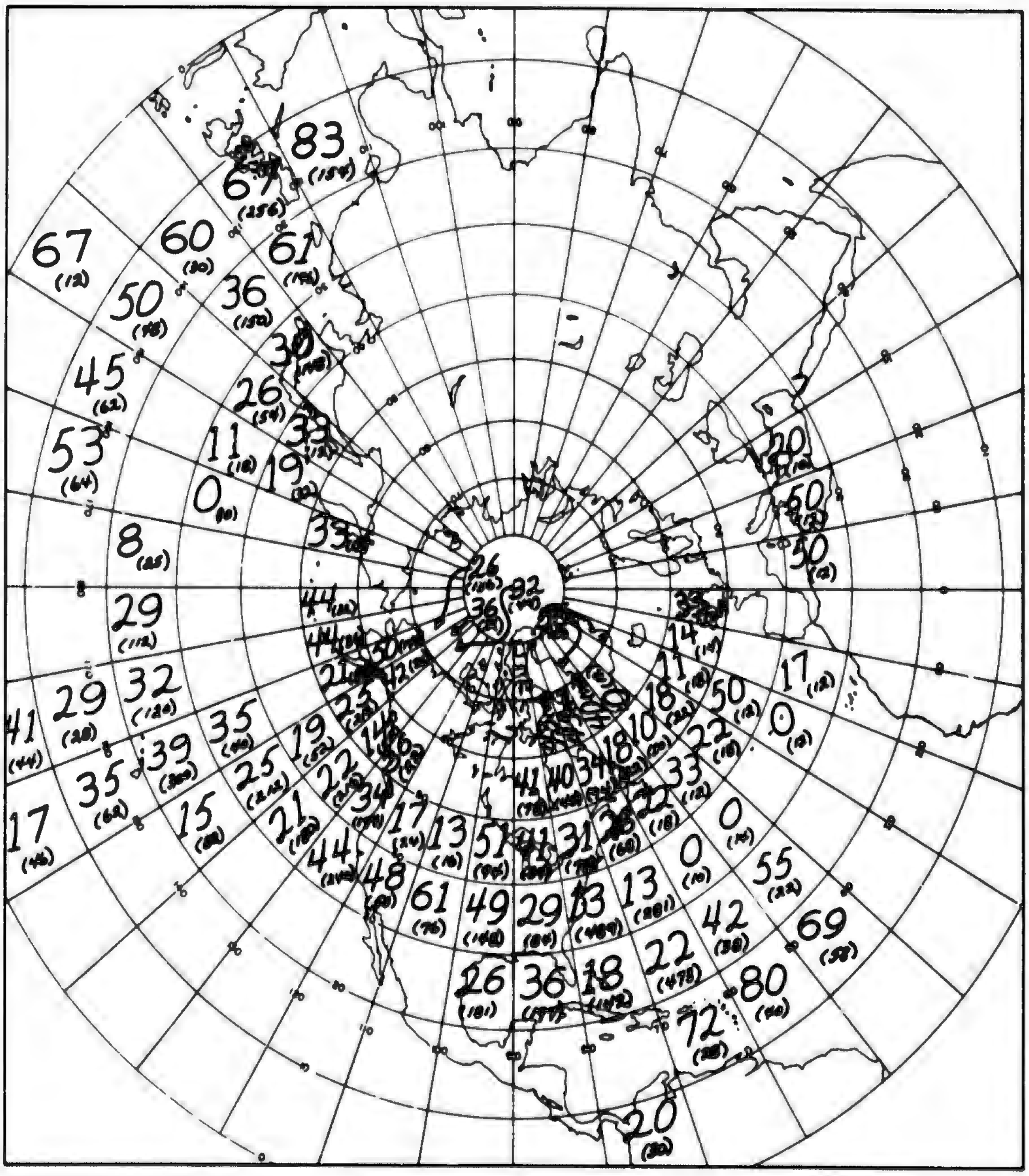

Figure A26. Estimates of the Probability of Seeing the Ground Directly Below the Aircraft (-90°) from Altitudes of 25,000 to 34,999 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

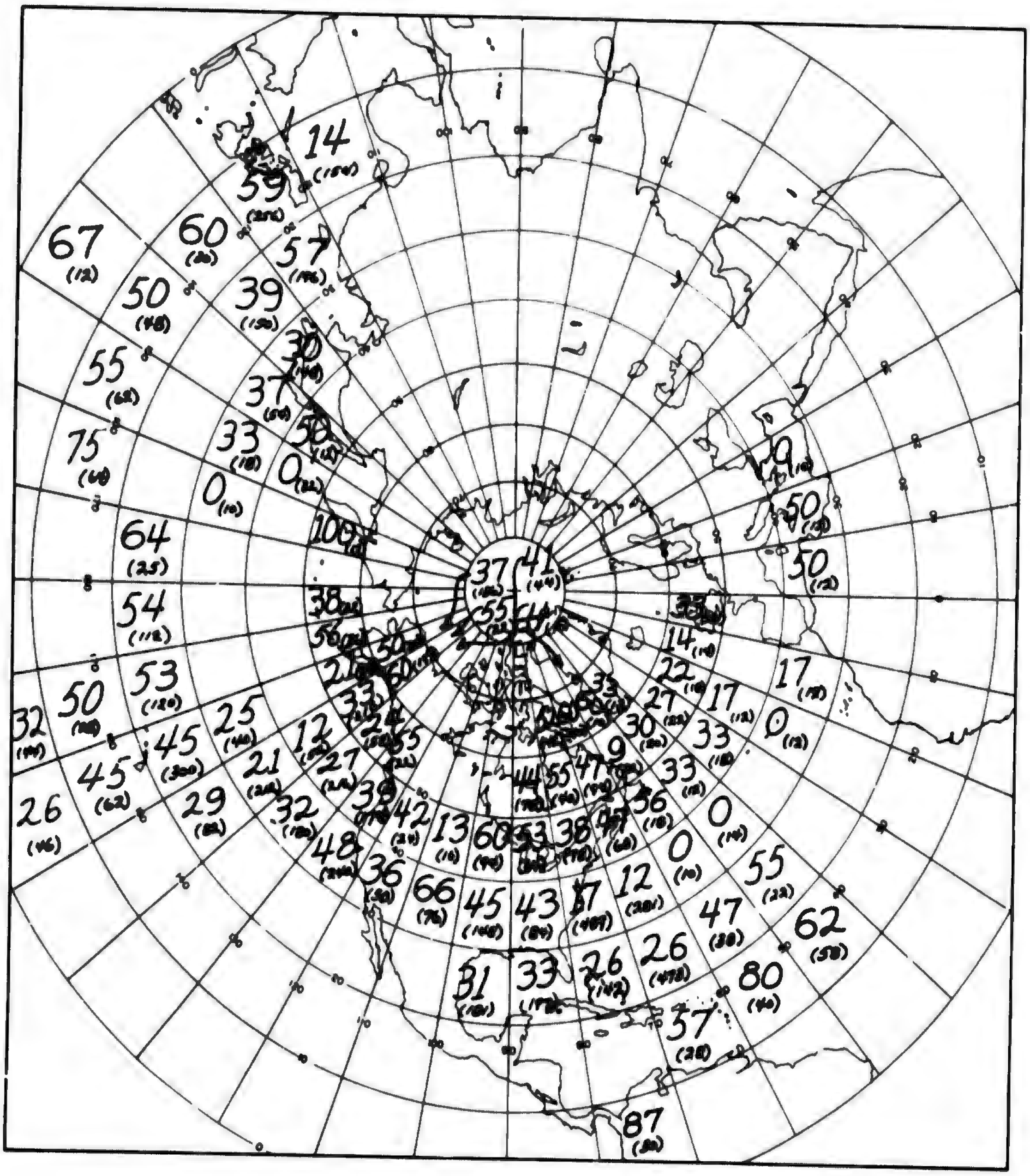

Figure A27. Estimates of the Probability of Seeing the Ground at 30° Below the Horizon (-30°) from Altitudes of 25,000 to 34,999 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

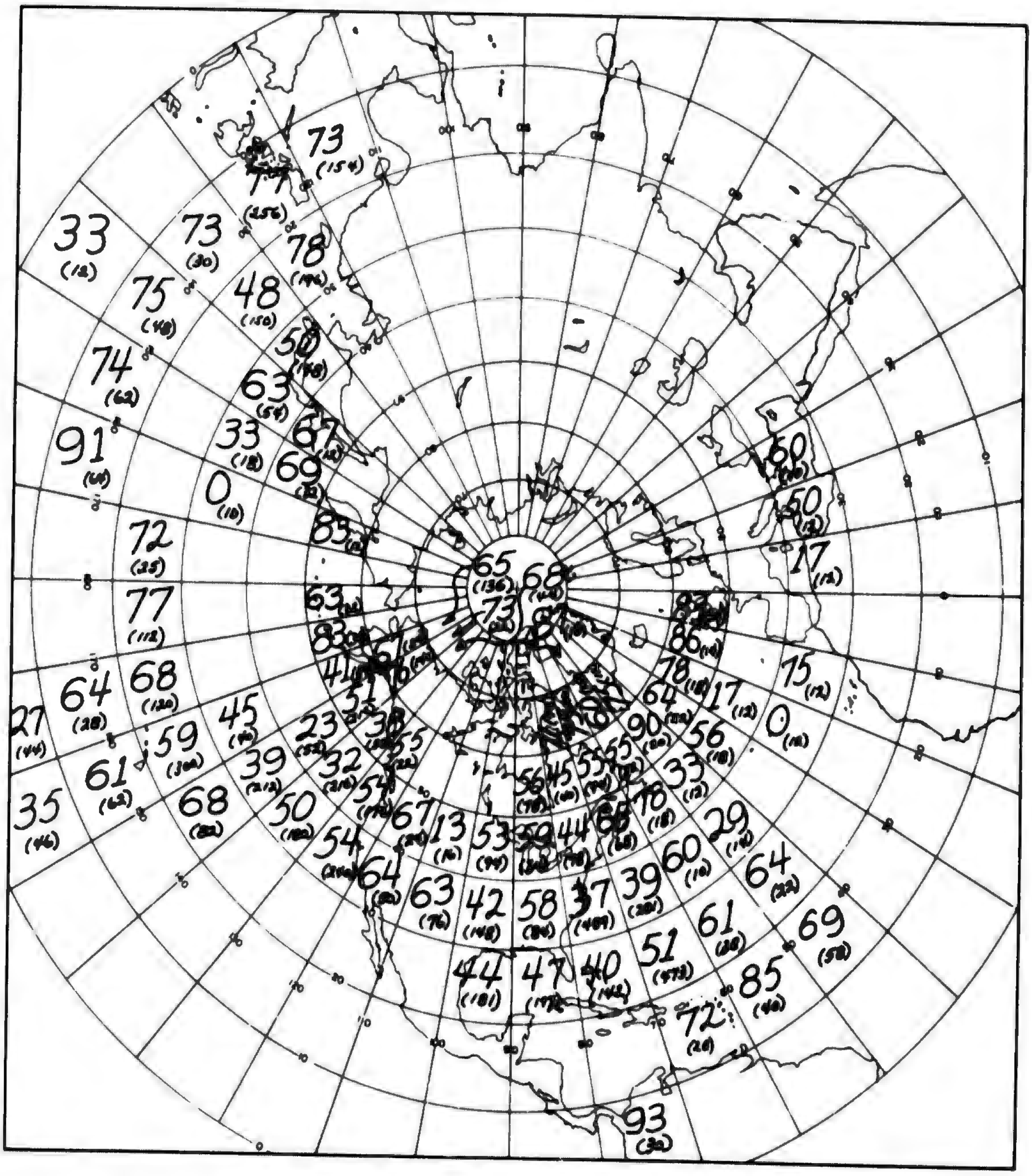

Figure A28. Estimates of the Probability of Seeing the Horizon from Altitudes of 25,000 to 34,999 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

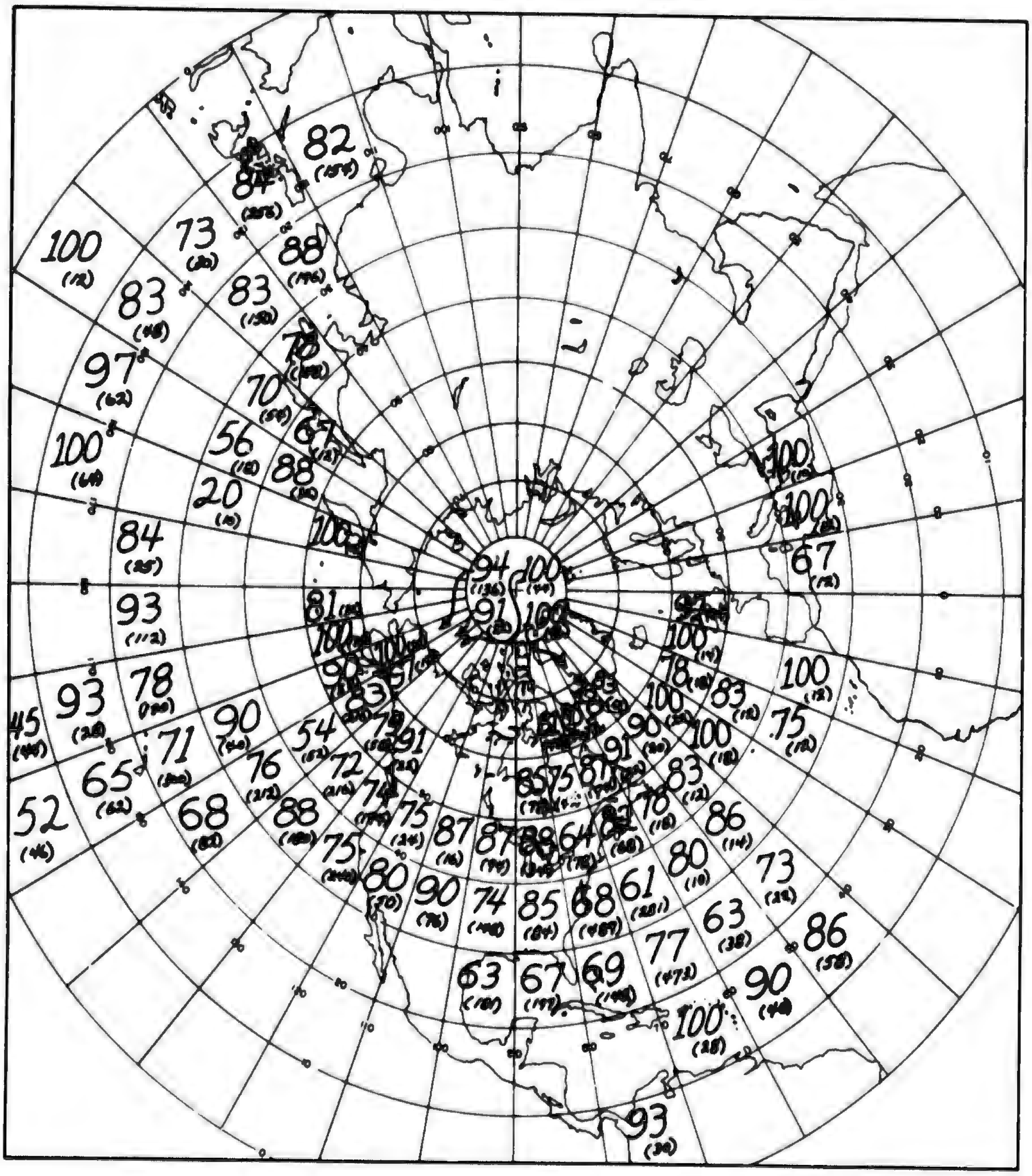

Figure A29. Estimates of the Probability of Seeing Blue Sky at 30° Above the Horizon (+ 30°) from Altitudes of 25,000 to 34,999 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

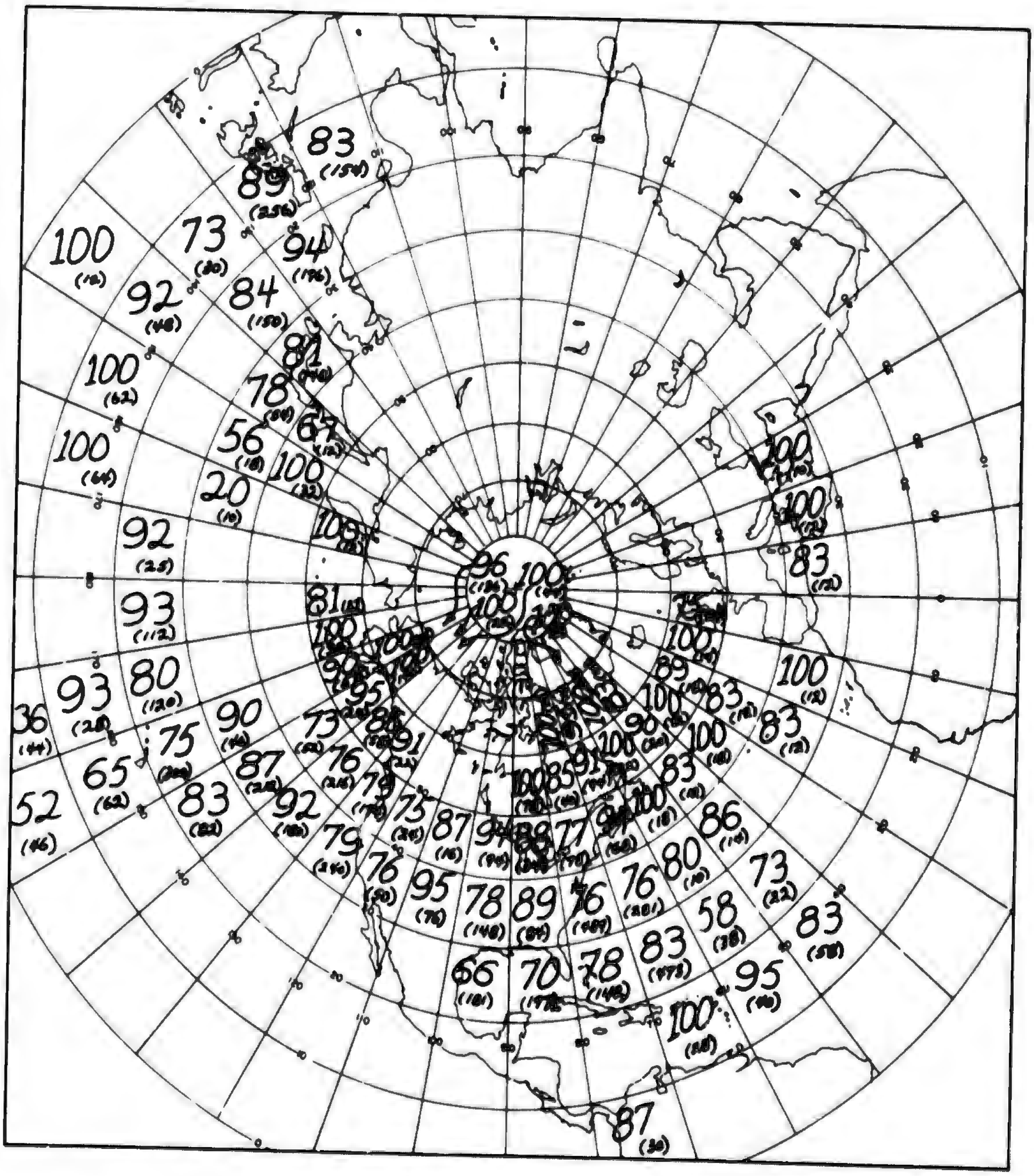

Figure A30. Estimates of the Probability of Seeing Blue Sky at 90° Above the Horizon (+ 90°) from Altitudes of 25,000 to 34,999 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

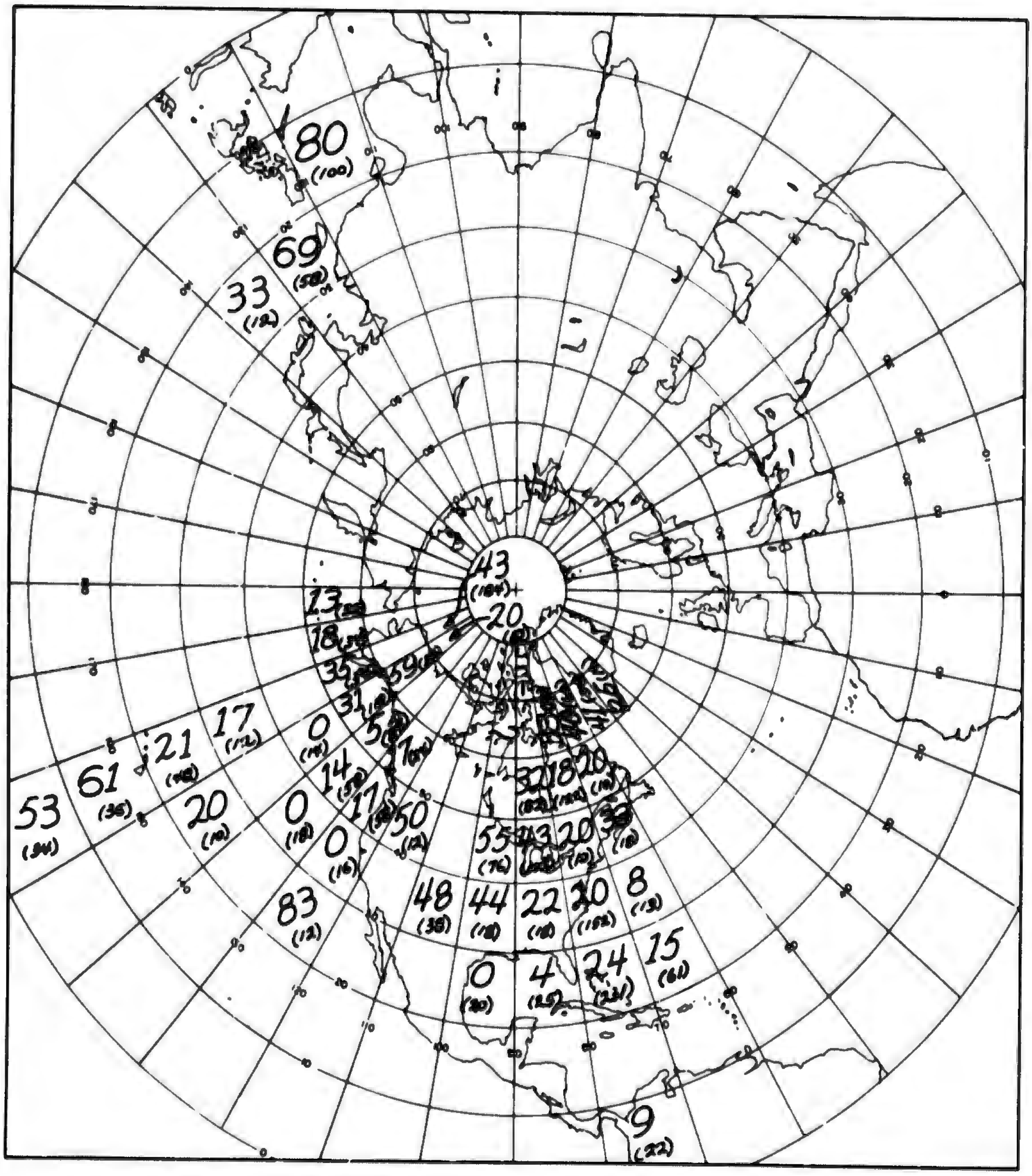

Figure A31. Estimates of the Probability of Seeing the Ground Directly Below the Aircraft (-90°) from Altitudes of 35,000 to 44,999 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

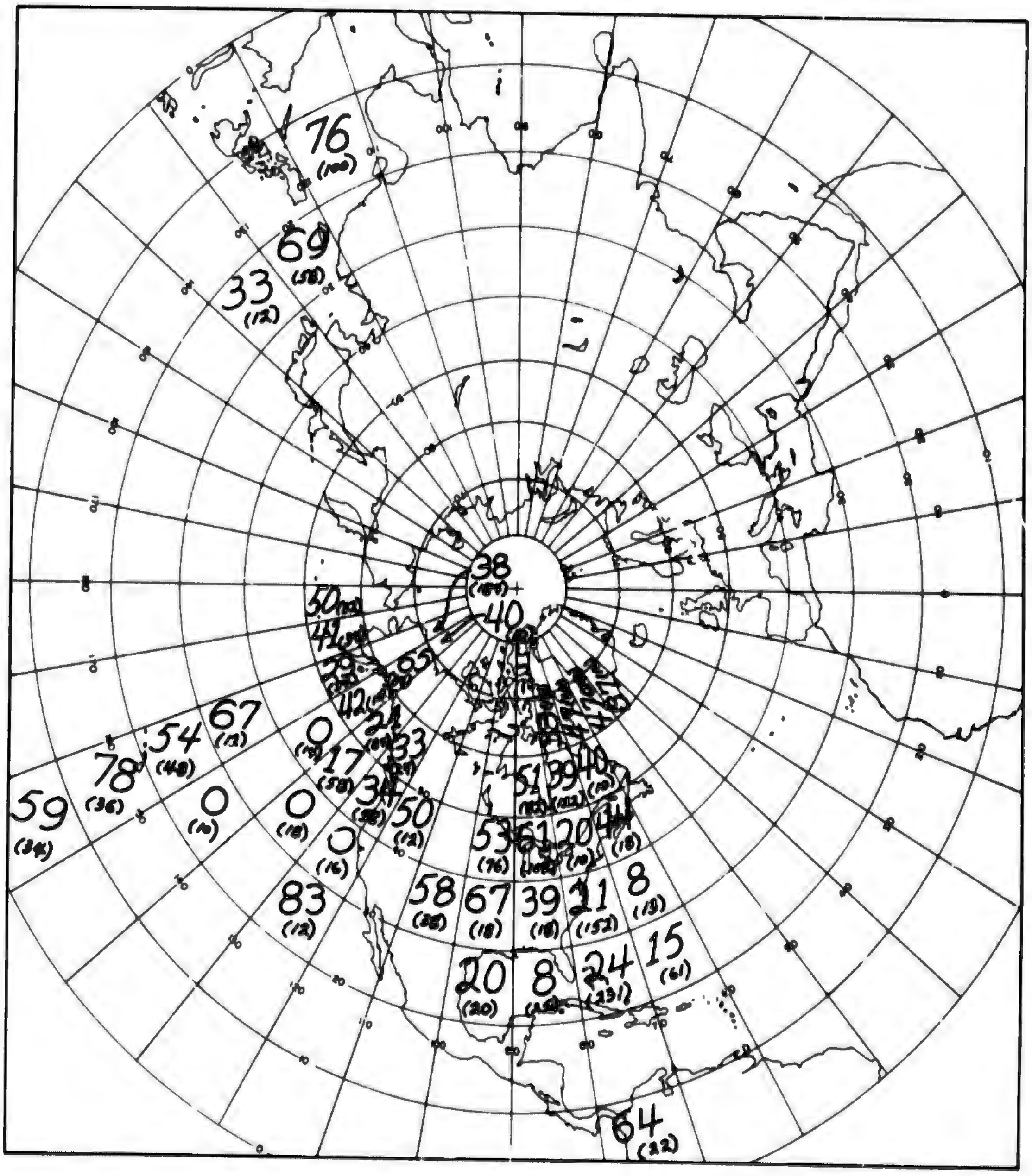

Figure A32. Estimates of the Probability of Seeing the Ground at 30° Below the Horizon (-30°) from Altitudes of 35,000 to 44,999 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

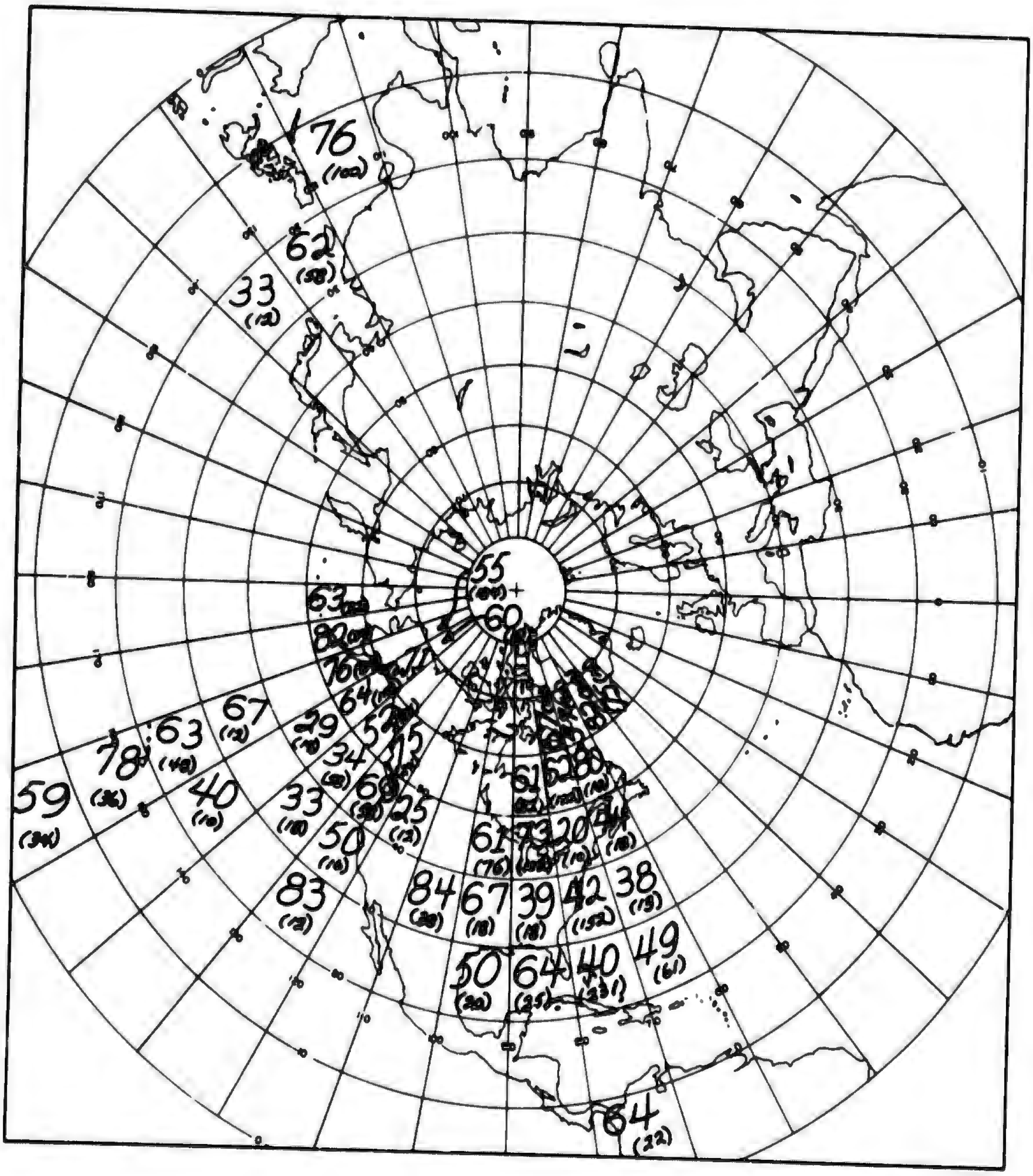

Figure A33. Estimates of the Probability of Seeing the Horizon from Altitudes of 35,000 to 44,999 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

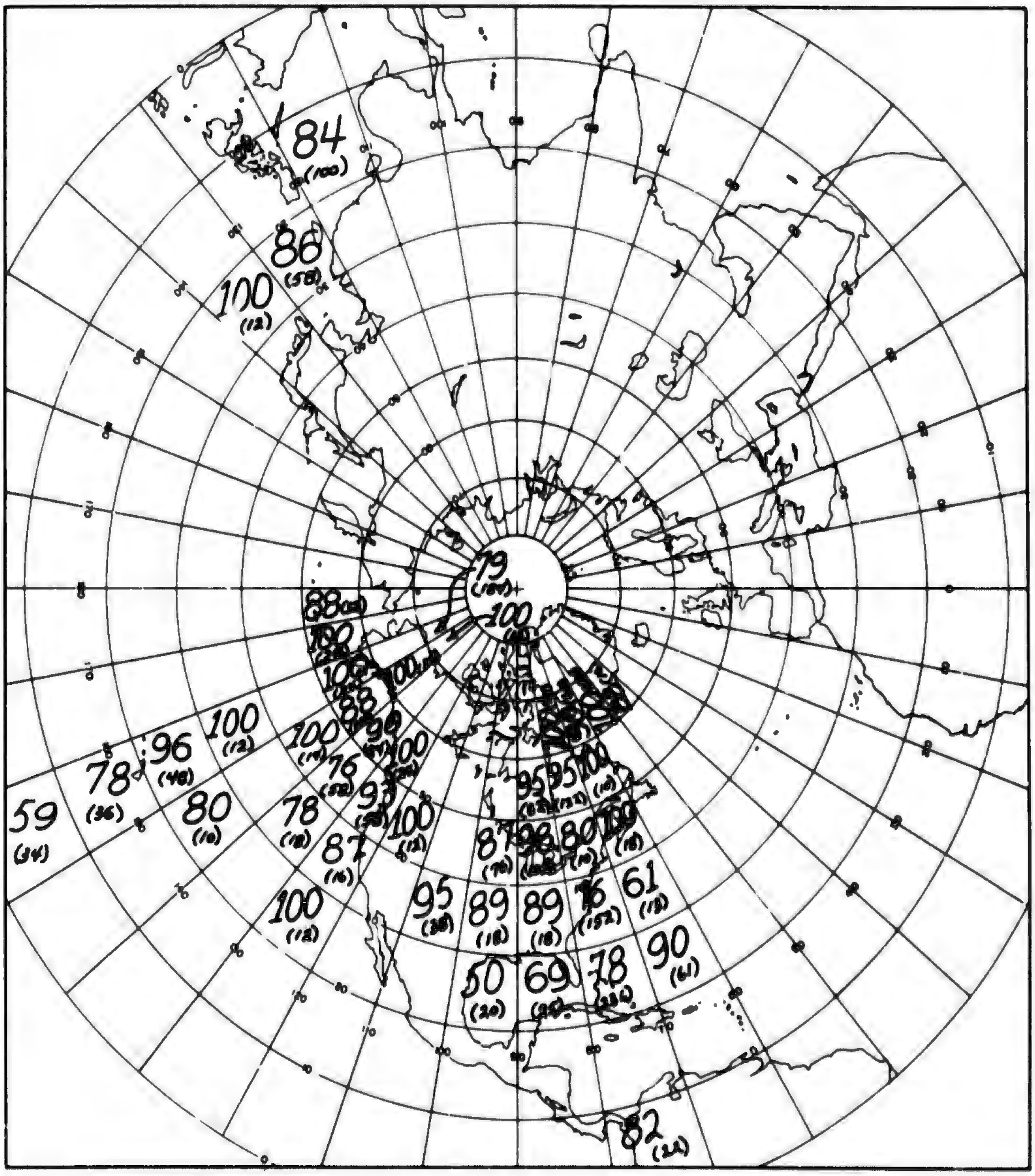

Figure A34. Estimates of the Probability of Seeing Blue Sky at 30° Above the Horizon (+ 30°) from Altitudes of 35,000 to 44,999 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

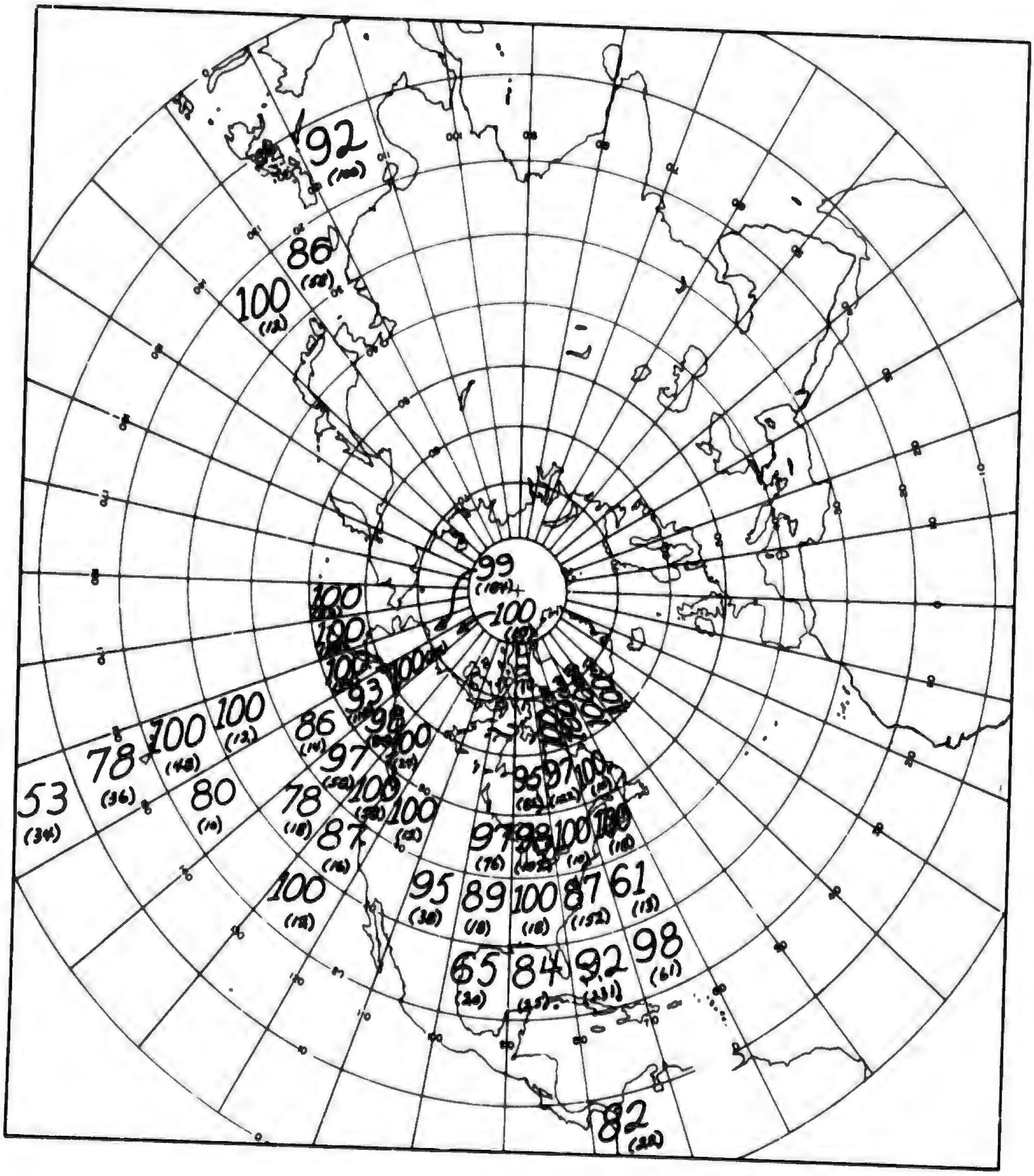

Figure A35. Estimates of the Probability of Seeing Blue Sky at 90° Above the Horizon (+ 90°) from Altitudes of 35,000 to 44,999 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

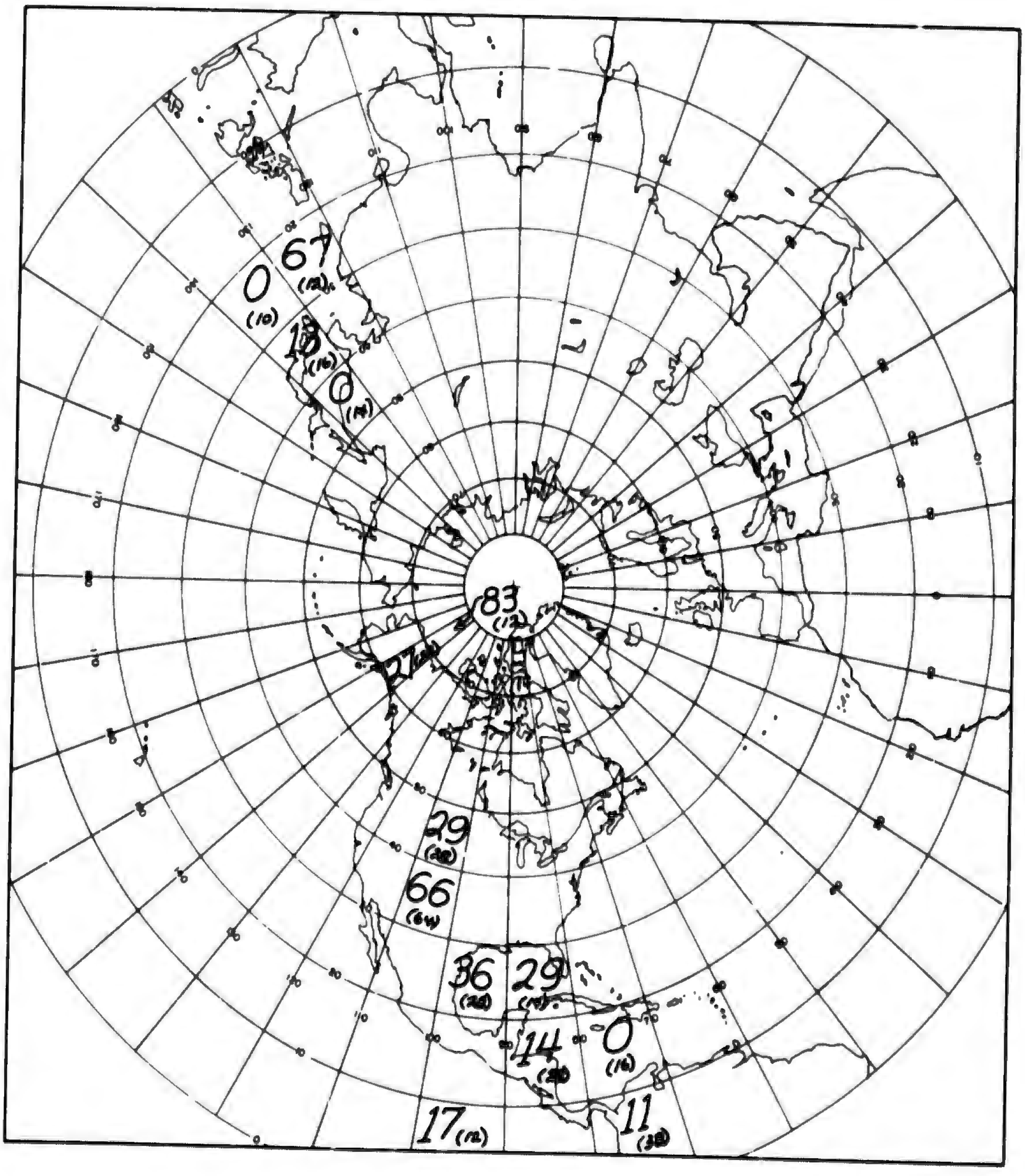

Figure A36. Estimates of the Probability of Seeing the Ground Directly Below the Aircraft (-90°) from Altitudes Above 45,000 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

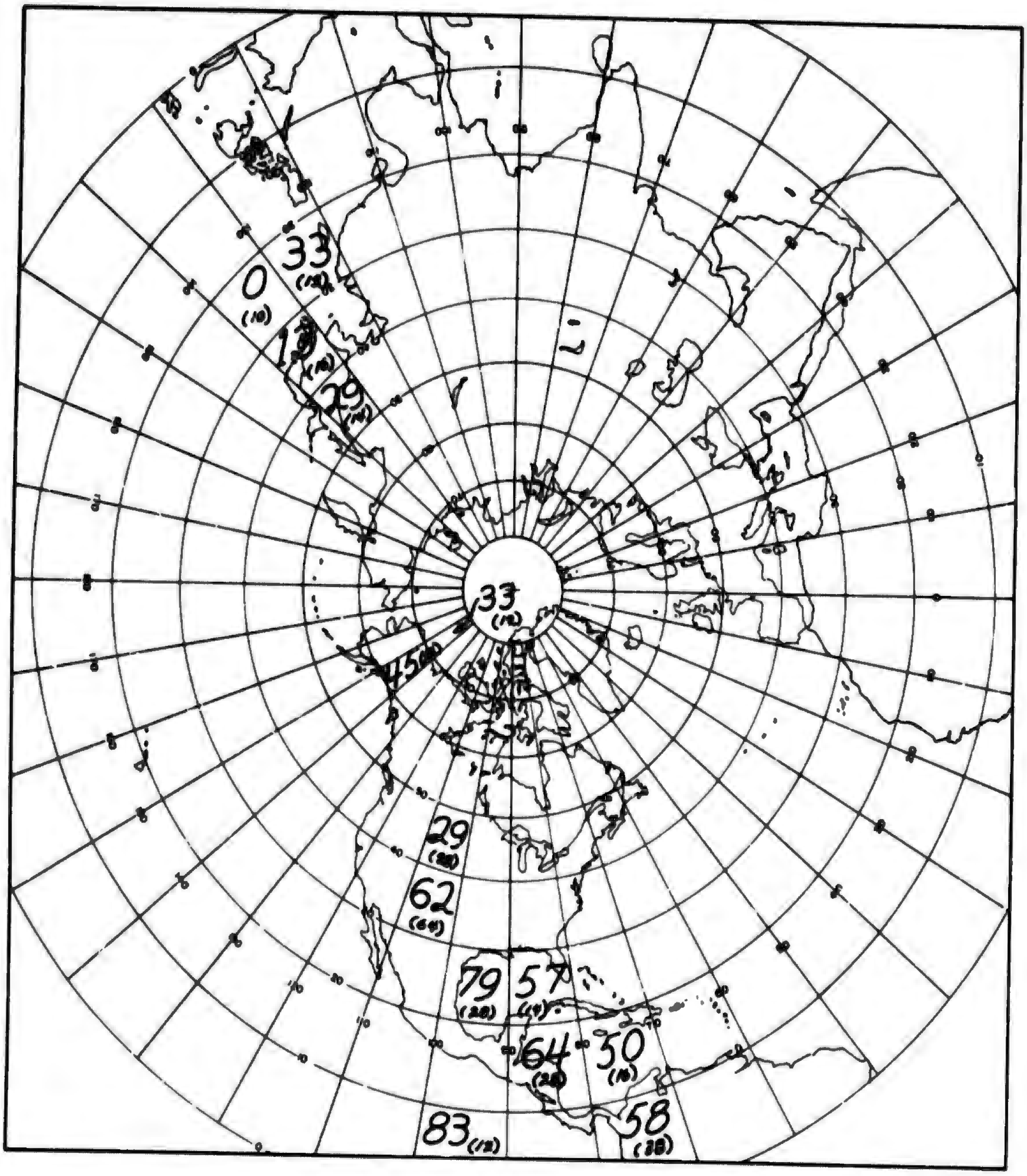

Figure A37. Estimates of the Probability of Seeing the Ground at 30° Below the Horizon (-30°) from Altitudes Above 45,000 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

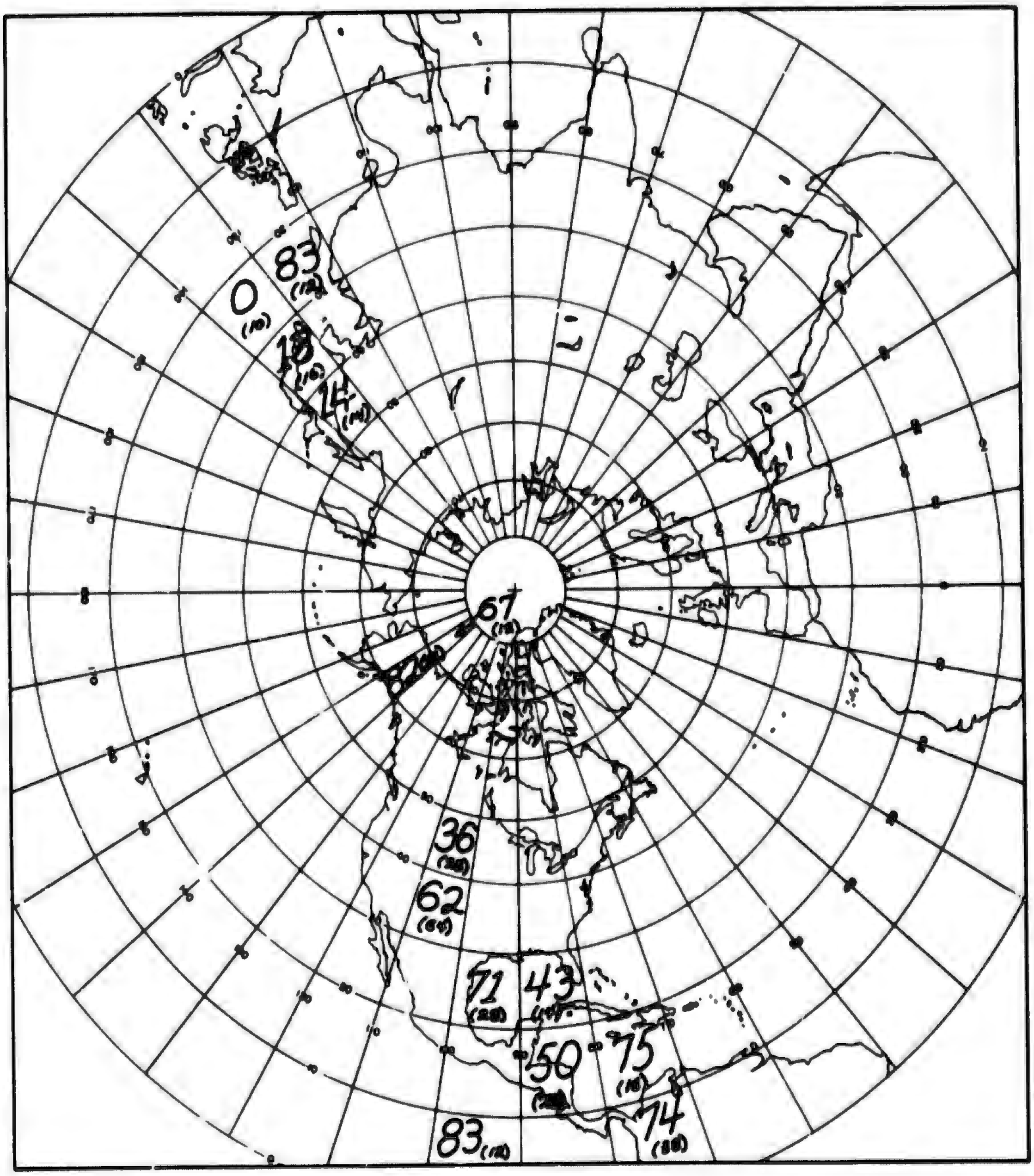

Figure A38. Estimates of the Probability of Seeing the Horizon from Altitudes Above 45,000 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

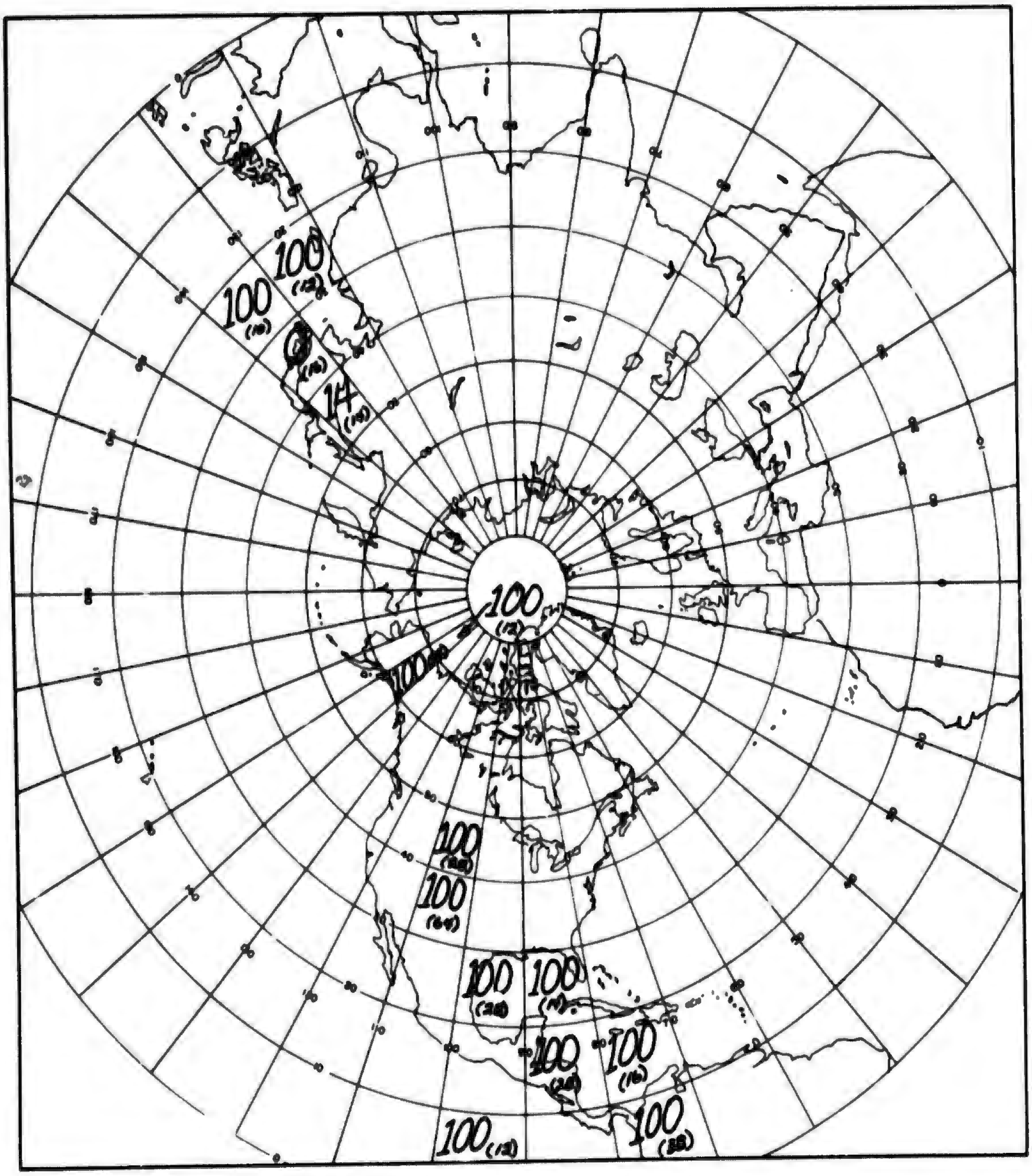

Figure A39. Estimates of the Probability of Seeing Blue Sky at 30° Above the Horizon (+ 30°) from Altitudes Above 45,000 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

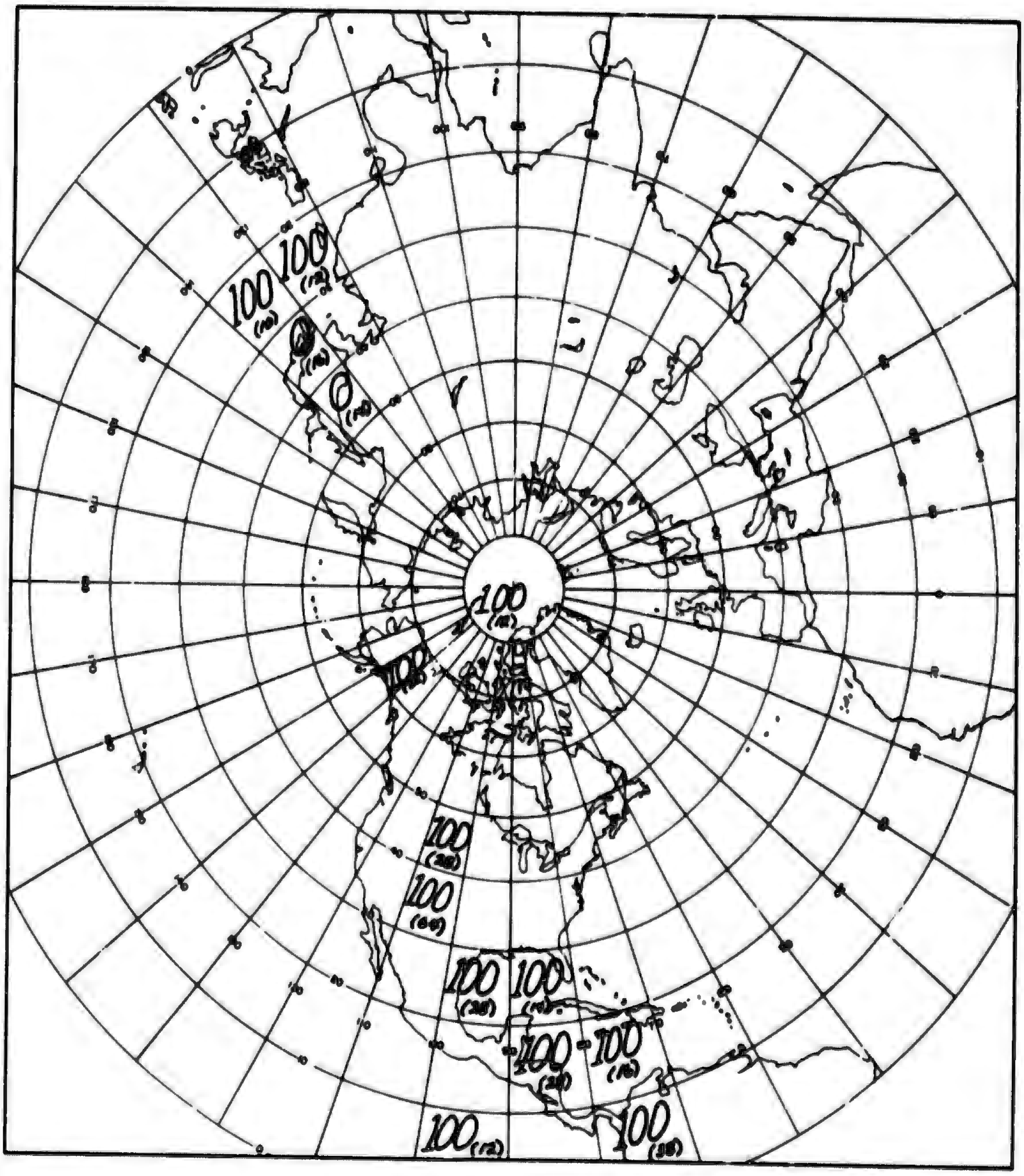

Figure A40. Estimates of the Probability of Seeing Blue Sky at 90° Above the Horizon (+ 90°) from Altitudes Above 45, 000 ft, in Winter. (Estimates are based on the number of observations shown in parentheses)

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Appendix B

Spring Estimates of Probability of a Clear Line-of-Sight

In this appendix are given Northern Hemisphere maps of estimates of the probability of a clear line-of-sight for spring (March, April, May) at five selected angles of vision: (a) ground at 90 degrees below the horizon (-90°); (b) ground at 30 degrees below the horizon (-30°); (c) horizon; (d) sky at 30 degrees above the horizon (+30°); (e) sky at 90 degrees above the horizon (+90°), and for eight altitude layers: below 1800 ft; 1801 to 3600 ft; 3601 to 7400 ft; 7401 to 14,999 ft; 15,000 to 24,999 ft; 25,000 to 34,999 ft; 35,000 to 44,999 ft; and above 45,000 ft. The Northern Hemisphere is divided into 10° latitude-longitude sectors. The values given in these sectors are estimates of the probability of a clear line-of-sight. Values in parentheses indicate the number of observations taken in that sector. Probabilities were not computed for sectors that reported less than 10 observations.

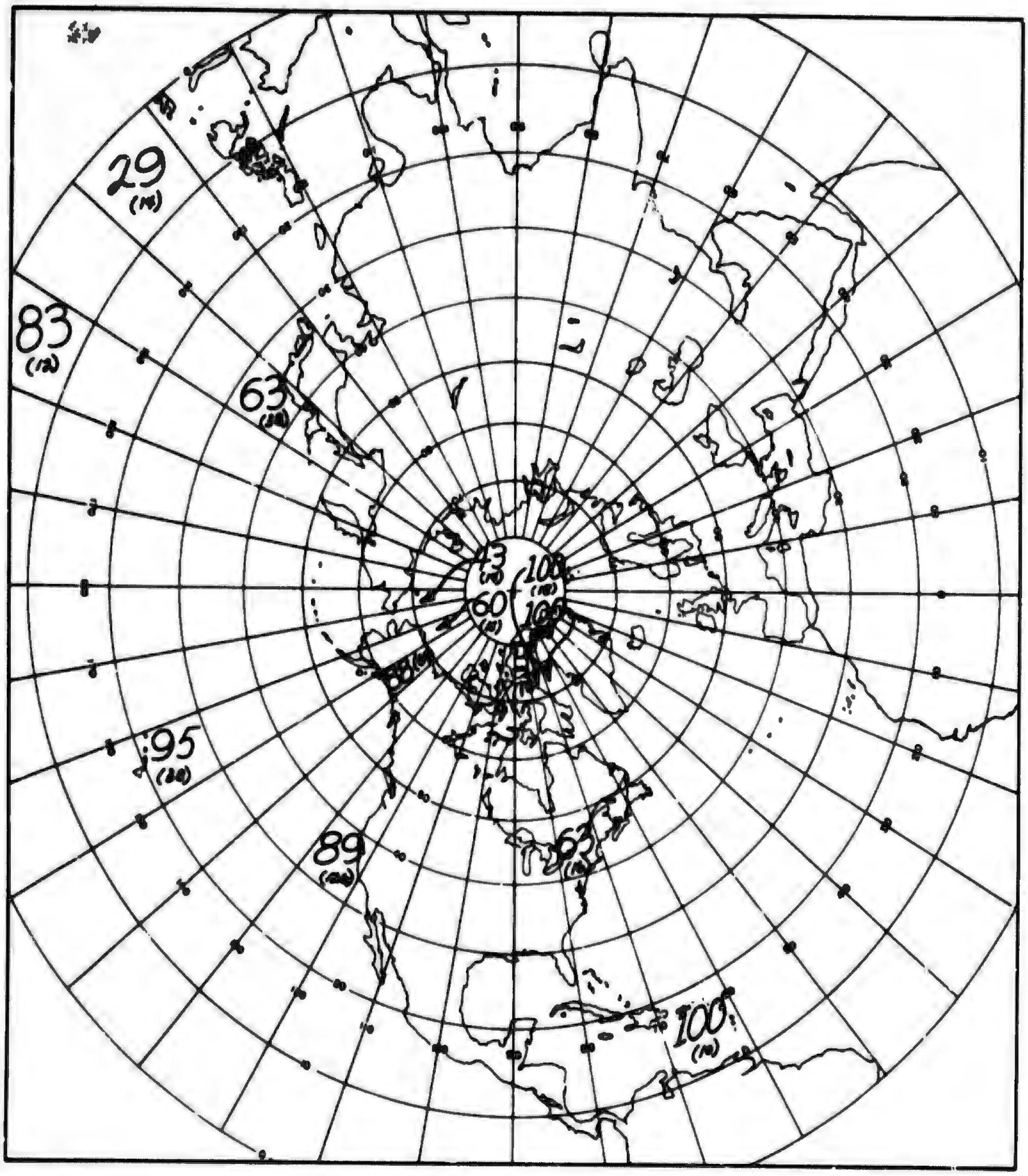

Figure B1. Estimates of the Probability of Seeing the Ground Directly Below the Aircraft (-90°) from Altitudes up to 1800 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

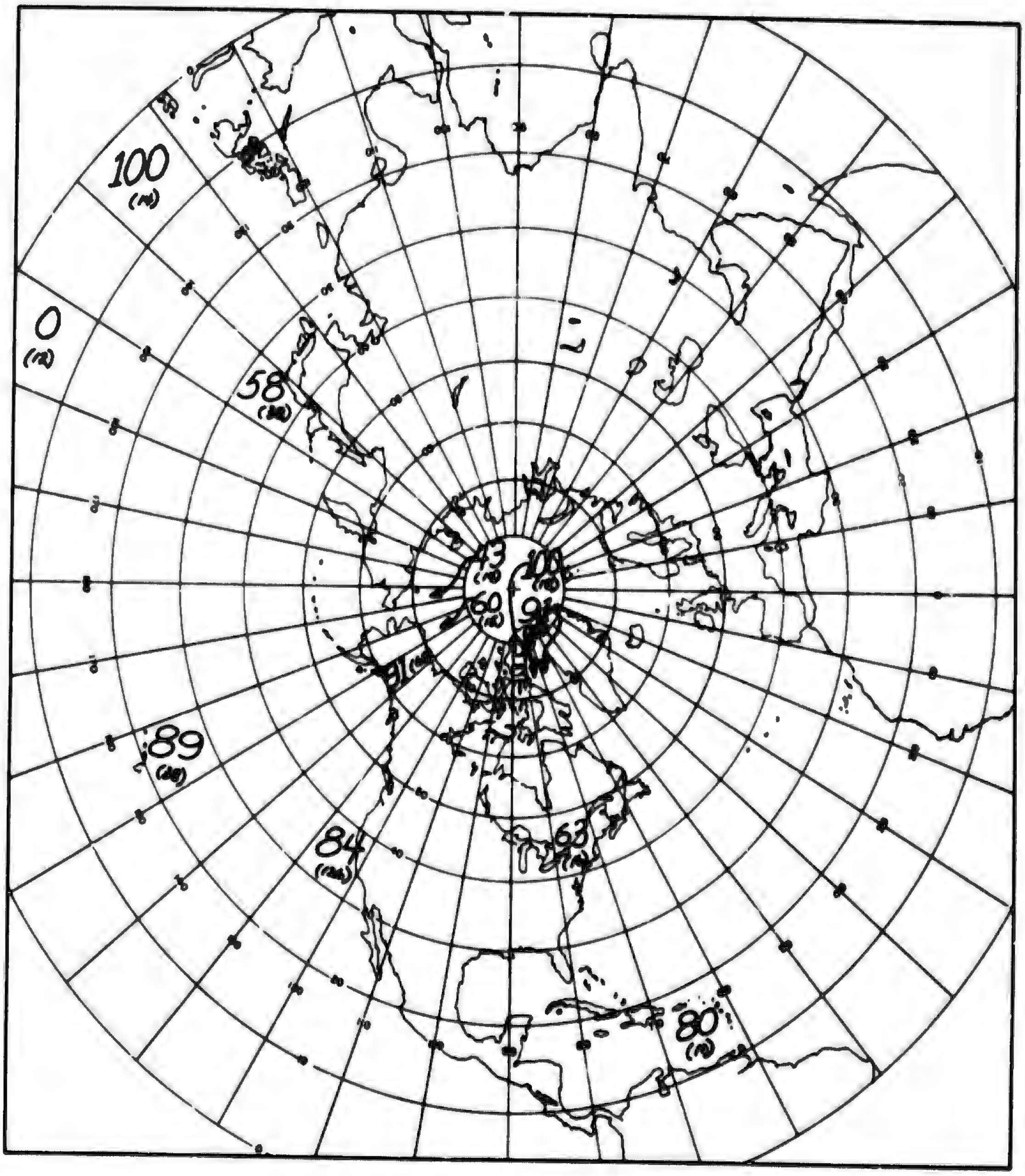

Figure B2. Estimates of the Probability of Seeing the Ground at 30° Below the Horizon (-30°) from Altitudes up to 1800 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

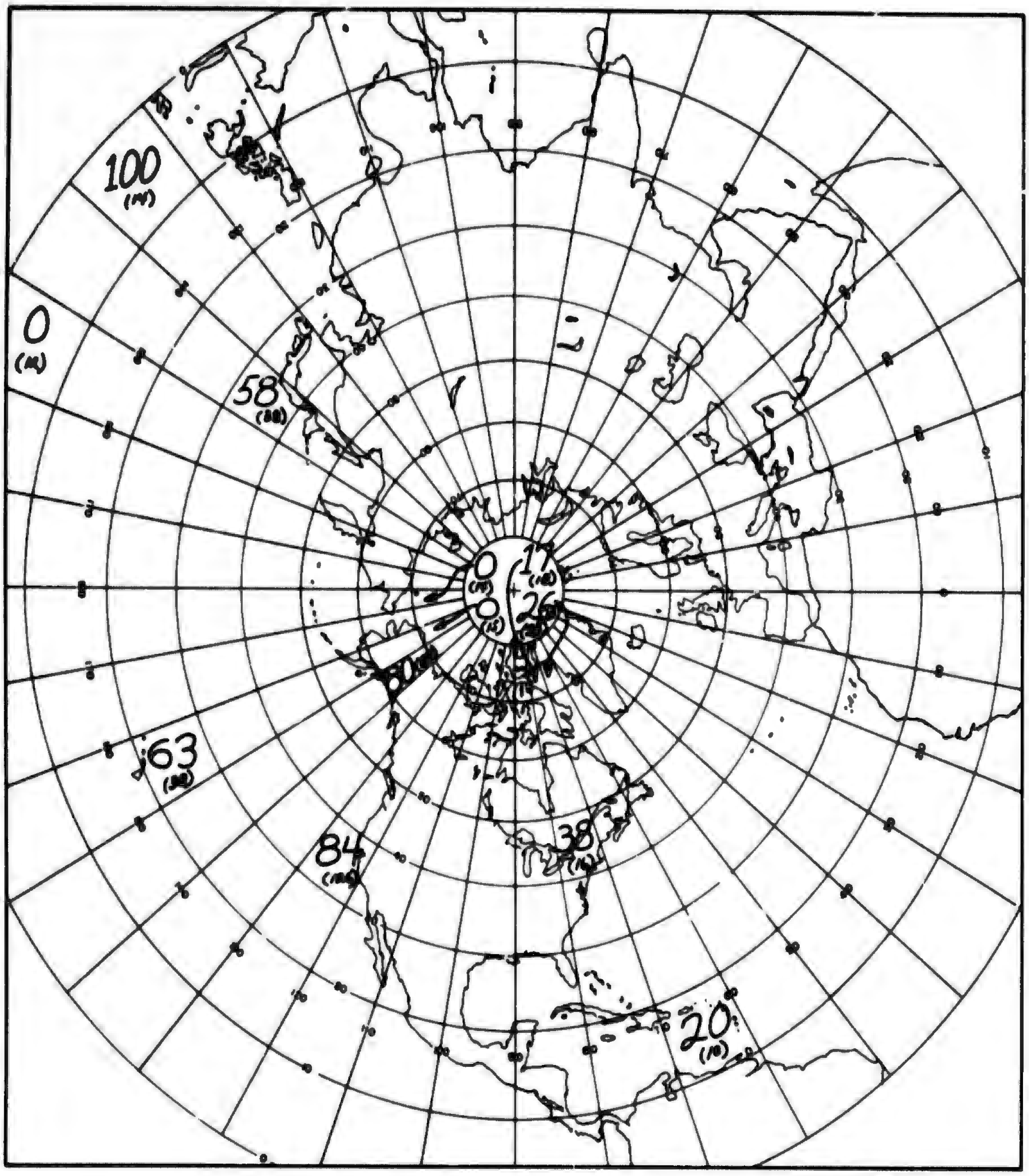

Figure B3. Estimates of the Probability of Seeing the Horizon from Altitudes up to 1800 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

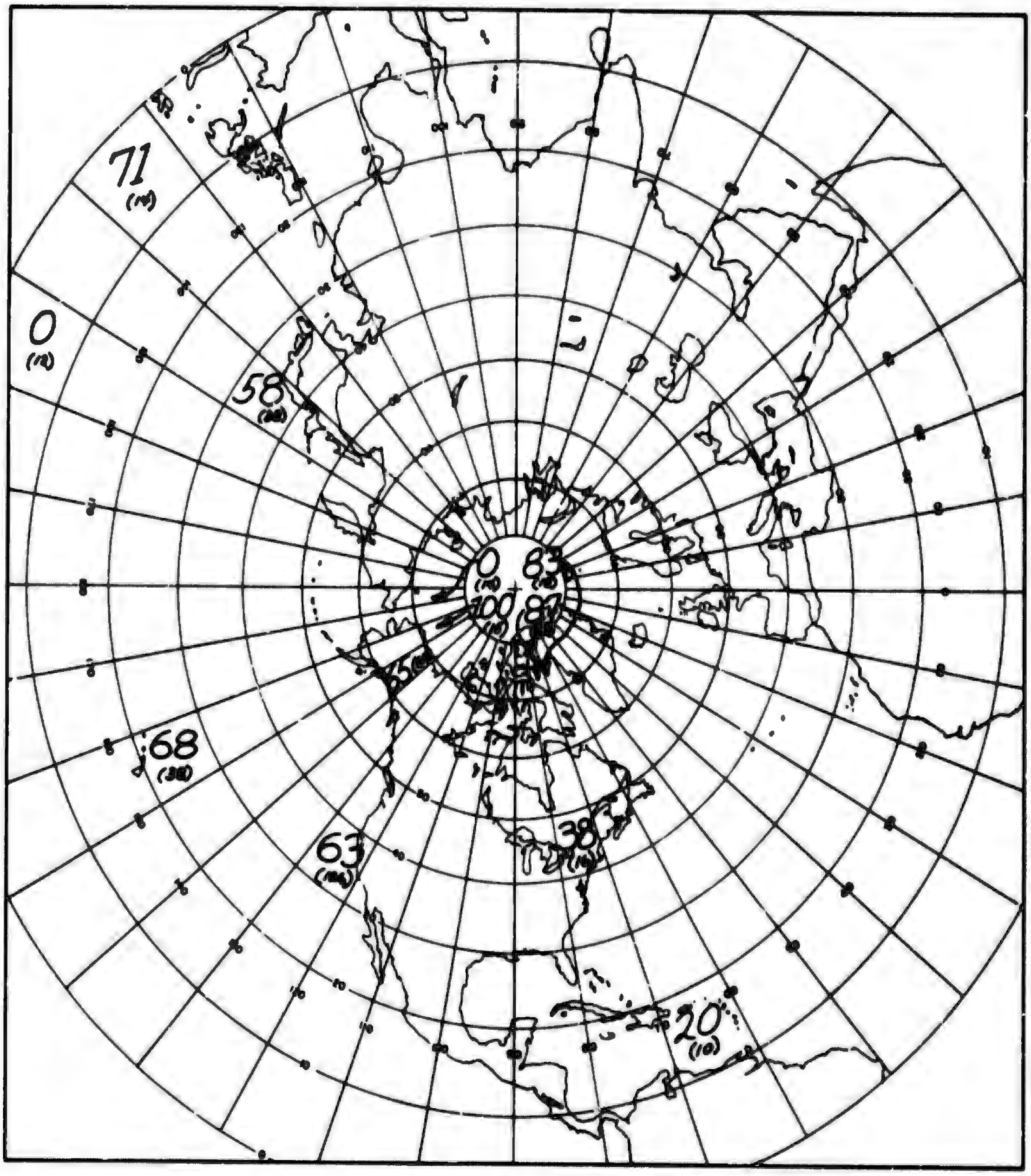

Figure B4. Estimates of the Probability of Seeing Blue Sky at 30° Above the Horizon (+ 30°) from Altitudes up to 1800 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

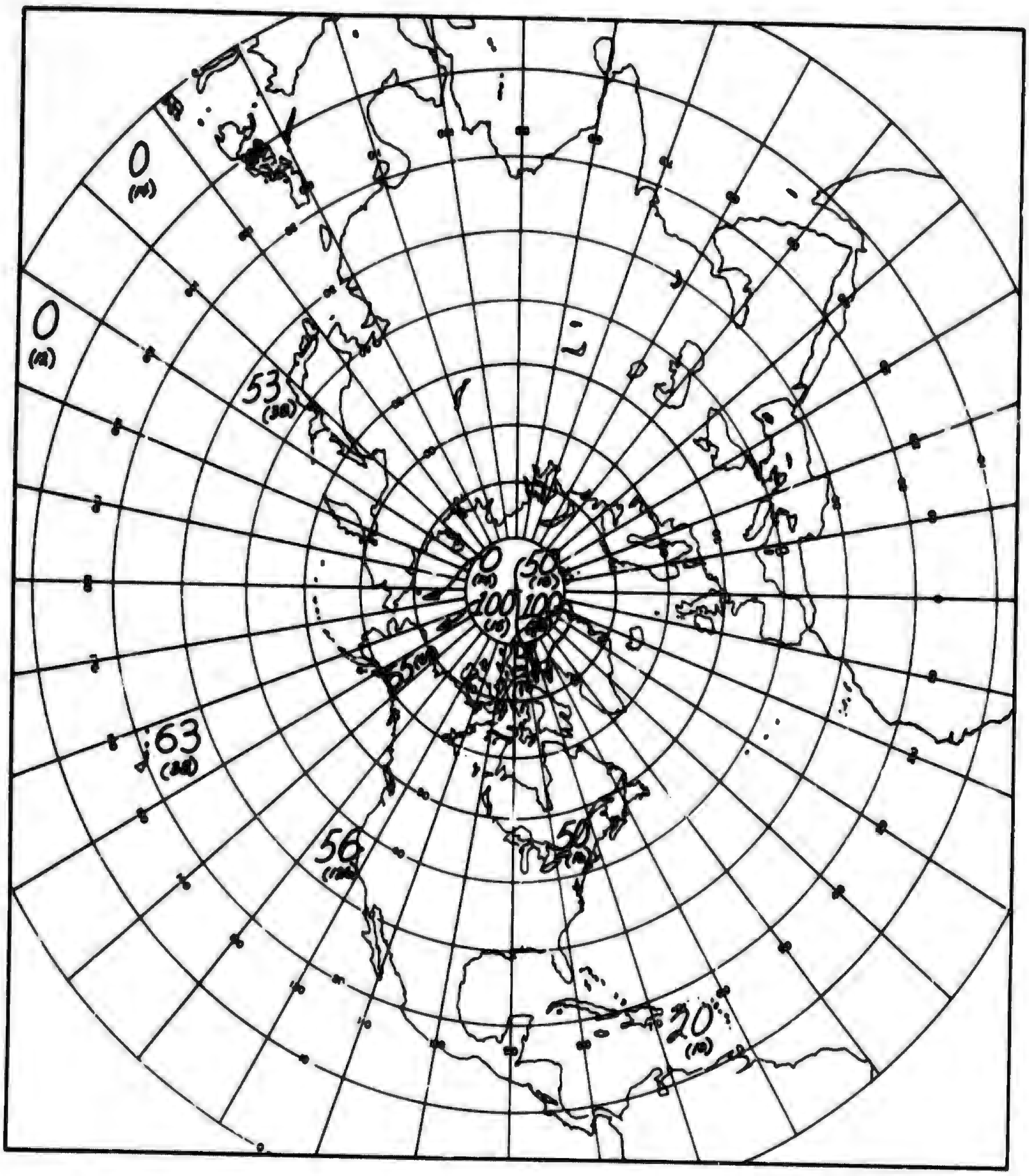

Figure B5. Estimates of the Probability of Seeing Blue Sky at 90° Above the Horizon (+ 90°) from Altitudes up to 1800 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

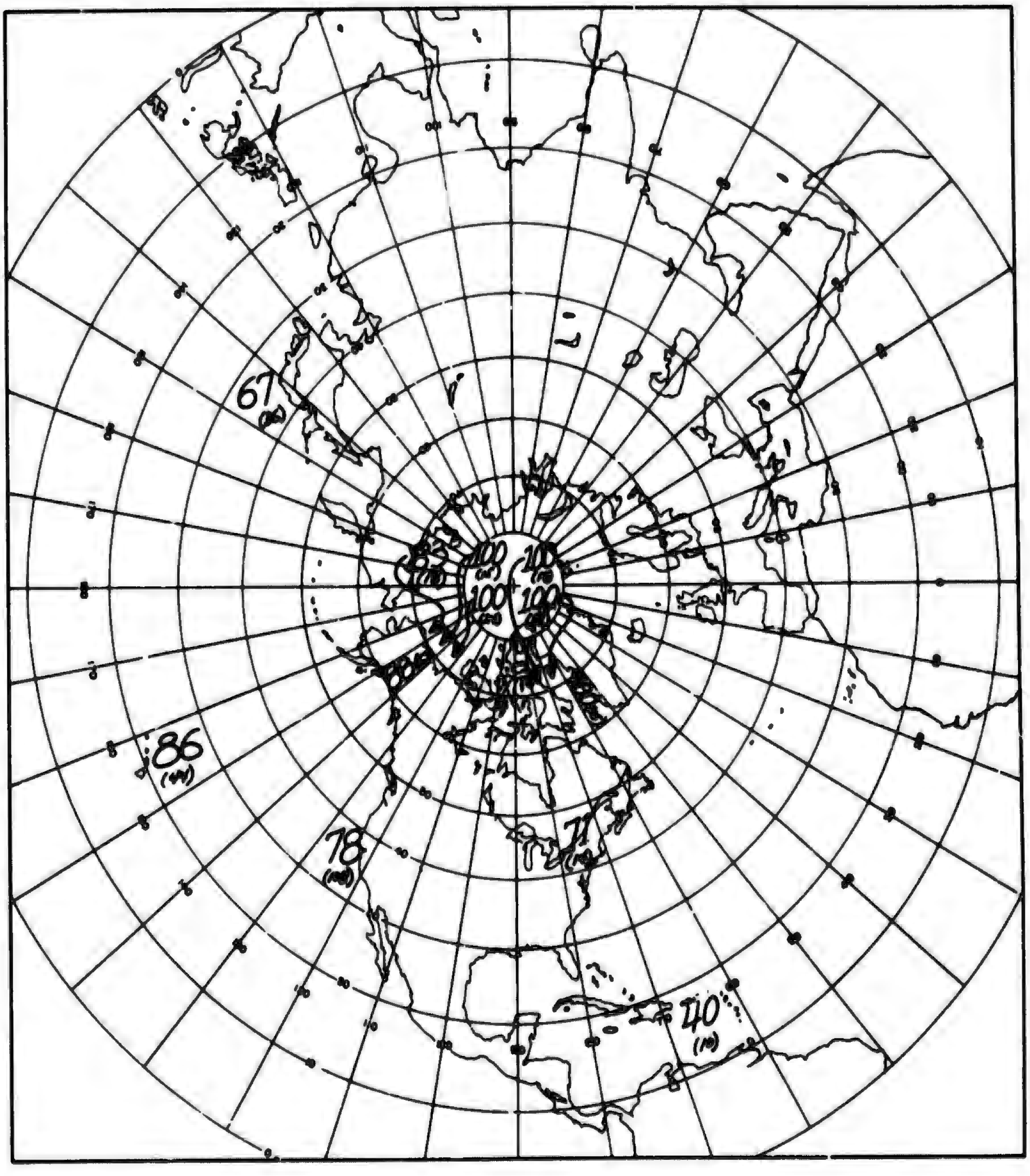

Figure B6. Estimates of the Probability of Seeing the Ground Directly Below the Aircraft (-90°) from Altitudes of 1801 to 3600 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

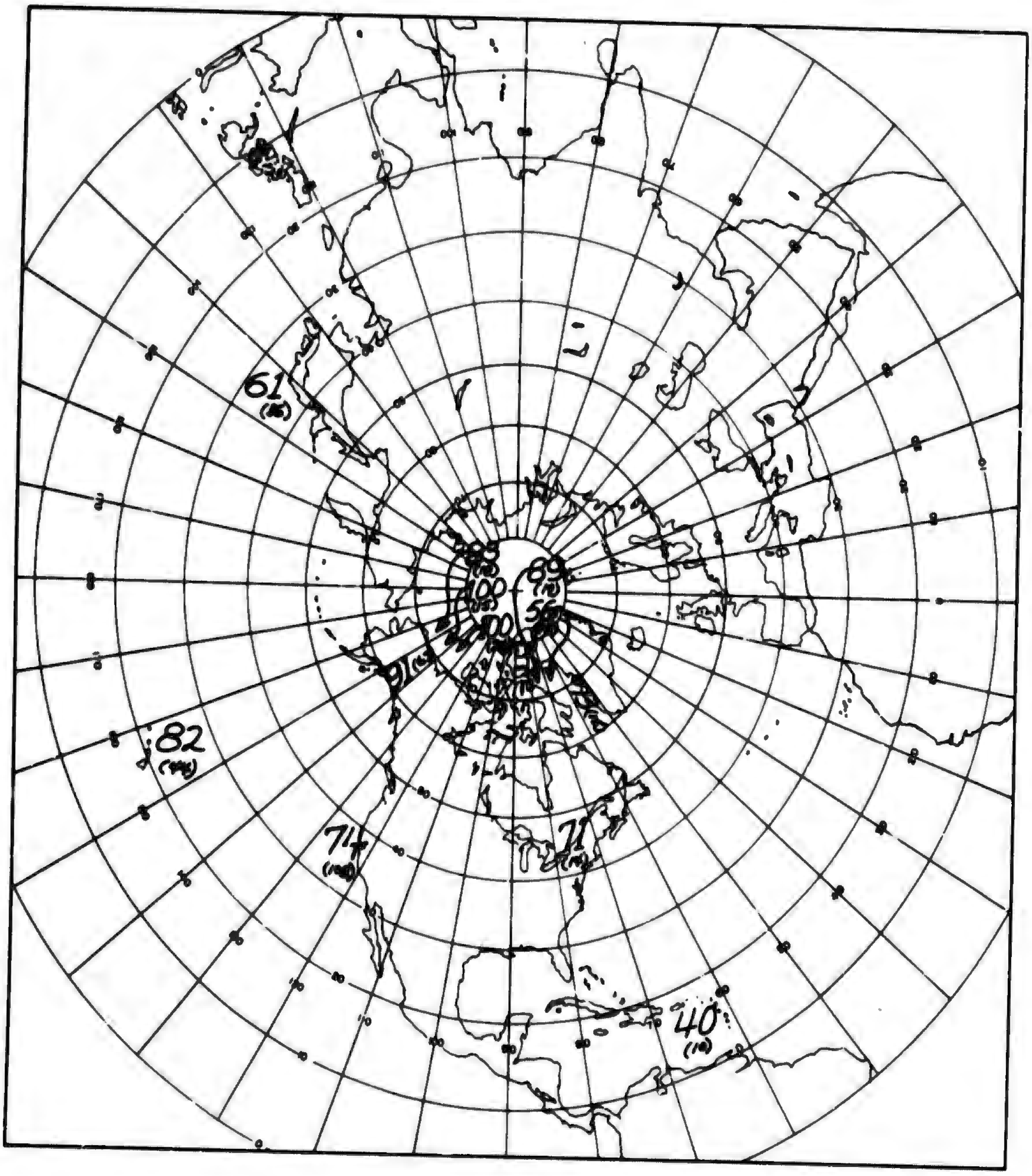

Figure B7. Estimates of the Probability of Seeing the Ground at 30° Below the Horizon (-30°) from Altitudes of 1801 to 3600 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

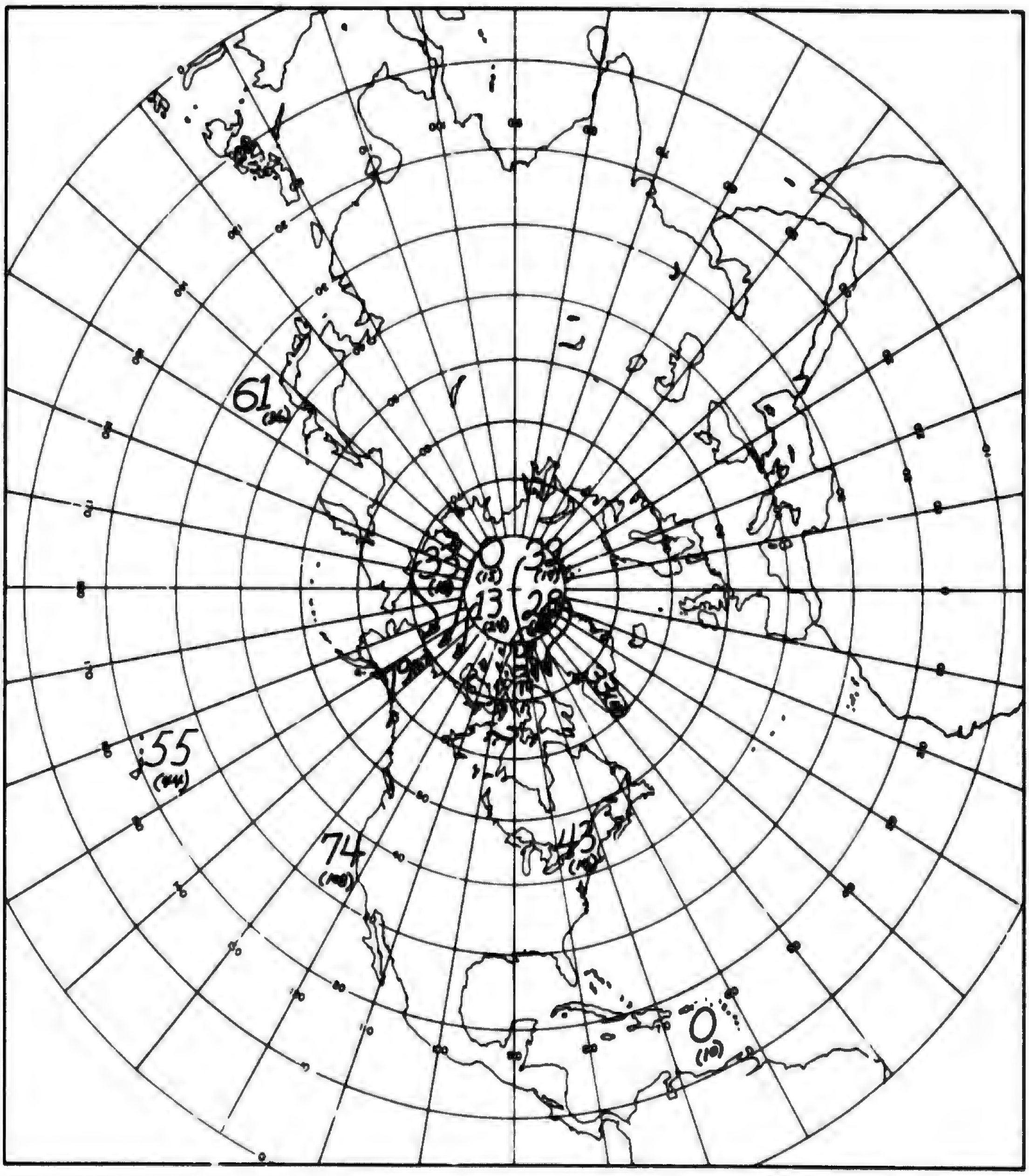

Figure B8. Estimates of the Probability of Seeing the Horizon from Altitudes of 1801 to 3600 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

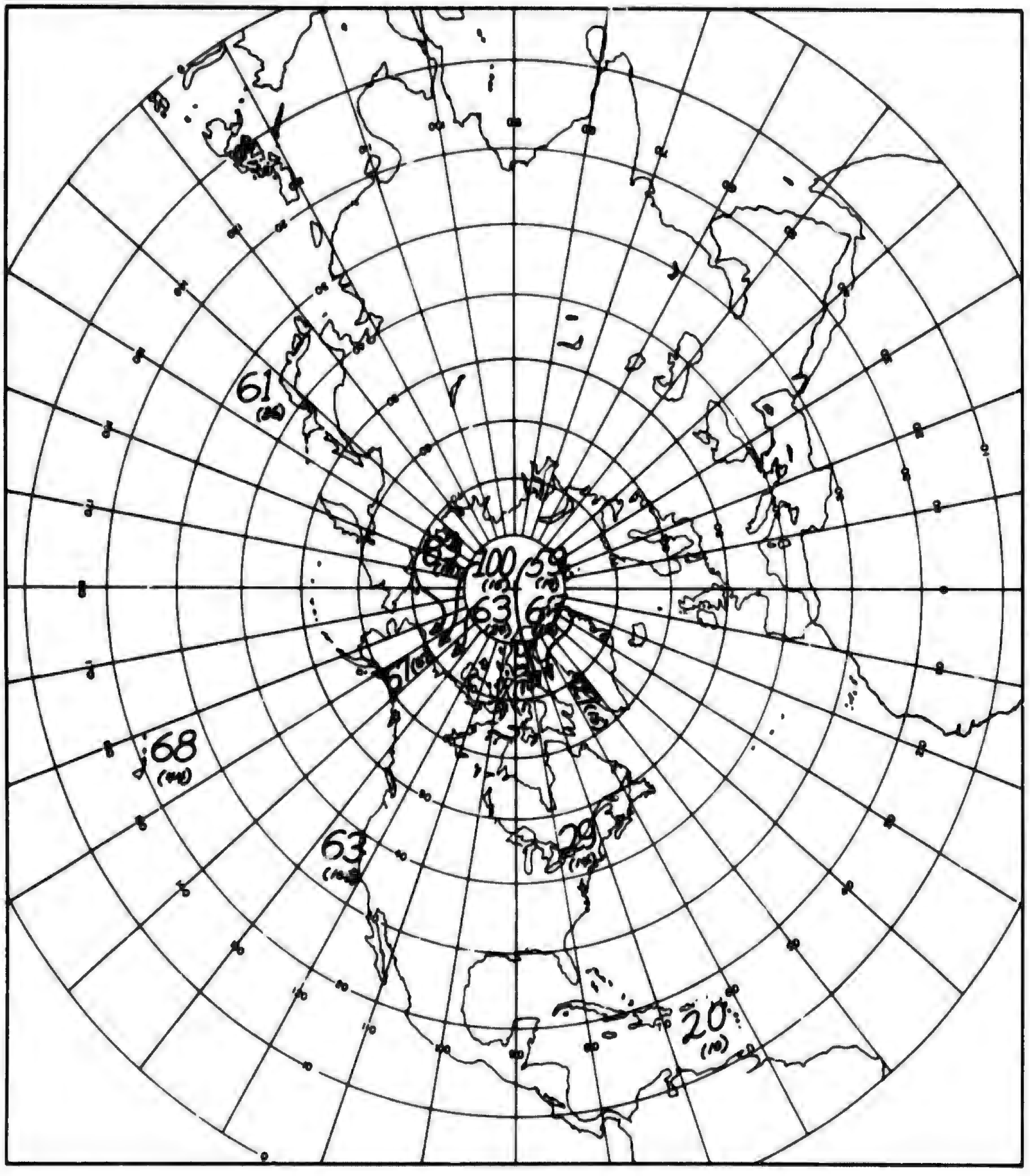

Figure B9. Estimates of the Probability of Seeing Blue Sky at 30° Above the Horizon (+ 30°) from Altitudes of 1801 to 3600 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

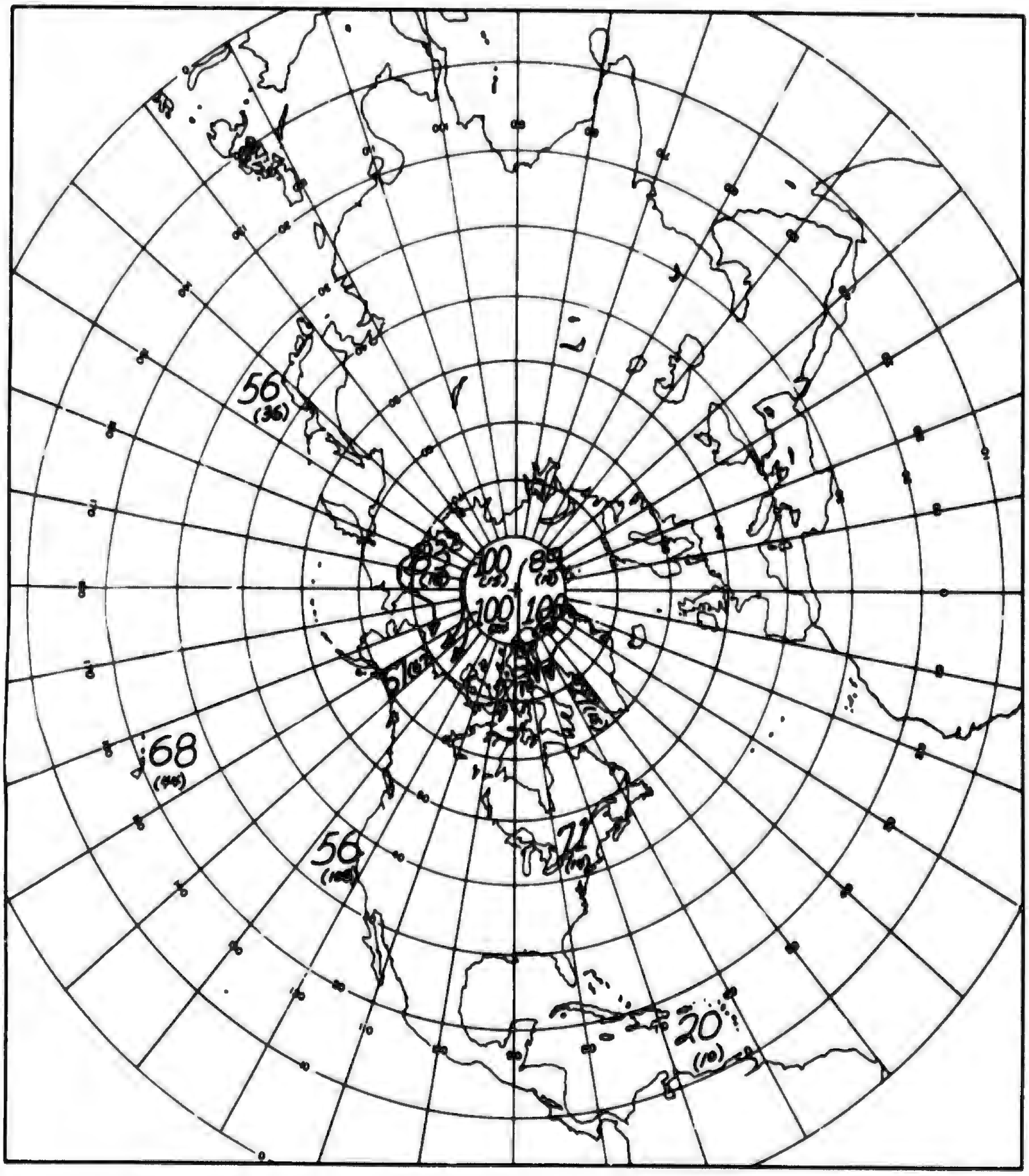

Figure B10. Estimates of the Probability of Seeing Blue Sky at 90° Above the Horizon (+90°) from Altitudes of 1801 to 3600 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

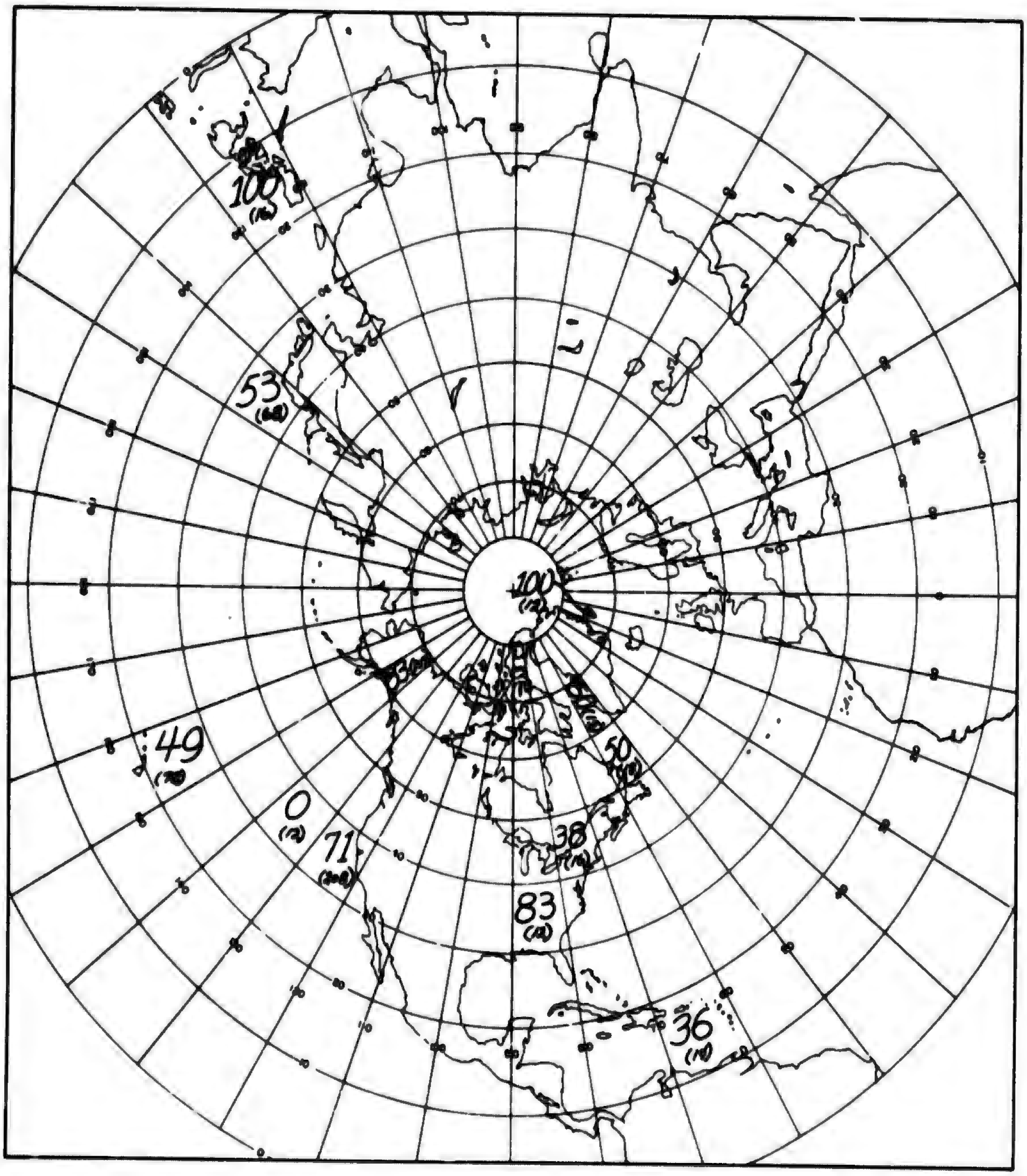

Figure B11. Estimates of the Probability of Seeing the Ground Directly Below the Aircraft (-90°) from Altitudes of 3601 to 7400 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

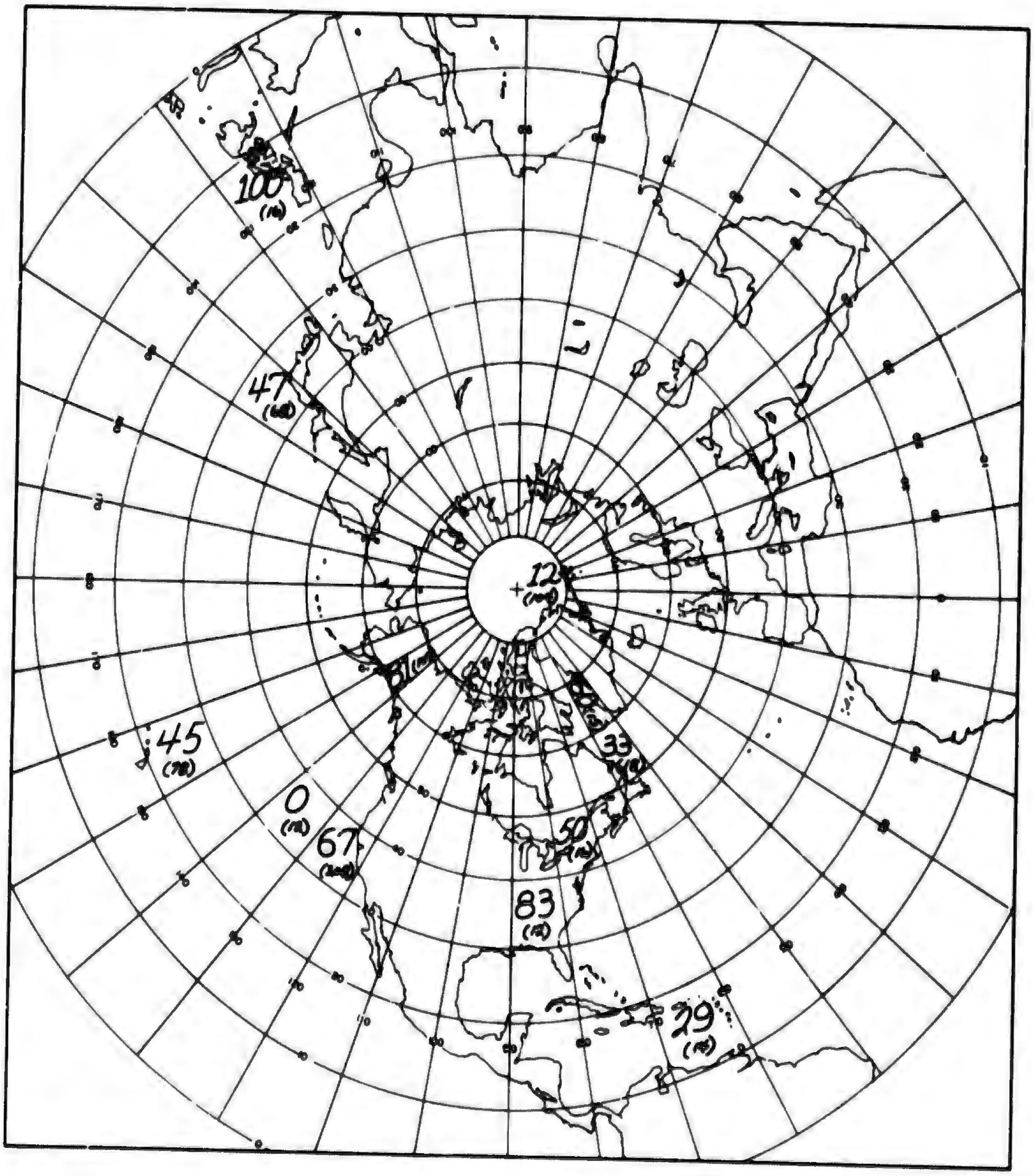

Figure B12. Estimates of the Probability of Seeing the Ground at 30° Below the Horizon (-30°) from Altitudes of 3601 to 7400 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

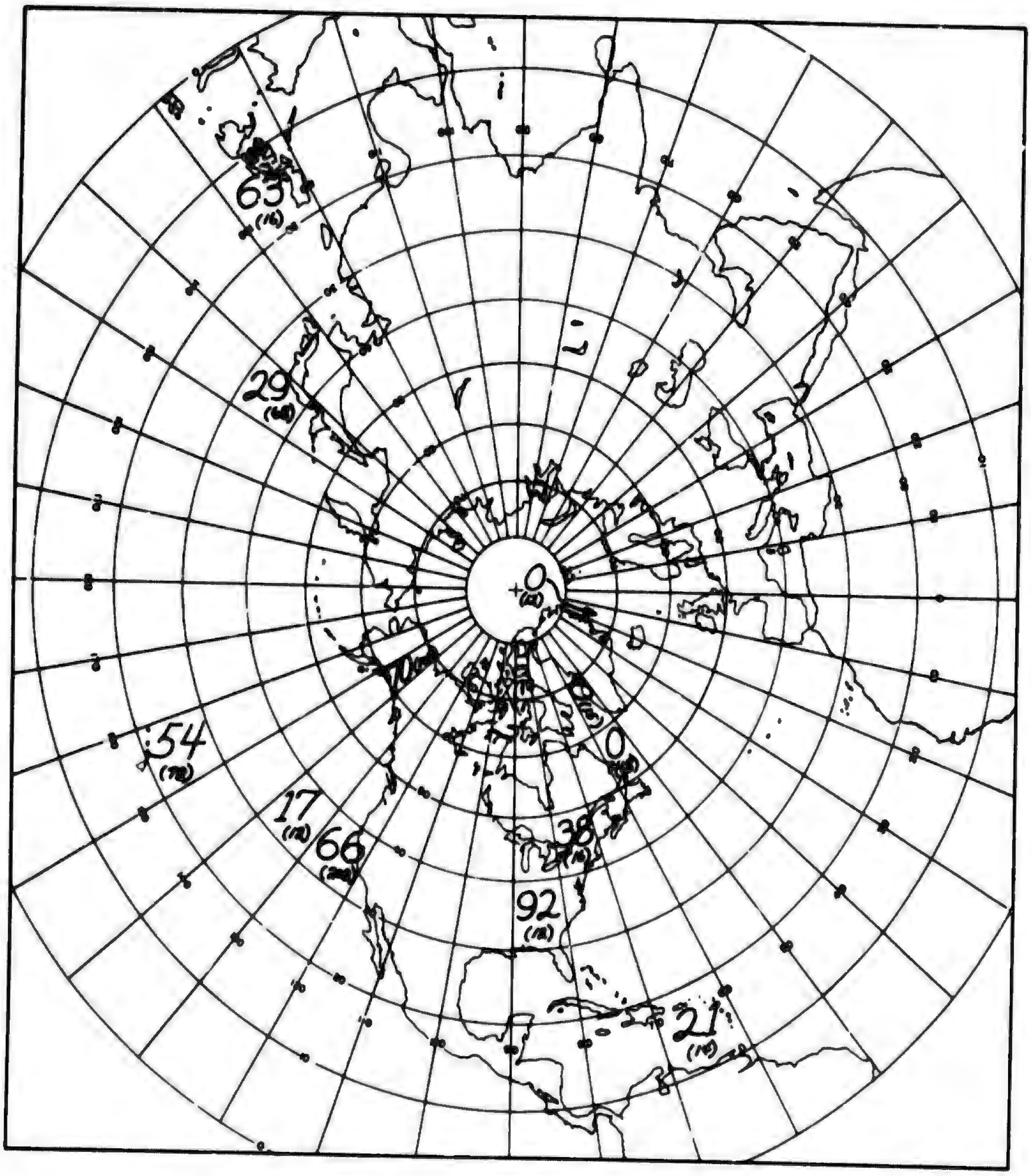

Figure B13. Estimates of the Probability of Seeing the Horizon from Altitudes of 3601 to 7400 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

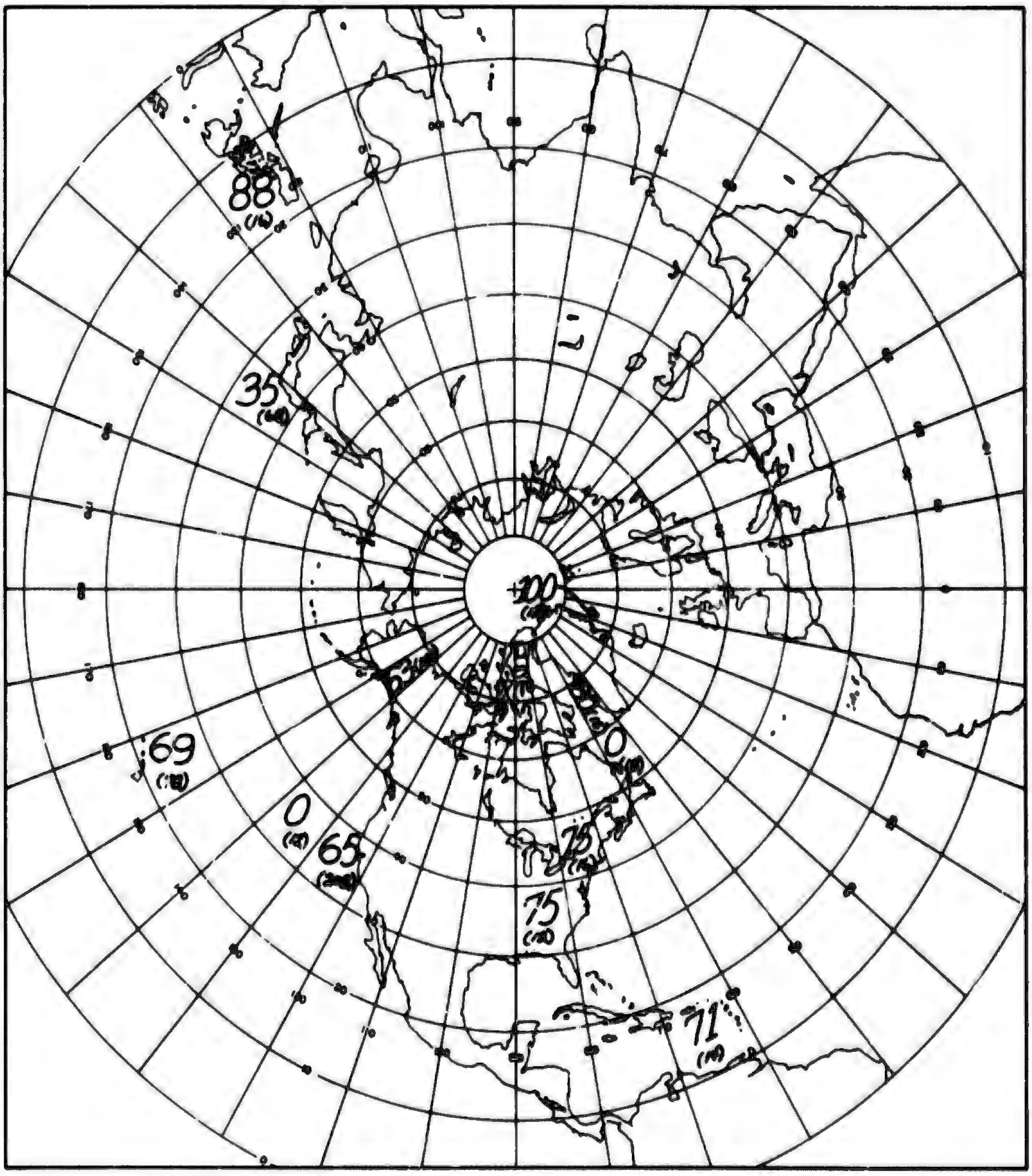

Figure B14. Estimates of the Probability of Seeing Blue Sky at 30° Above the Horizon (+ 30°) from Altitudes of 3601 to 7400 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

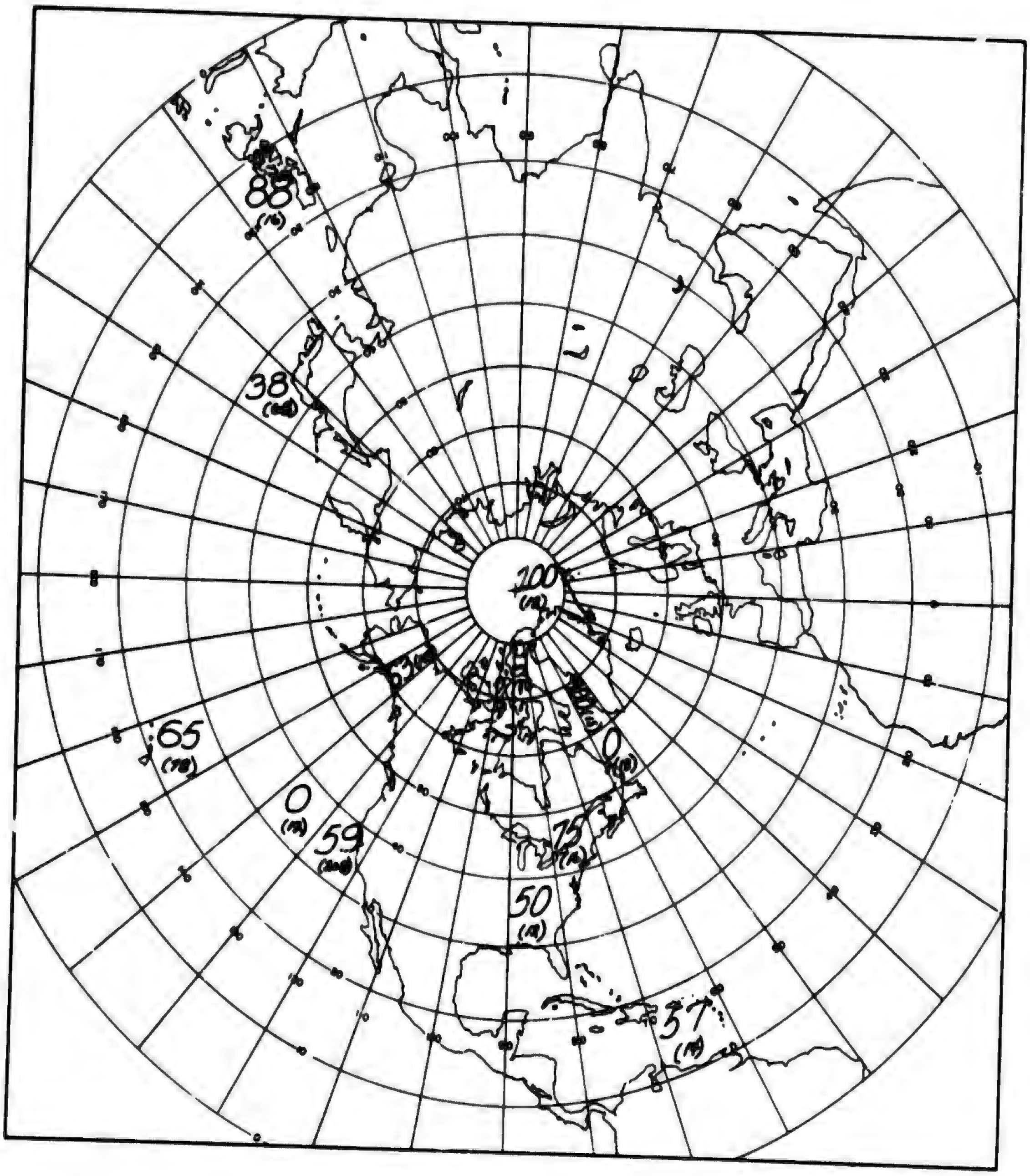

Figure B15. Estimates of the Probability of Seeing Blue Sky at 90° Above the Horizon (+90°) from Altitudes of 3601 to 7400 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

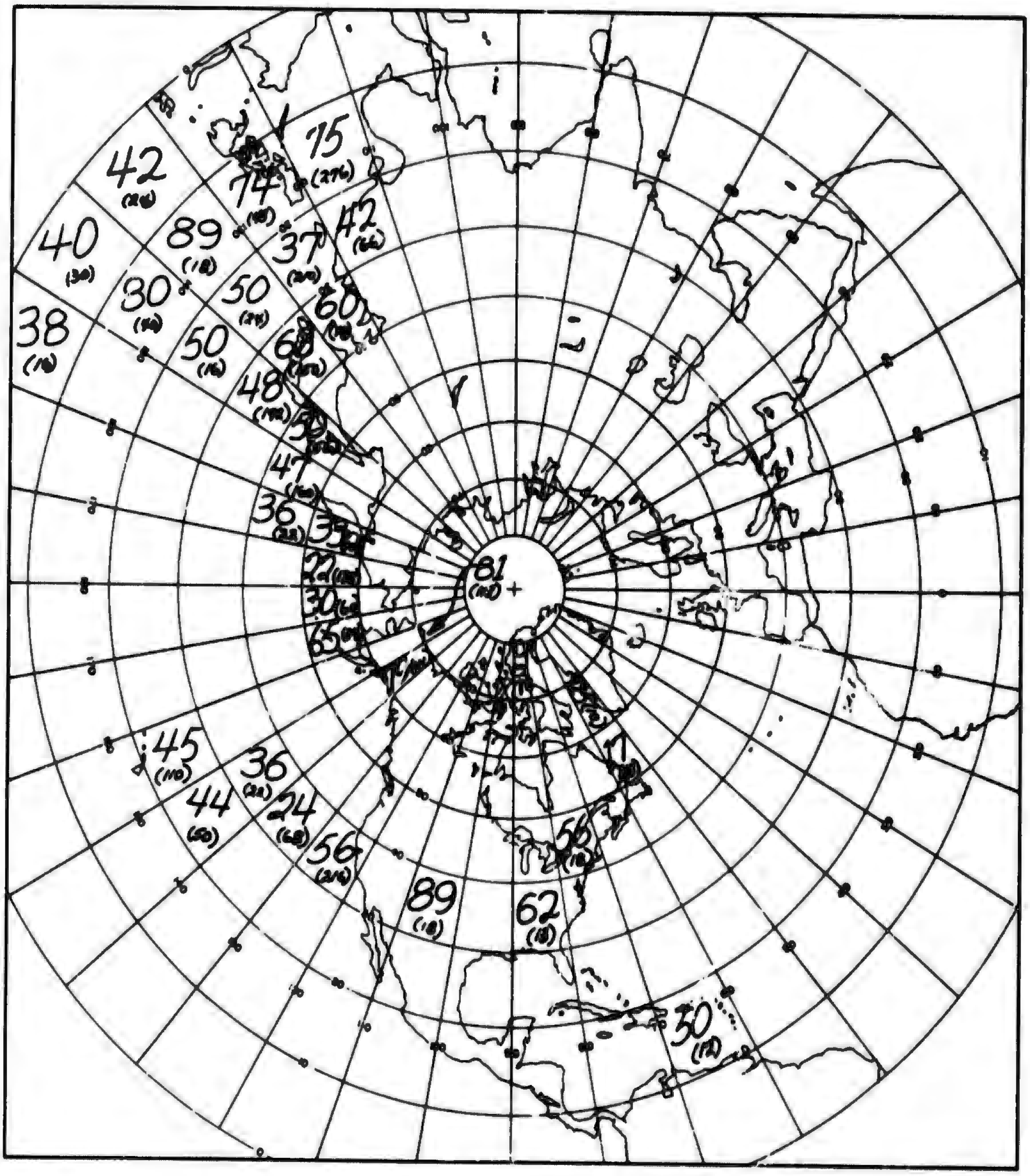

Figure B16. Estimates of the Probability of Seeing the Ground Directly Below the Aircraft (-90°) from Altitudes of 7401 to 14,999 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

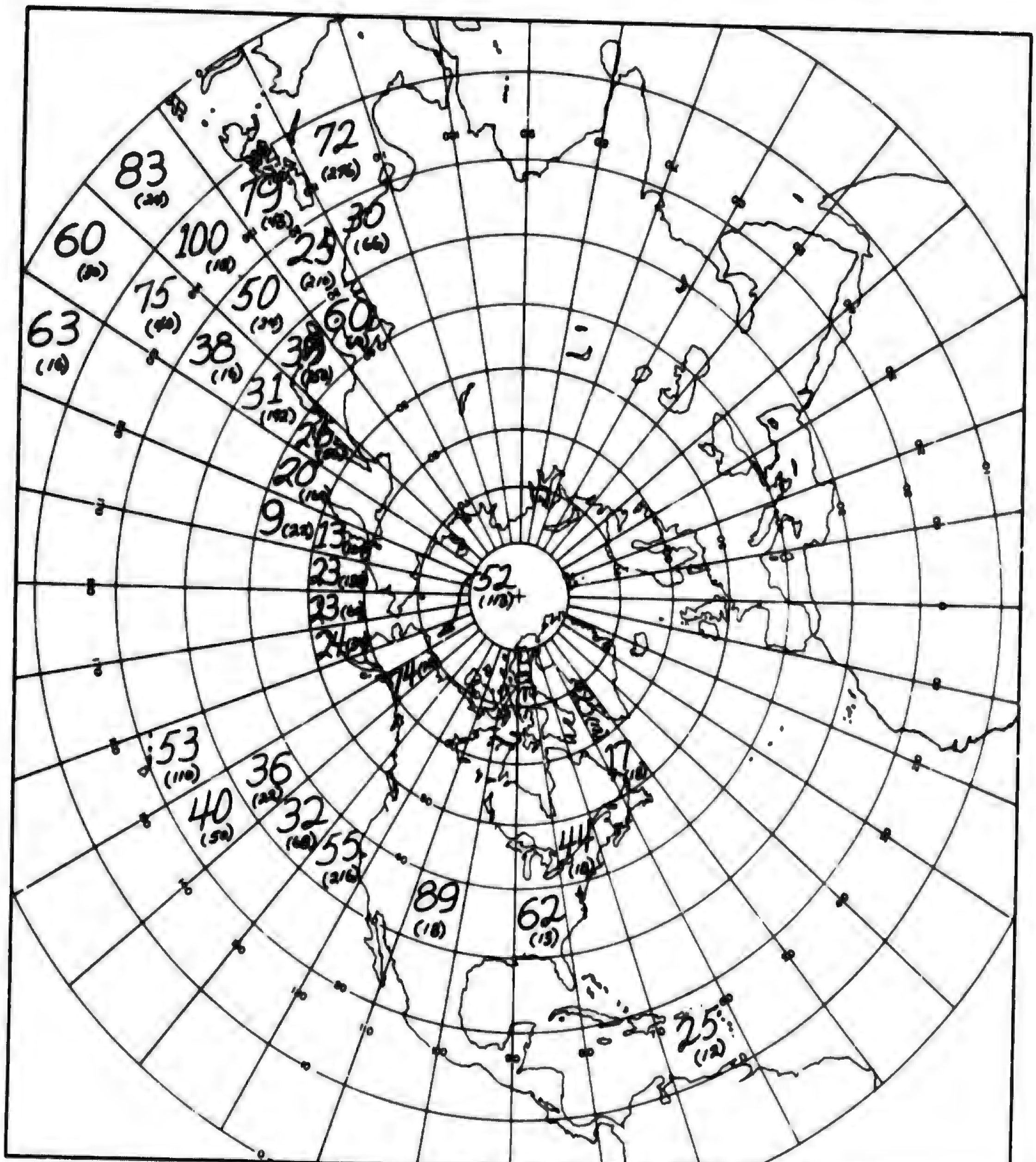

Figure B17. Estimates of the Probability of Seeing the Ground at 30° Below the Horizon (-30°) from Altitudes of 7401 to 14,999 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

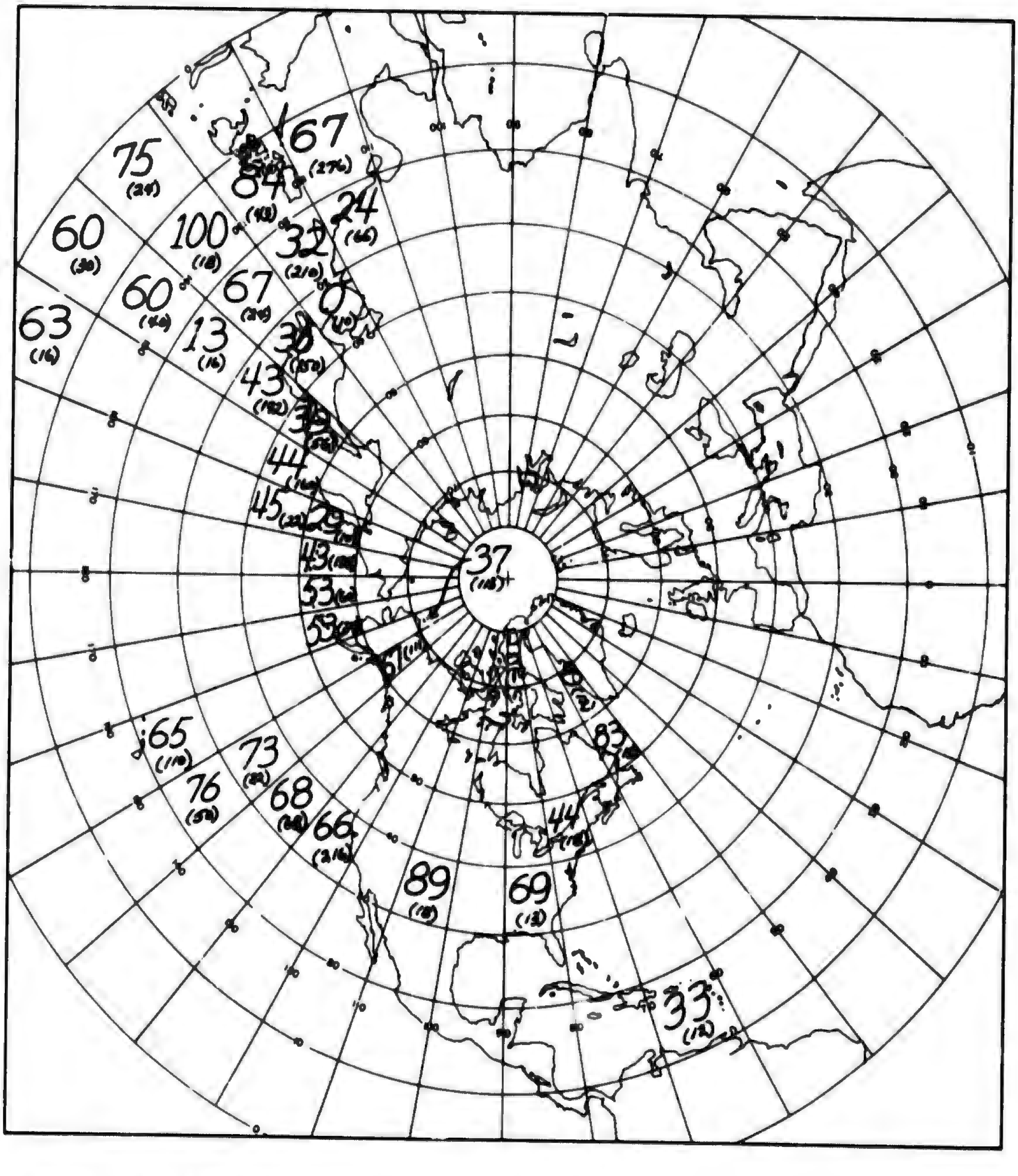

Figure B18. Estimates of the Probability of Seeing the Horizon from Altitudes of 7401 to 14,999 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

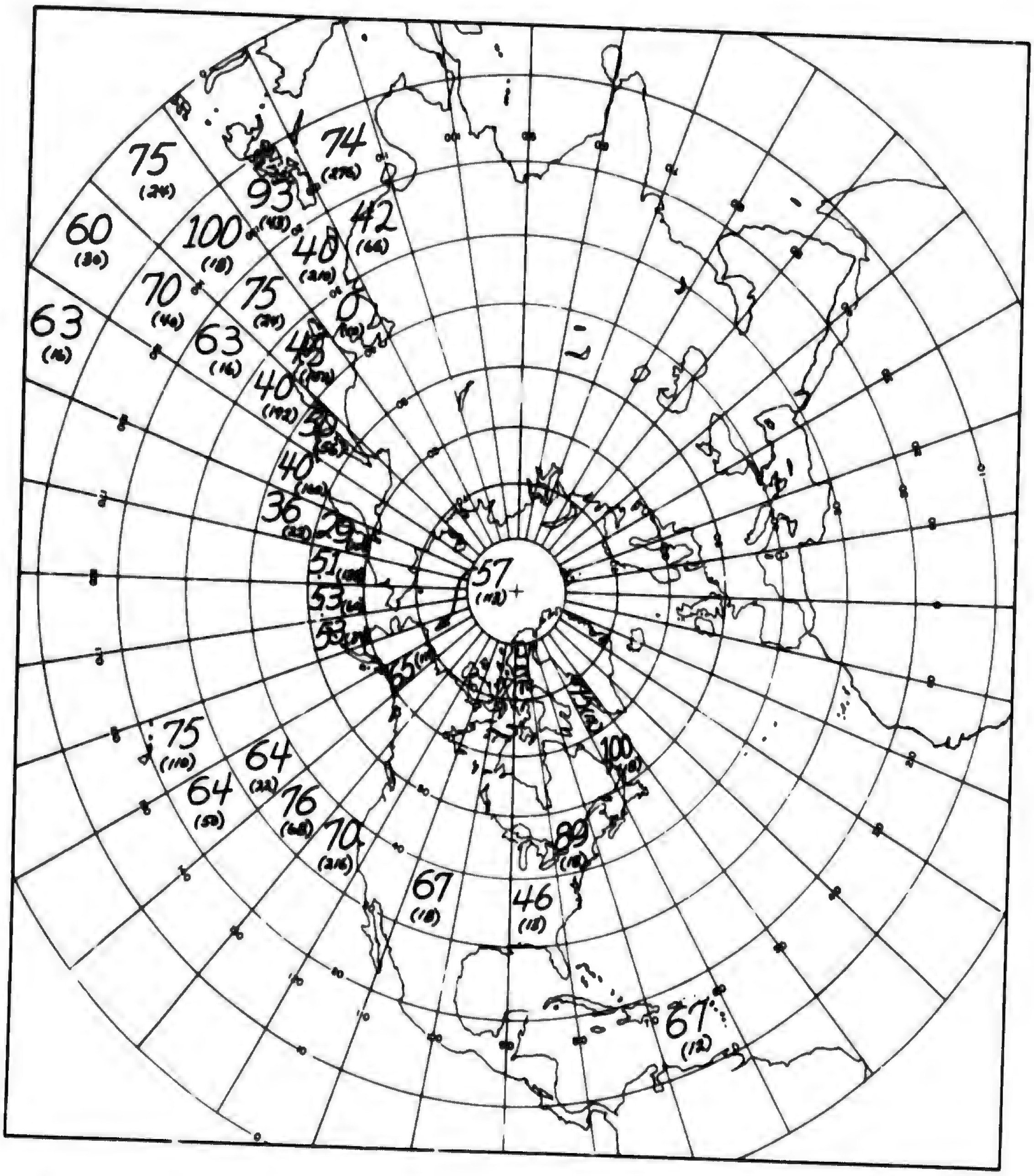

Figure B19. Estimates of the Probability of Seeing Blue Sky at 30° Above the Horizon (+ 30°) from Altitudes of 7401 to 14,999 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

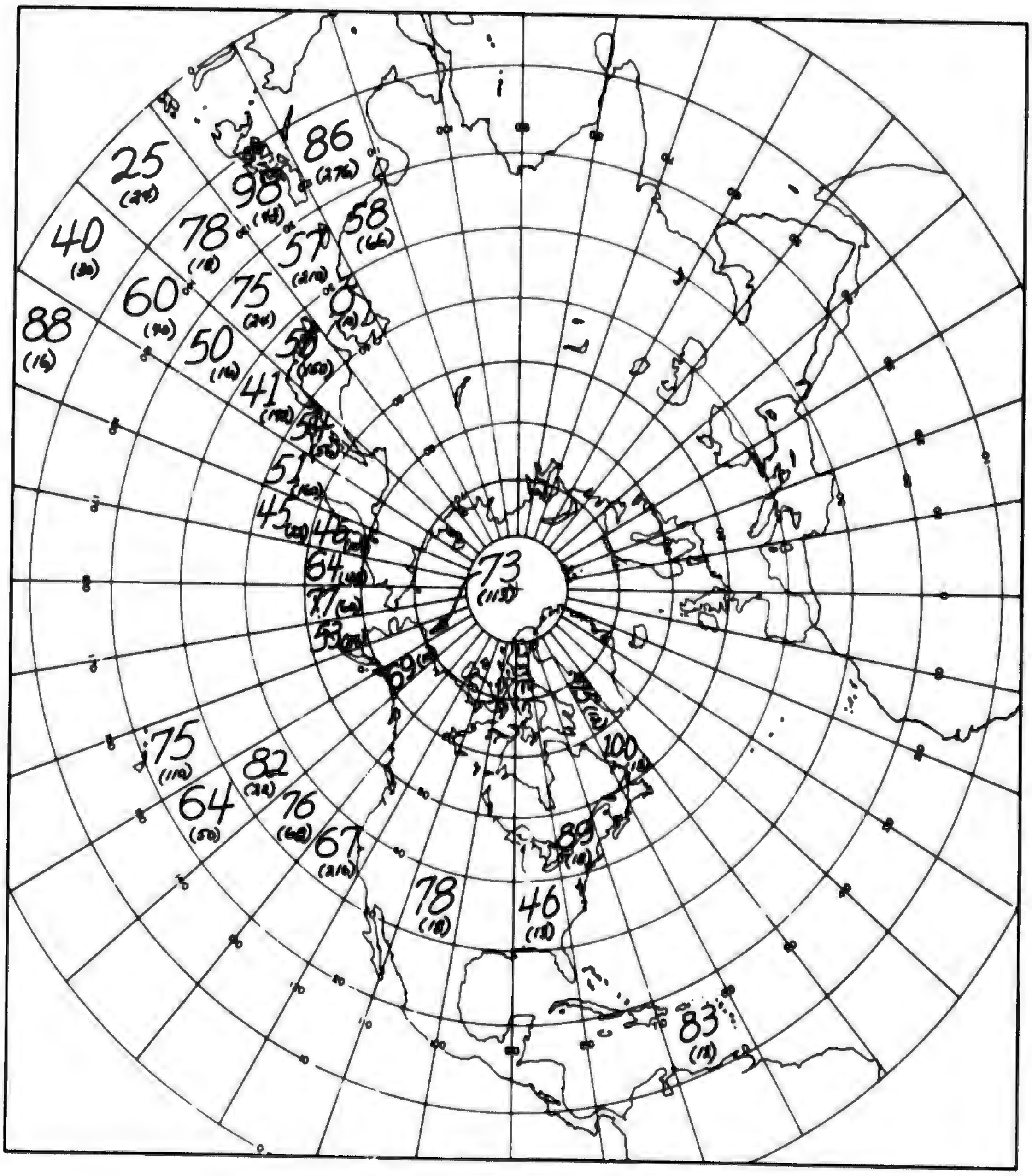

Figure B20. Estimates of the Probability of Seeing Blue Sky at 90° Above the Horizon (+ 90°) from Altitudes of 7401 to 14,999 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

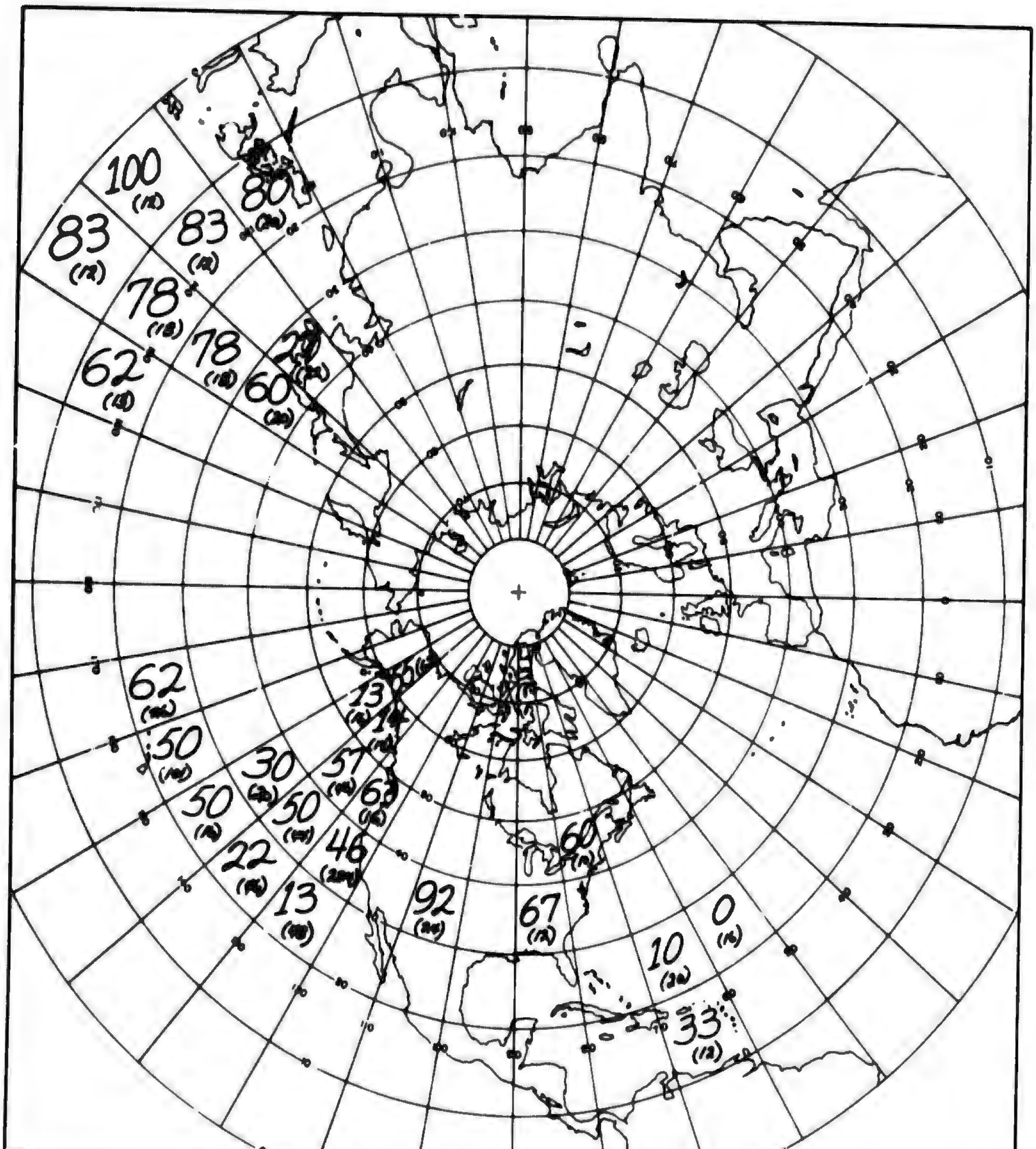

Figure B21. Estimates of the Probability of Seeing the Ground Directly Below the Aircraft (-90°) from Altitudes of 15,000 to 24,999 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

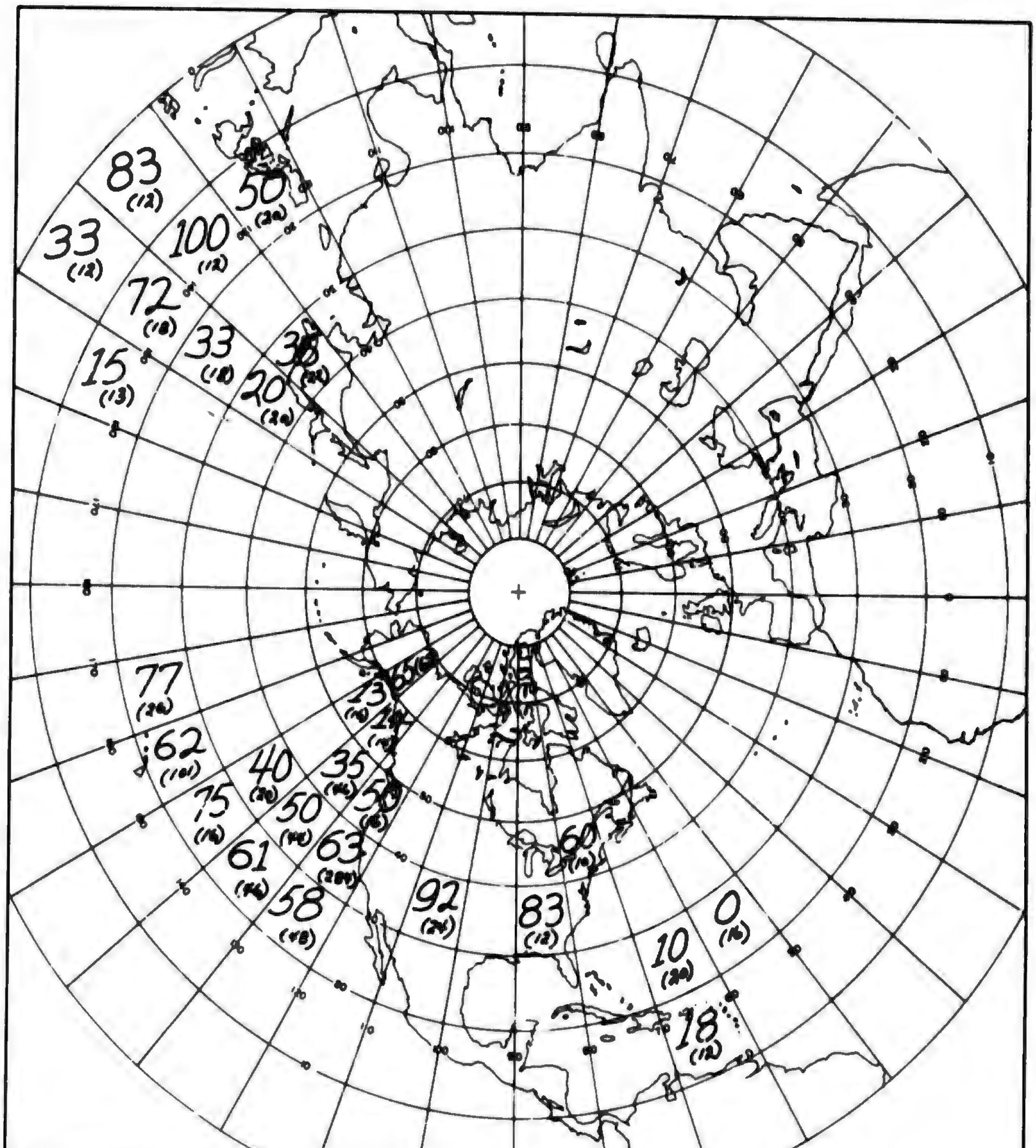

Figure B22. Estimates of the Probability of Seeing the Ground at 30° Below the Horizon (-30°) from Altitudes of 15,000 to 24,999 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

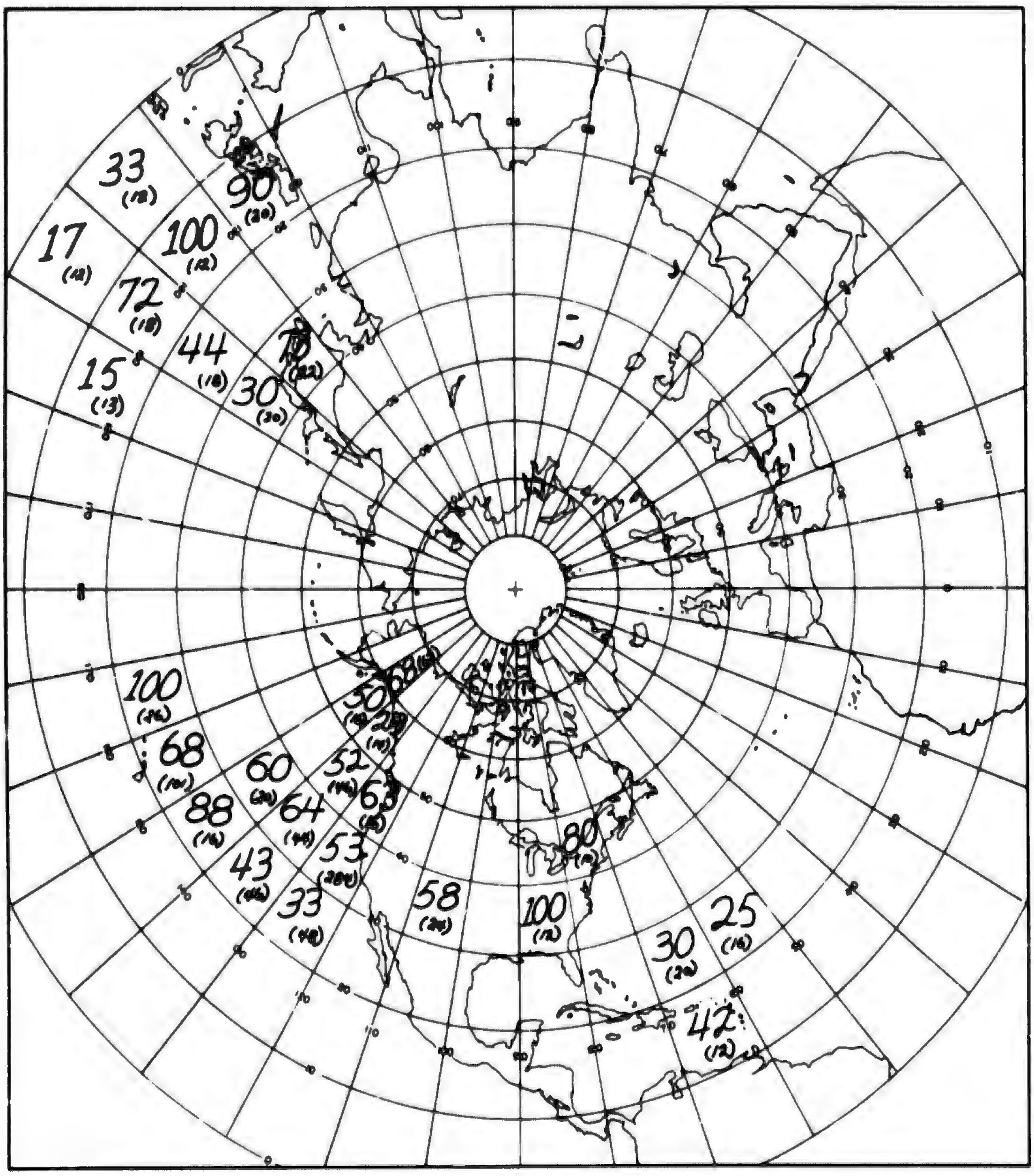

Figure B23. Estimates of the Probability of Seeing the Horizon from Altitudes of 15,000 to 24,999 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

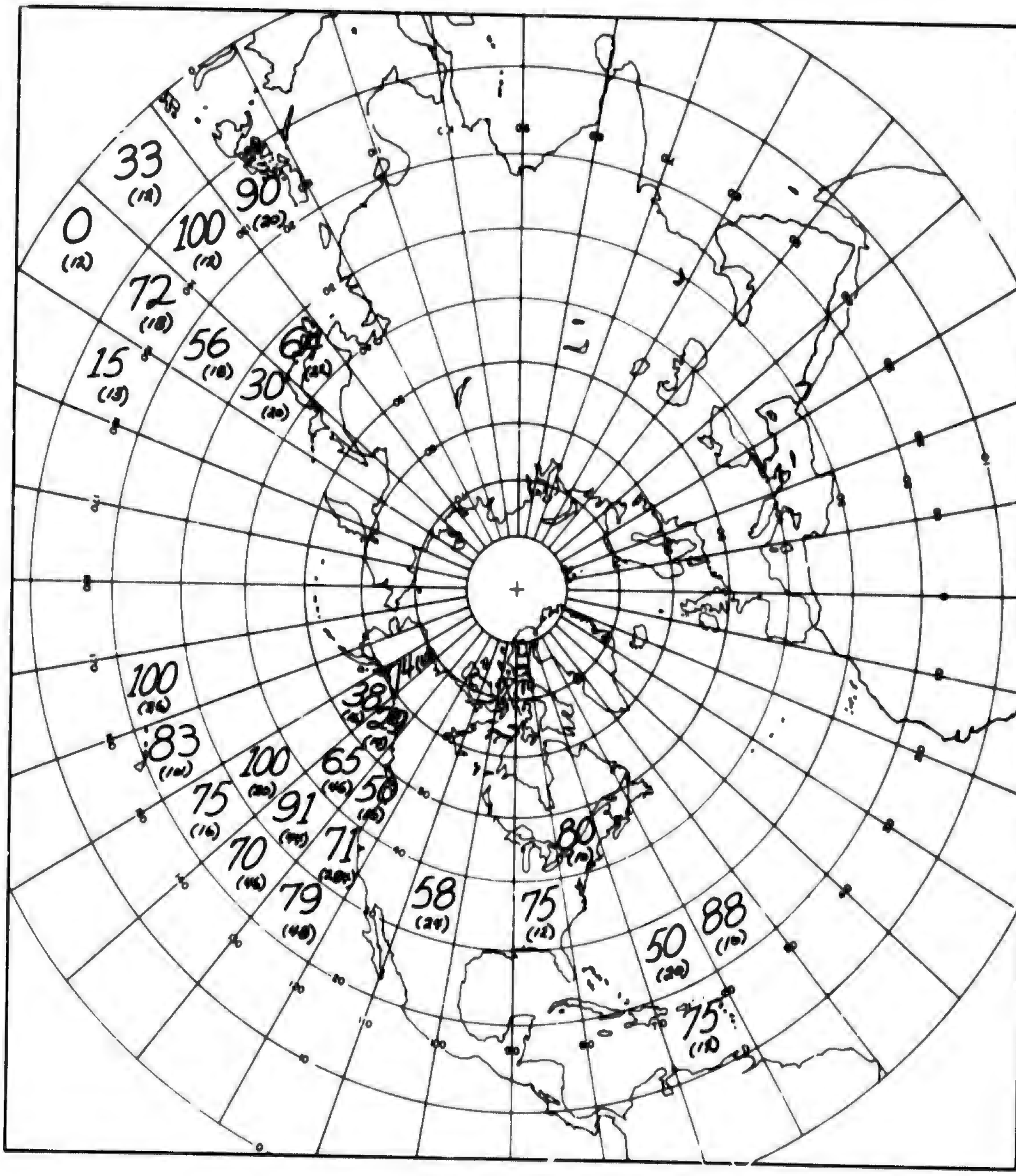

Figure B24. Estimates of the Probability of Seeing Blue Sky at 30° Above the Horizon (+ 30°) from Altitudes of 15,000 to 24,999 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

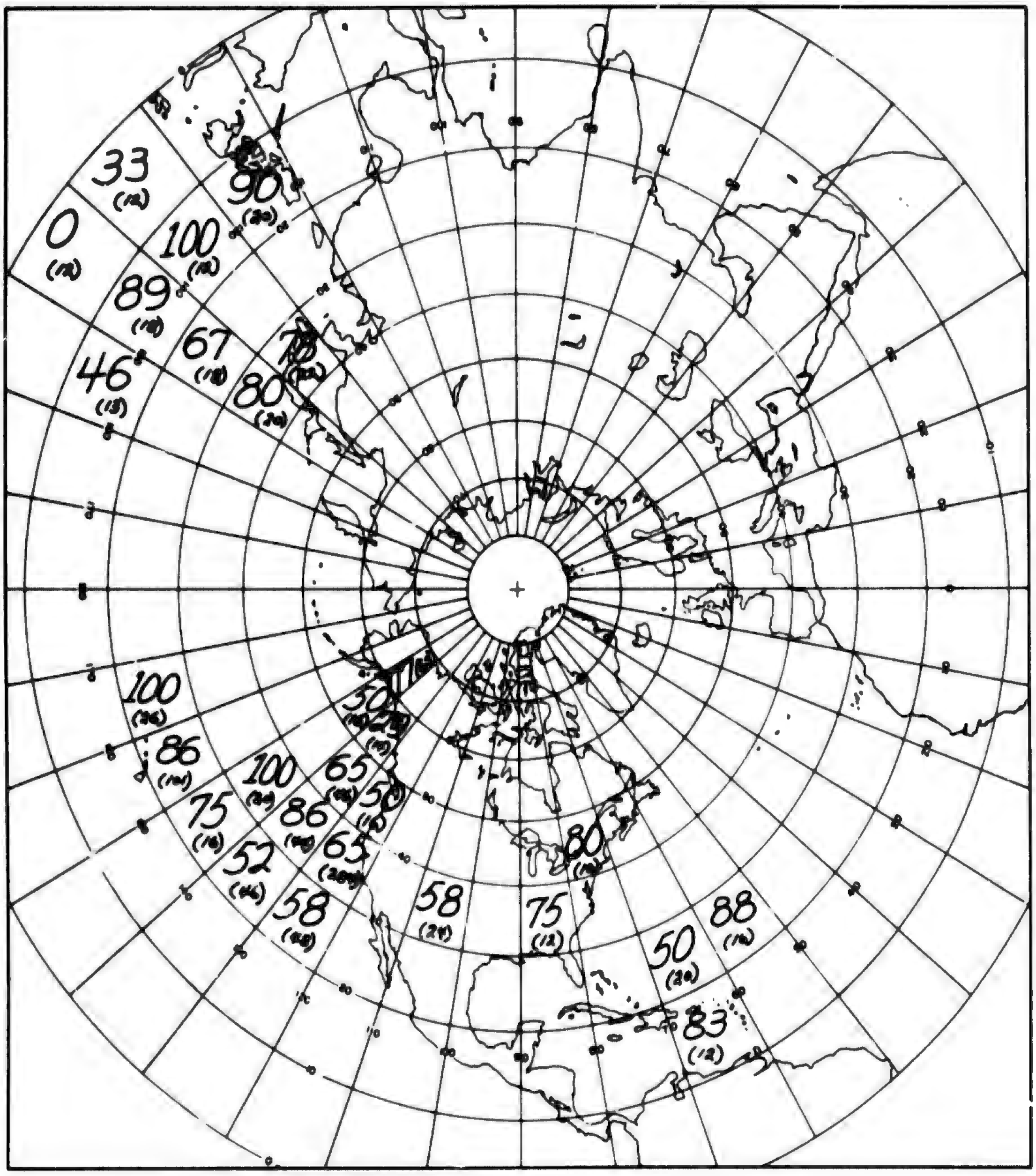

Figure B25. Estimates of the Probability of Seeing Blue Sky at 90° Above the Horizon (+90°) from Altitudes of 15,000 to 24,999 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

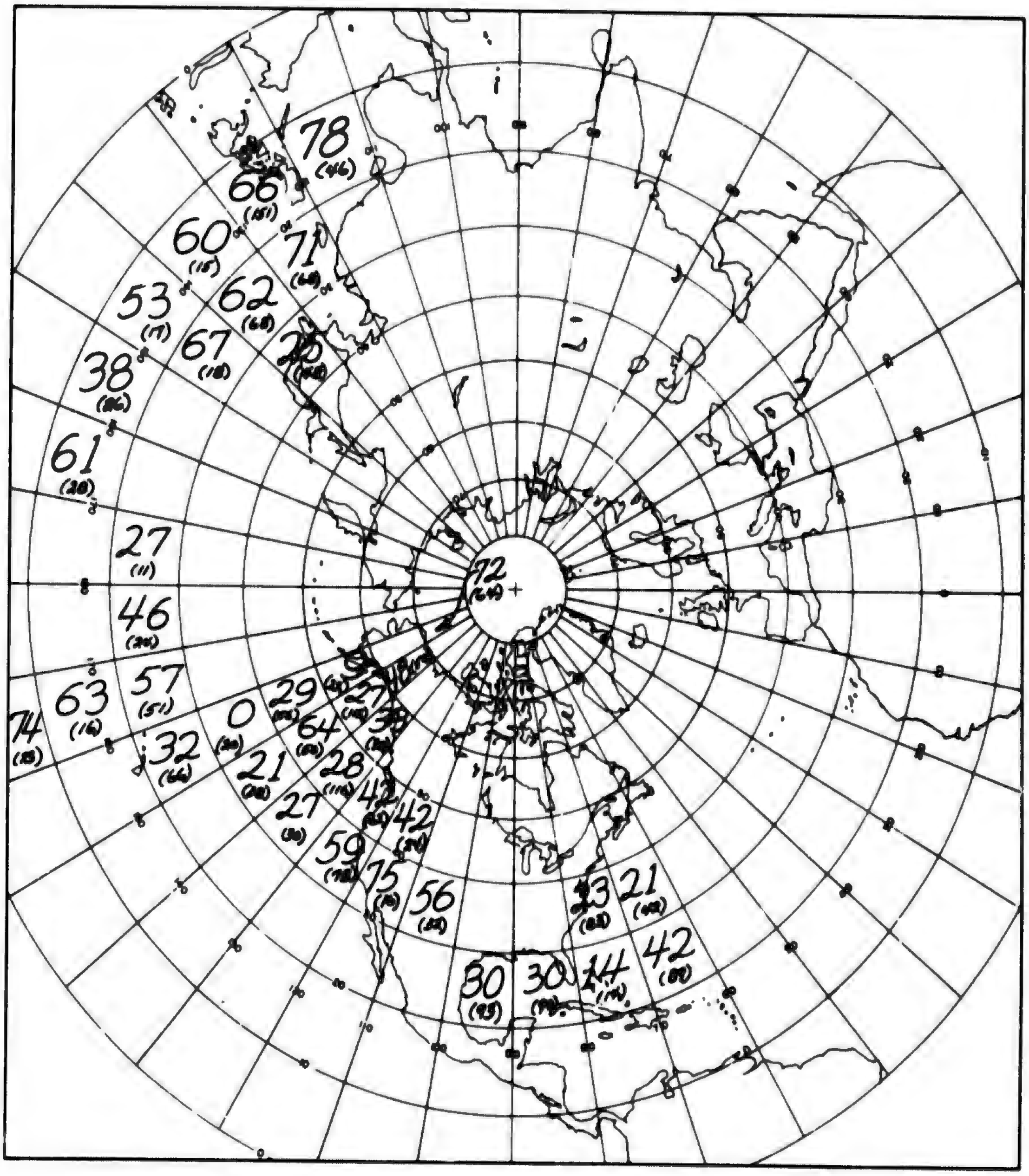

Figure B26. Estimates of the Probability of Seeing the Ground Directly Below the Aircraft (-90°) from Altitudes of 25,000 to 34,999 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

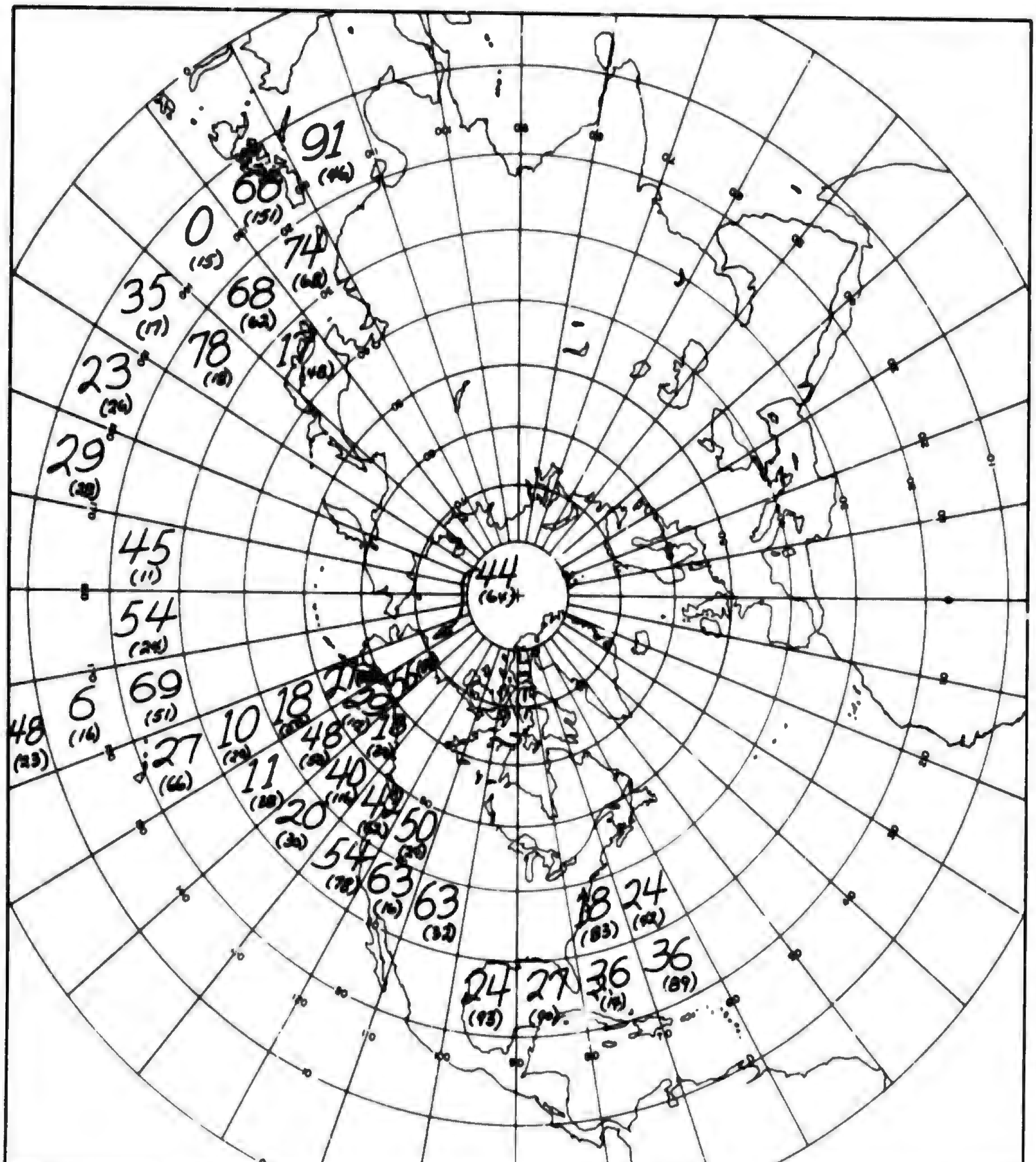

Figure B27. Estimates of the Probability of Seeing the Ground at 30° Below the Horizon (-30°) from Altitudes of 25,000 to 34,999 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

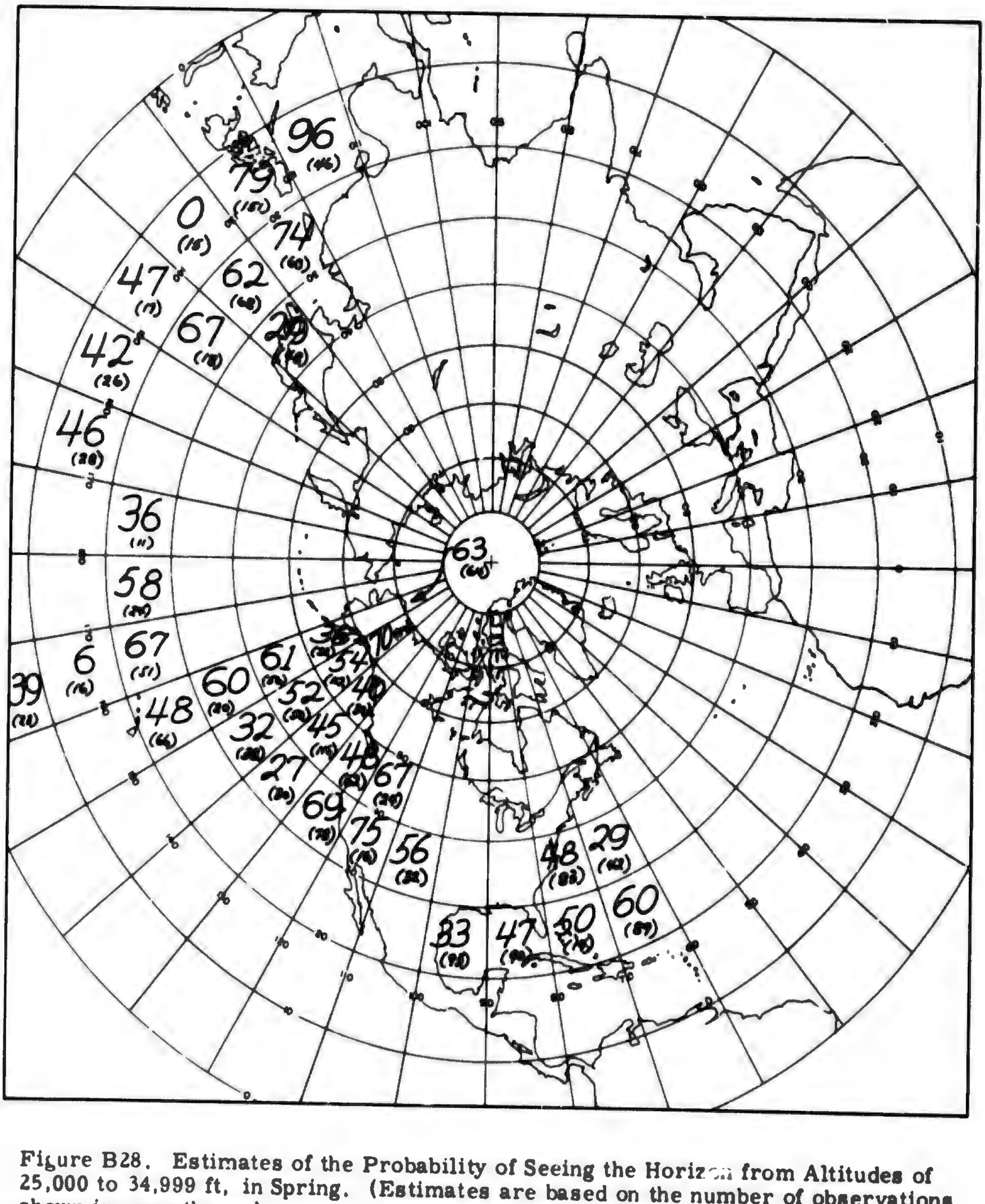

Figure B28. Estimates of the Probability of Seeing the Horizon from Altitudes of 25,000 to 34,999 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

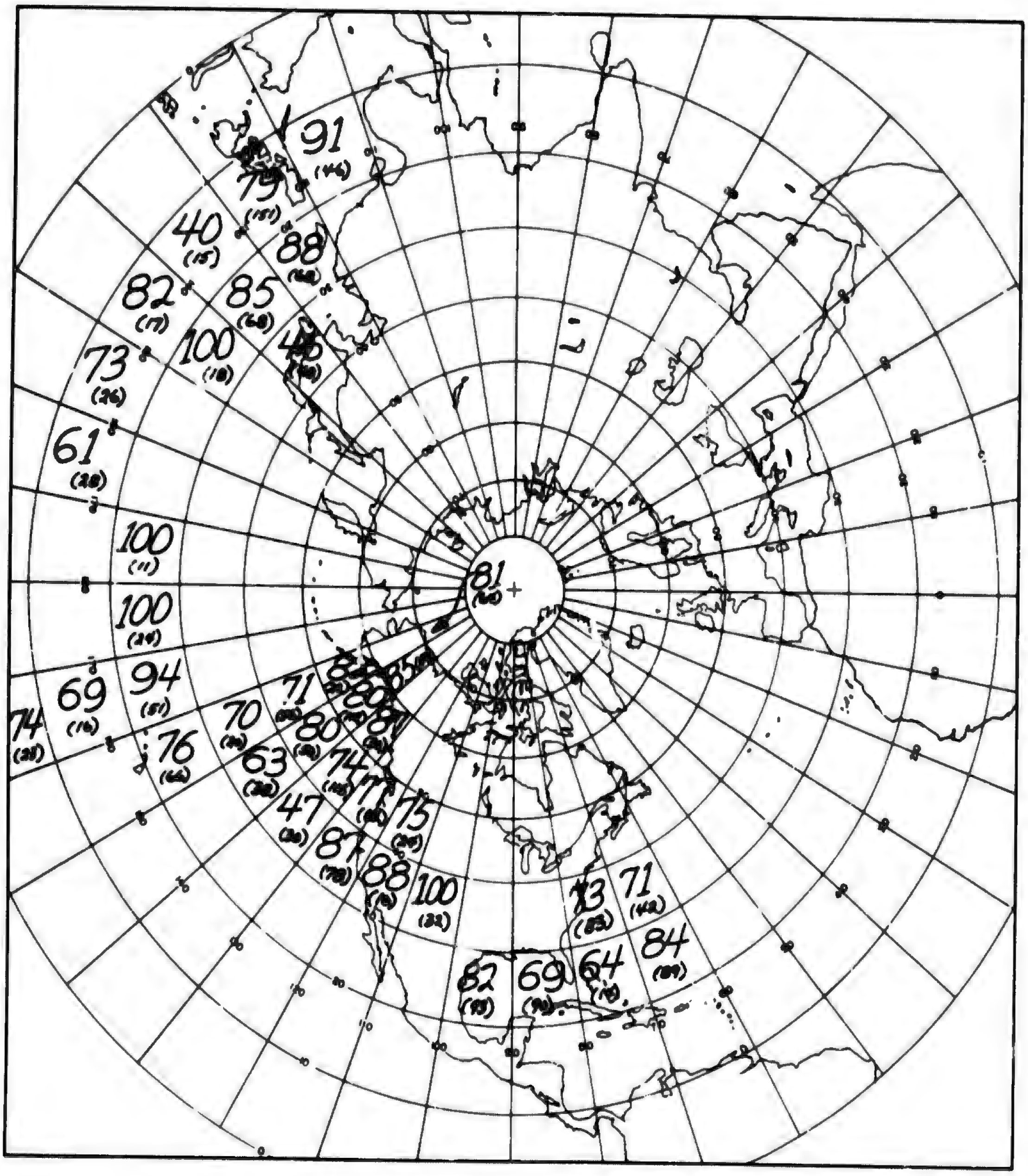

Figure B29. Estimates of the Probability of Seeing Blue Sky at 30° Above the Horizon (+30°) from Altitudes of 25,000 to 34,999 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

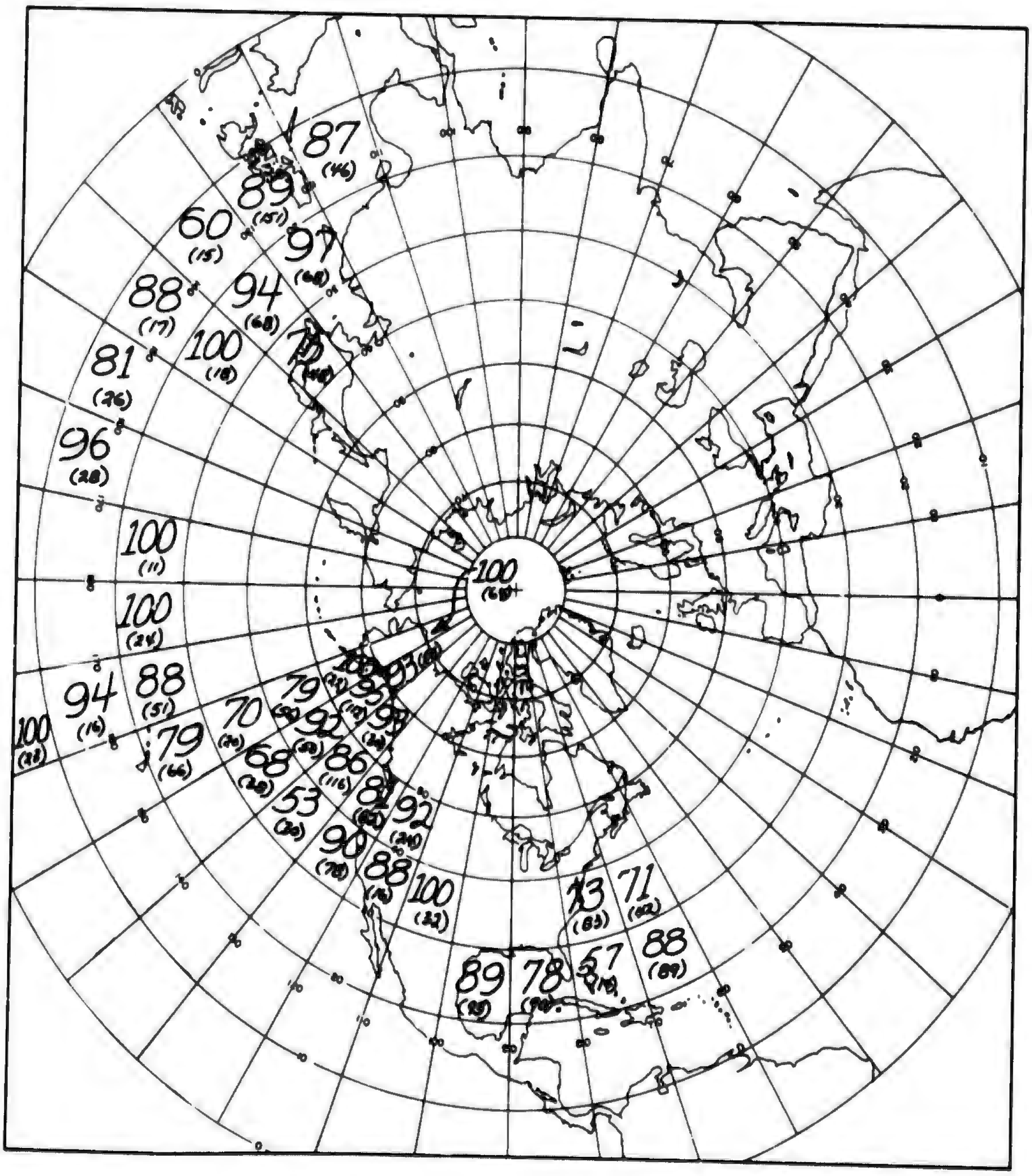

Figure B30. Estimates of the Probability of Seeing Blue Sky at 90° Above the Horizon (+ 90°) from Altitudes of 25,000 to 34,999 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

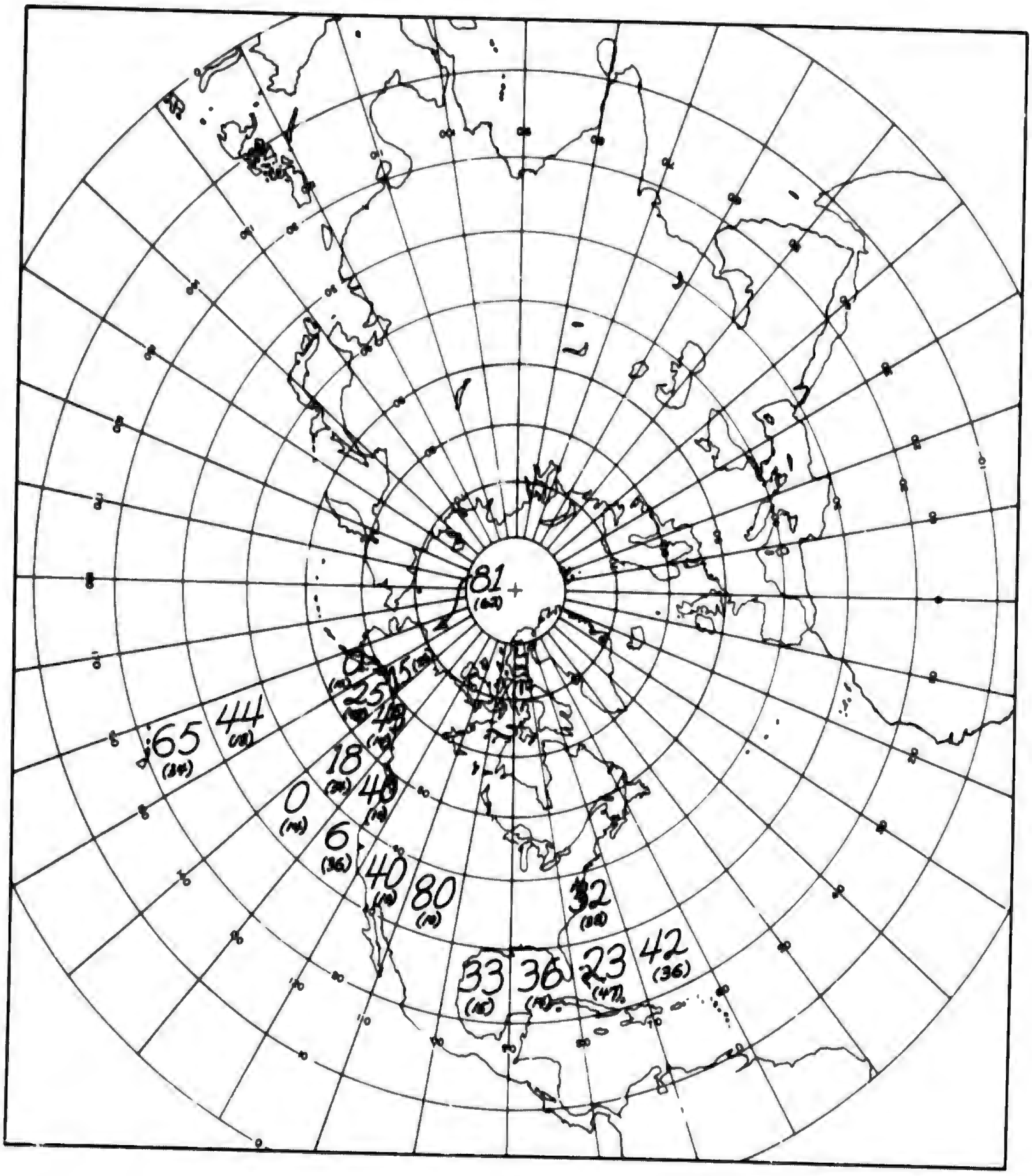

Figure B31. Estimates of the Probability of Seeing the Ground Directly Below the Aircraft (-90°) from Altitudes of 35,000 to 44,999 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

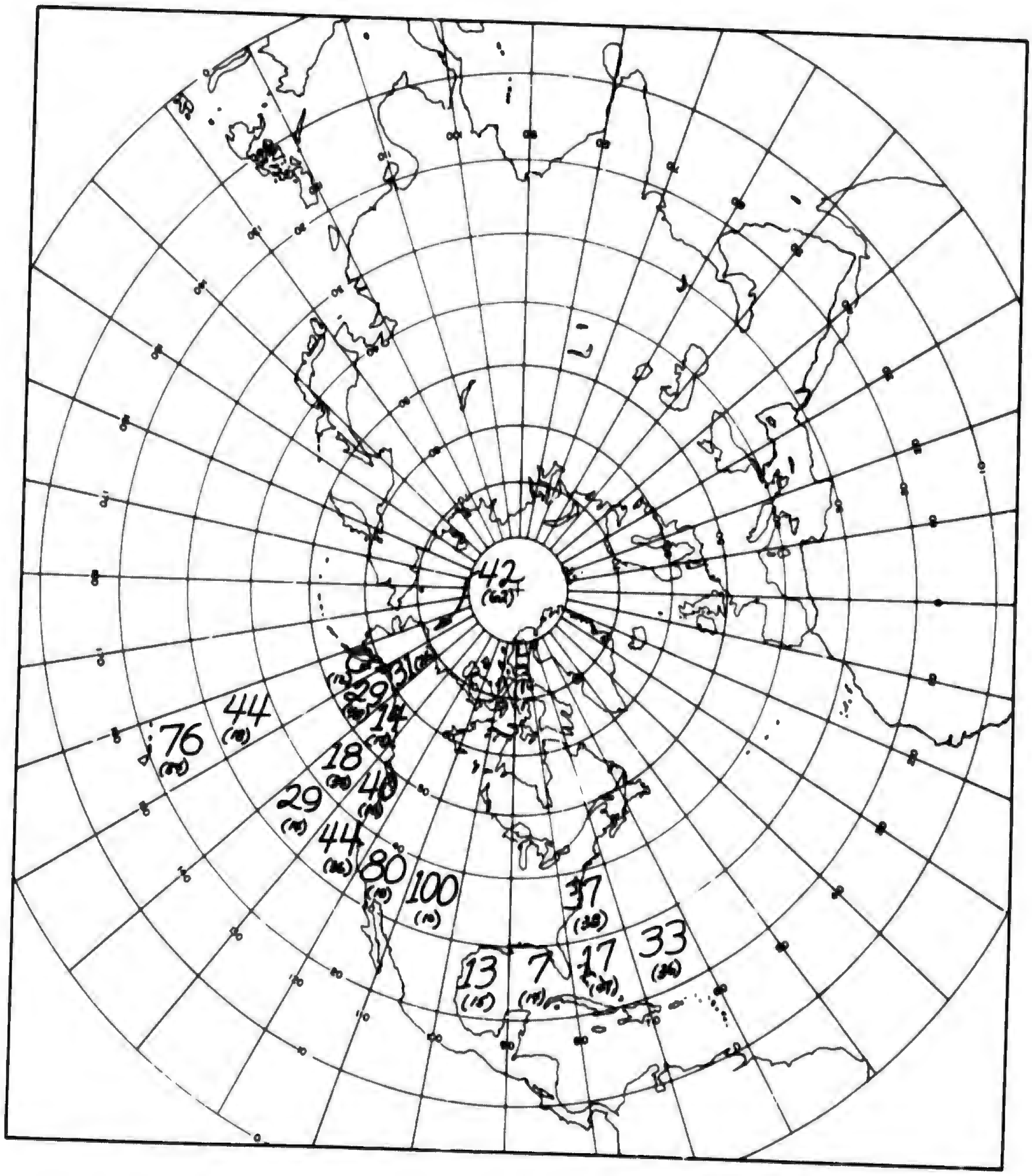

Figure B32. Estimates of the Probability of Seeing the Ground at 30° Below the Horizon (-30°) from Altitudes of 35,000 to 44,999 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

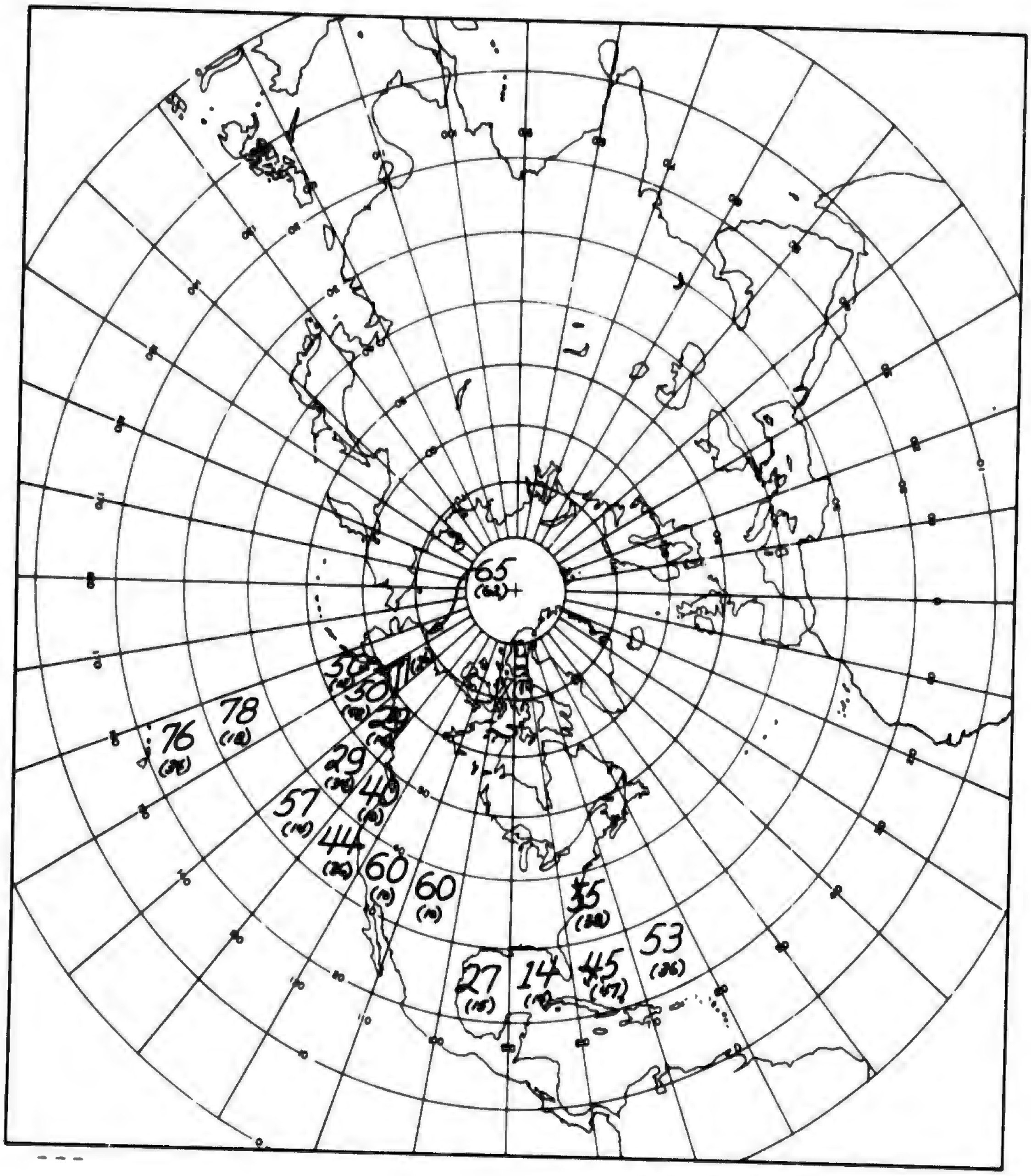

Figure B33. Estimates of the Probability of Seeing the Horizon from Altitudes of 35,000 to 44,999 ft, in Spring. (Estimates are based on the number of ob: ervations shown in parentheses)

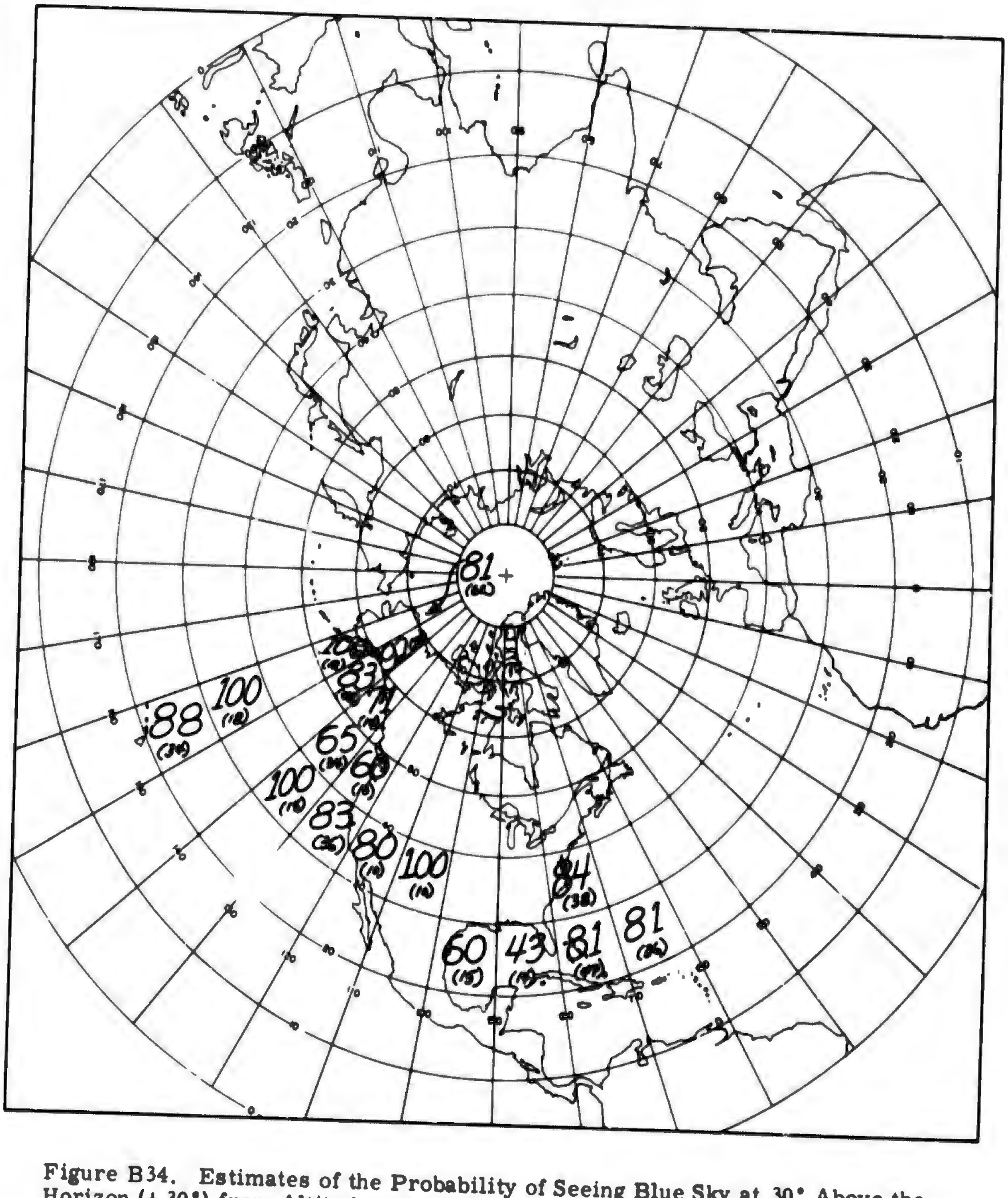

Figure B34. Estimates of the Probability of Seeing Blue Sky at 30° Above the Horizon (+ 30°) from Altitudes of 35,000 to 44,999 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

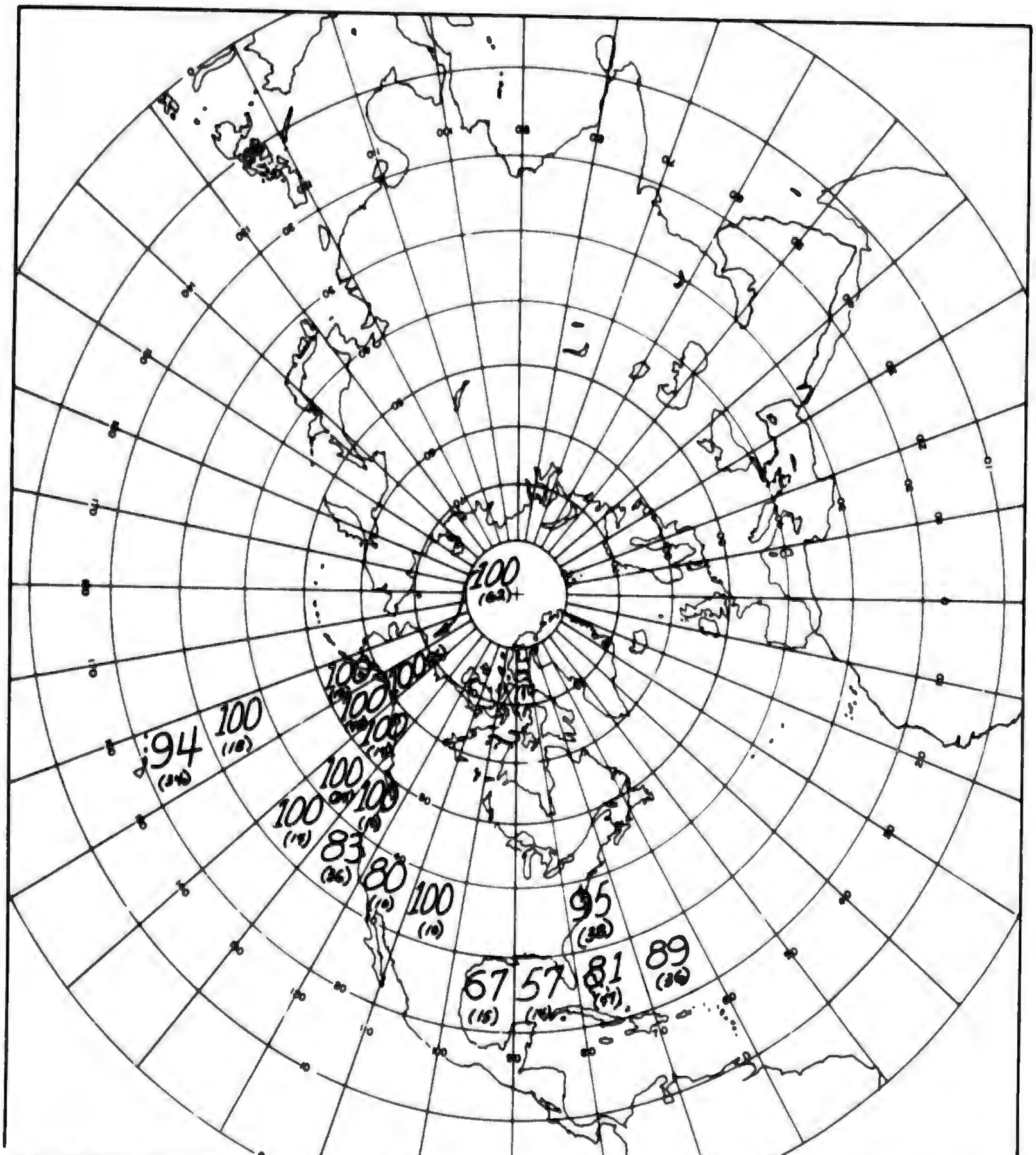

Figure B35. Estimates of the Probability of Seeing Blue Sky at 90° Above the Horizon (+ 90°) from Altitudes of 35,000 to 44,999 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

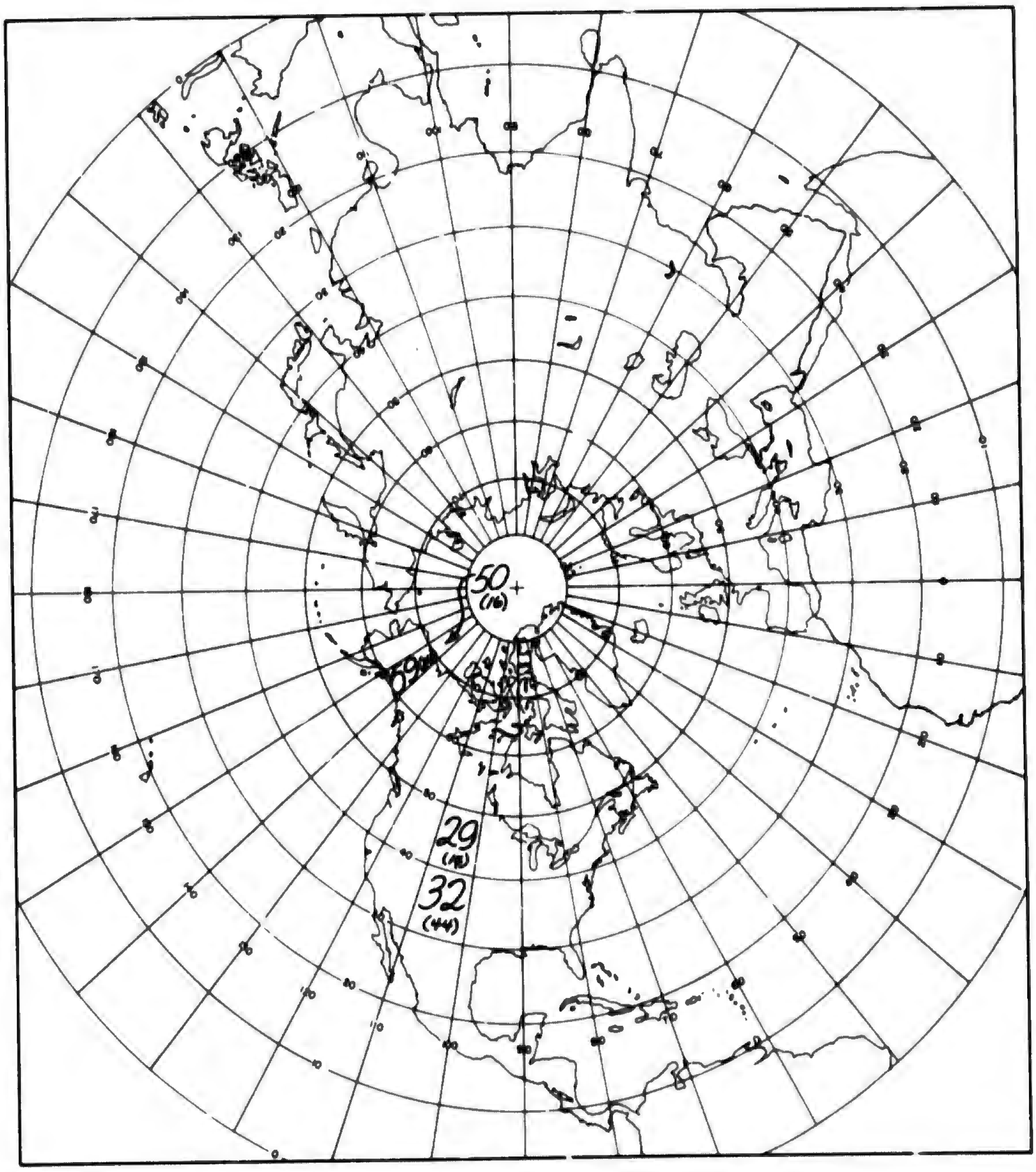

Figure B36. Estimates of the Probability of Seeing the Ground Directly Below the Aircraft (-90°) from Altitudes Above 45,000 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

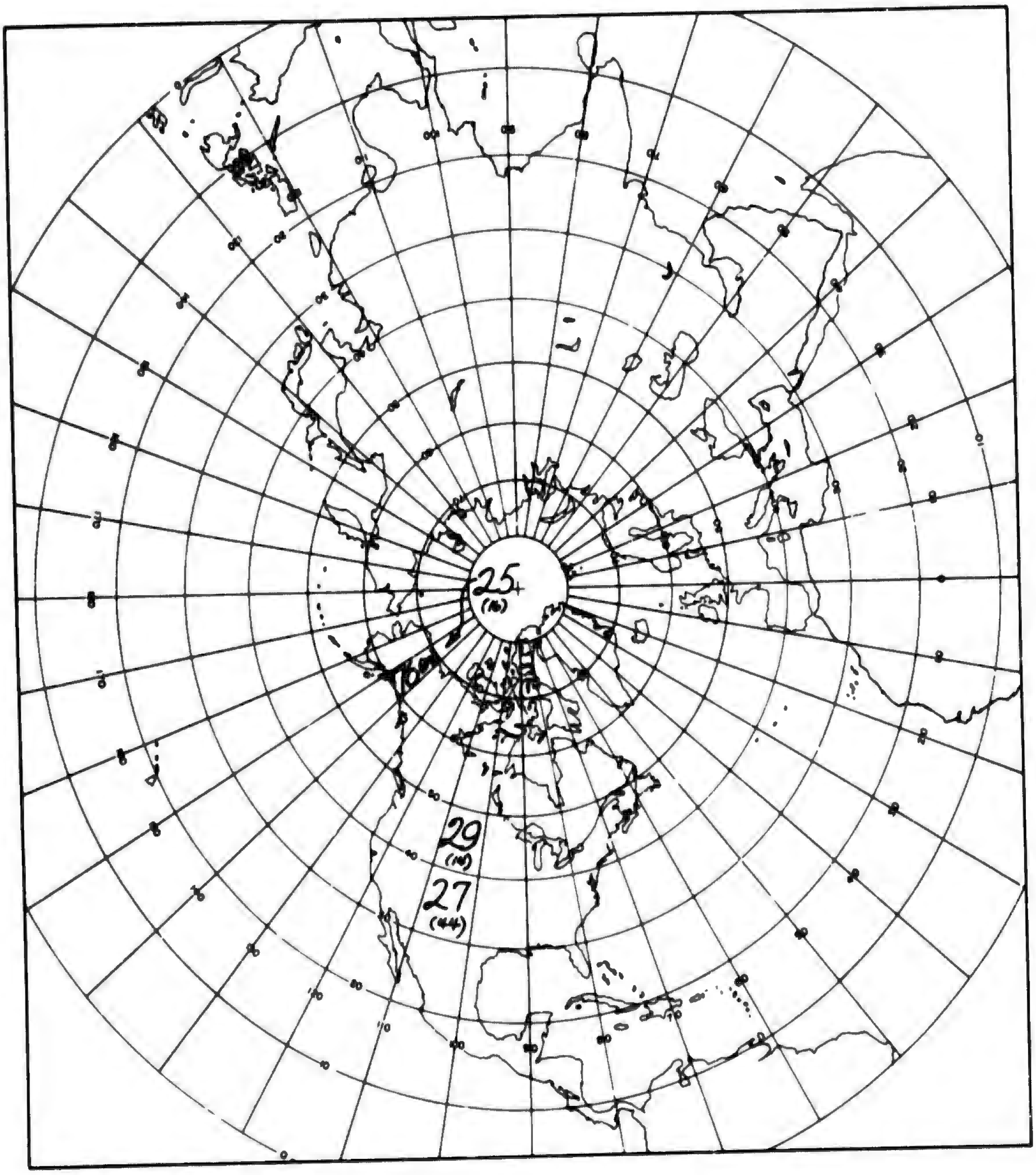

Figure B37. Estimates of the Probability of Seeing the Ground at 30° Below the Horizon (-30°) from Altitudes Above 45,000 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

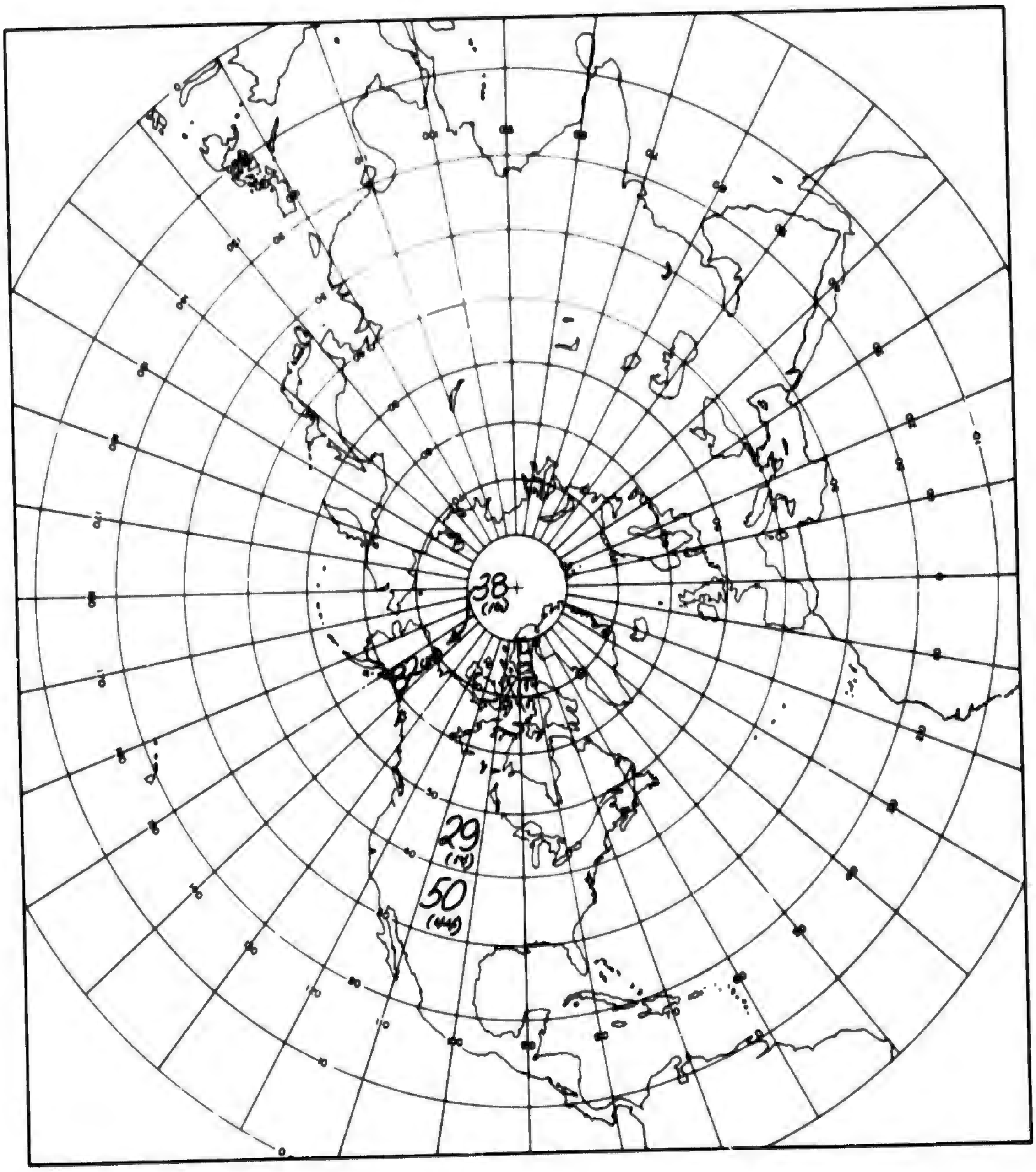

Figure B 38. Estimates of the Probability of Seeing the Horizon from Altitudes Above 45,000 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

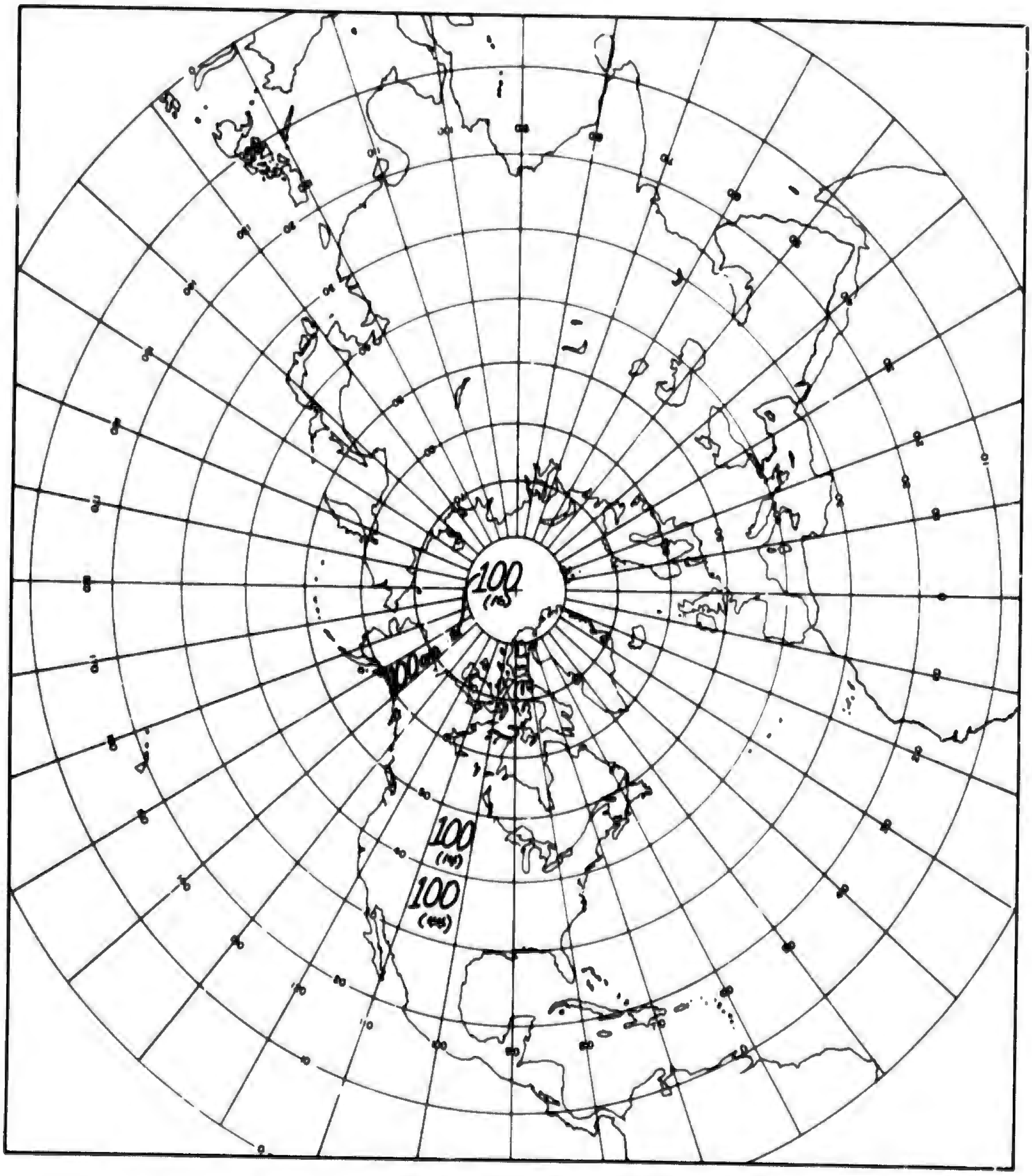

Figure B39. Estimates of the Probability of Seeing Blue Sky at 30° Above the Horizon (+ 30°) from Altitudes Above 45, 000 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

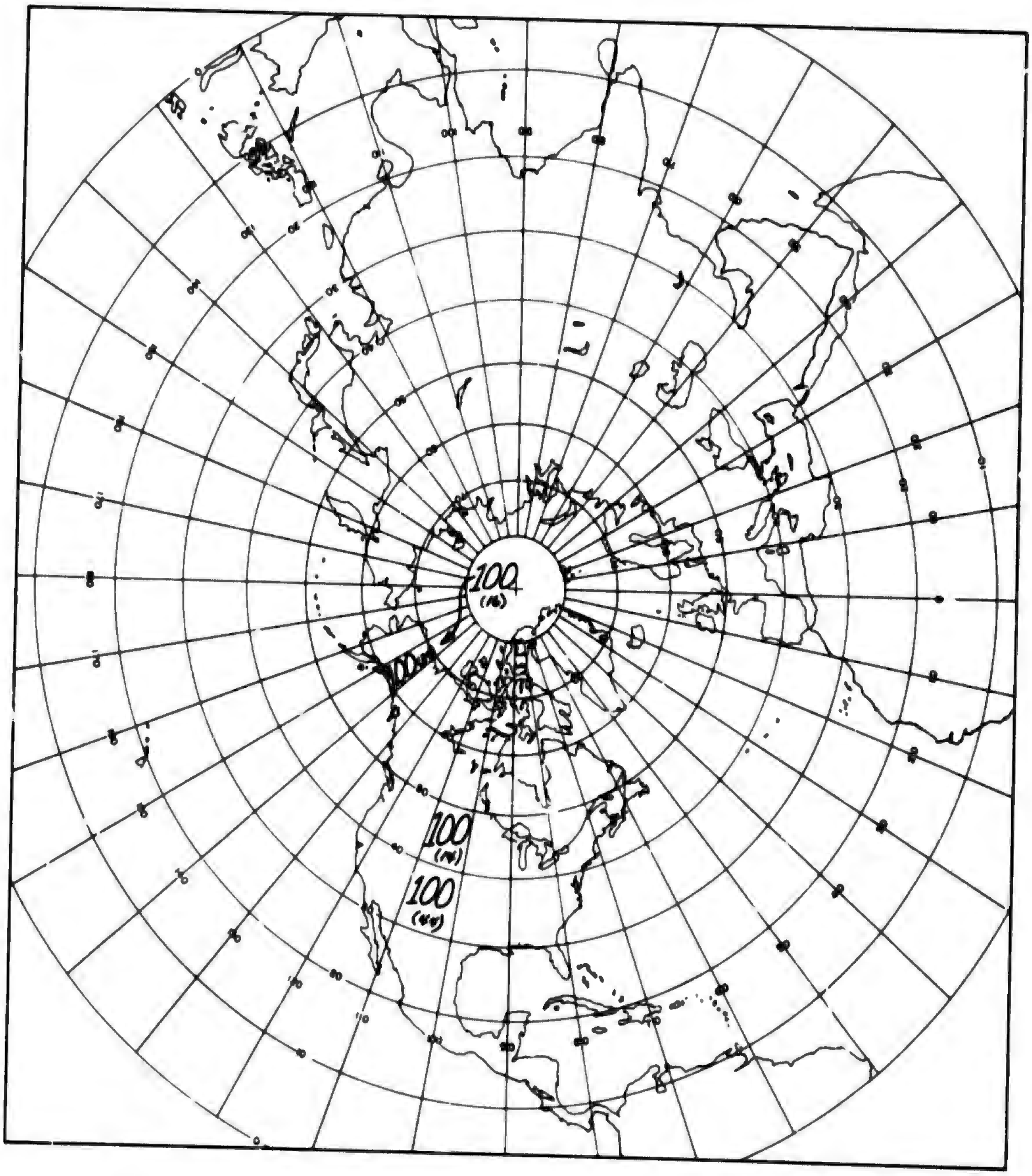

Figure B40. Estimates of the Probability of Seeing Blue Sky at 90° Above the Horizon (+ 90°) from Altitudes Above 45,000 ft, in Spring. (Estimates are based on the number of observations shown in parentheses)

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Appendix C

Summer Estimates of Probability of a Clear Line-of-Sight

In this appendix are given Northern Hemisphere maps of estimates of the probability of a clear line-of-sight for summer (June, July, August) at five selected angles of vision: (a) ground at 90 degrees below the horizon (-90°); (b) ground at 30 degrees below the horizon (-30°); (c) horizon; (d) sky at 30 degrees above the horizon (+30°); (e) sky at 90 degrees above the horizon (+90°), and for eight altitude layers: below 1800 ft; 1801 to 3600 ft; 3601 to 7400 ft; 7401 to 14,999 ft; 15,000 to 24,999 ft; 25,000 to 34,999 ft; 35,000 to 44,999 ft; and above 45,000 ft. The Northern Hemisphere is divided into 10° latitude-longitude sectors. The values given in these sectors are estimates of the probability of a clear line-of-sight. Values in parentheses indicate the number of observations taken in that sector. Probabilities were not computed for sectors that reported less than 10 observations.

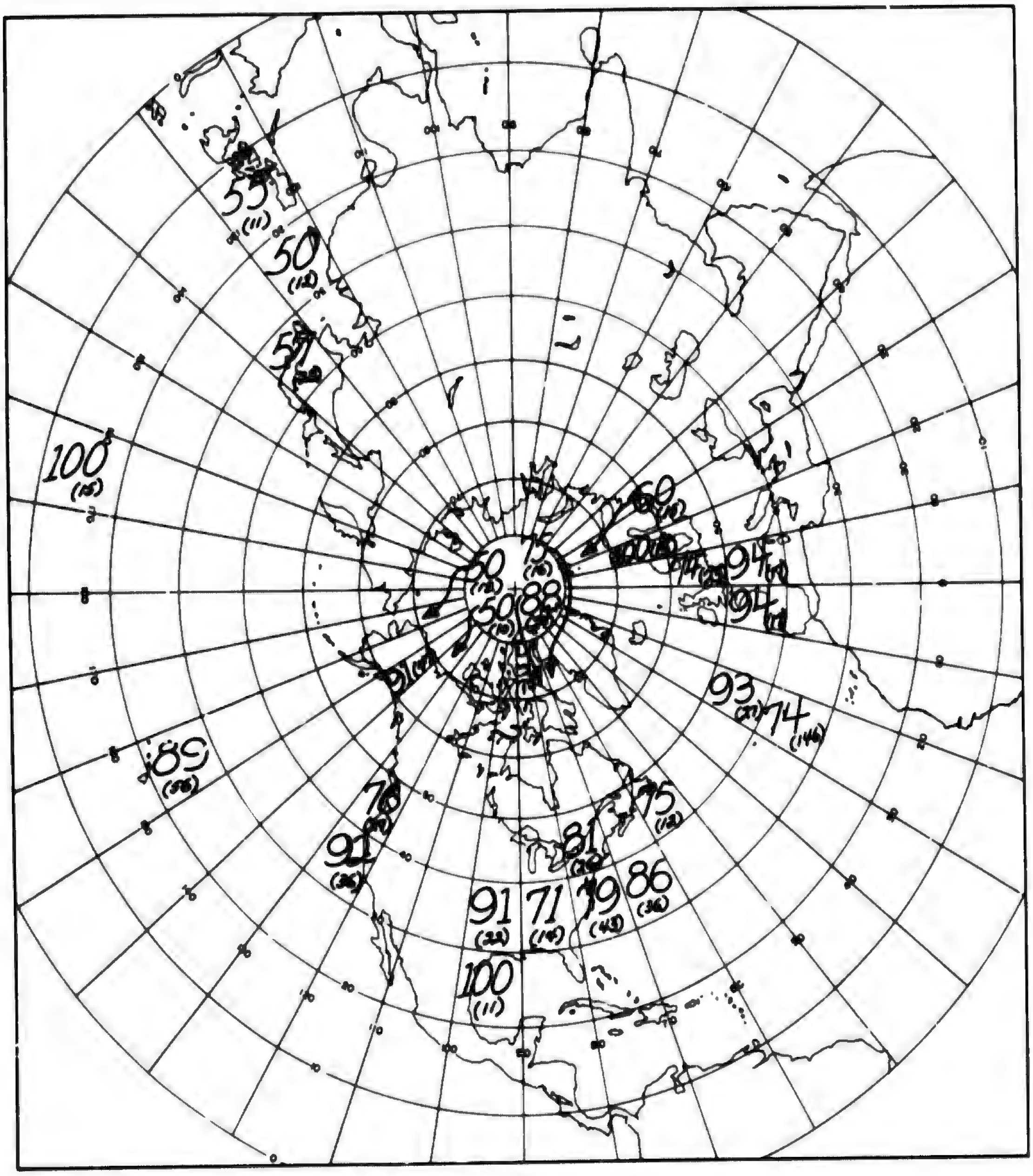

Figure C1. Estimates of the Probability of Seeing the Ground Directly Below the Aircraft (-90°) from Altitudes up to 1800 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

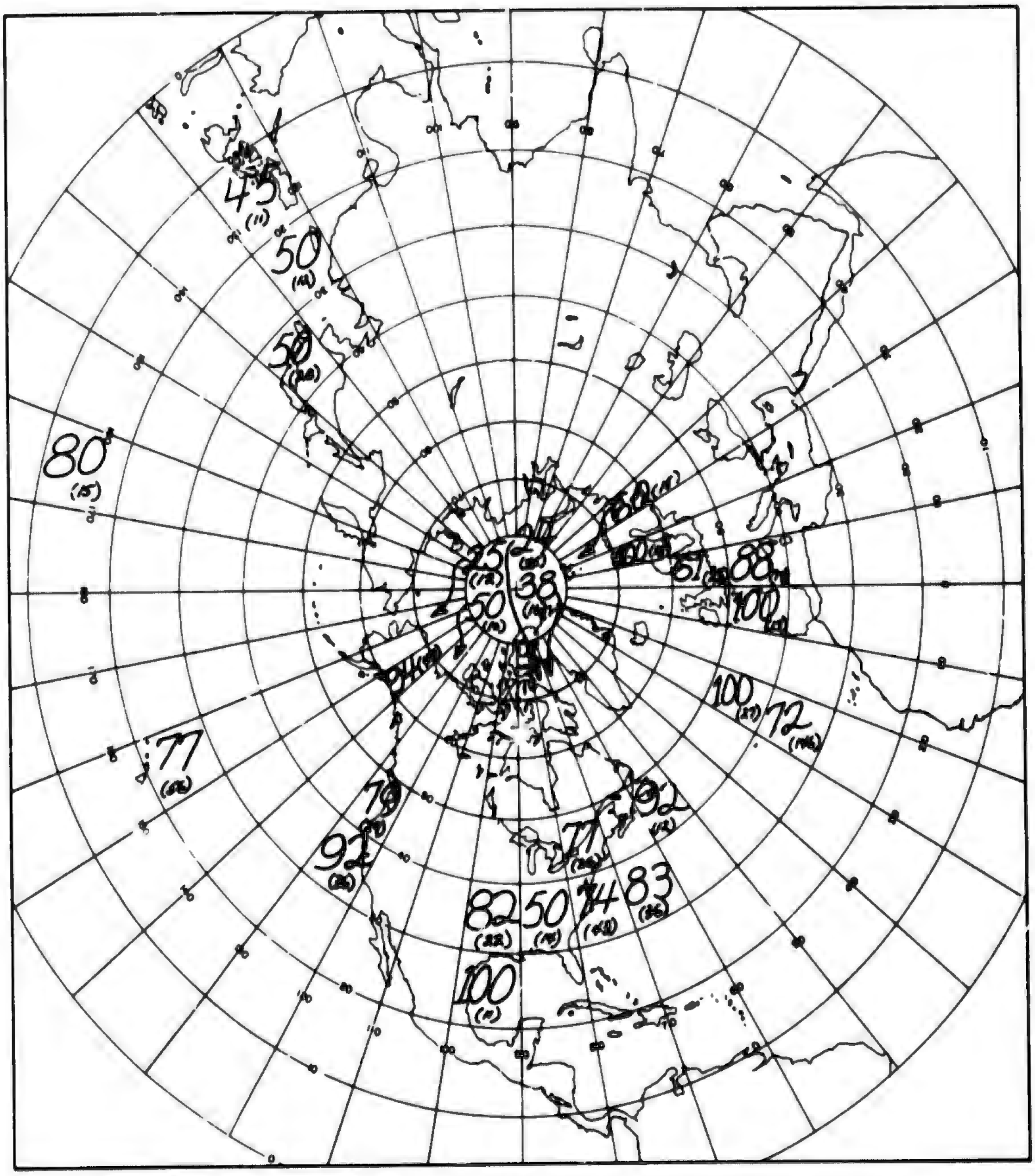

Figure C2. Estimates of the Probability of Seeing the Ground at 30° Below the Horizon (-30°) from Altitudes up to 1800 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

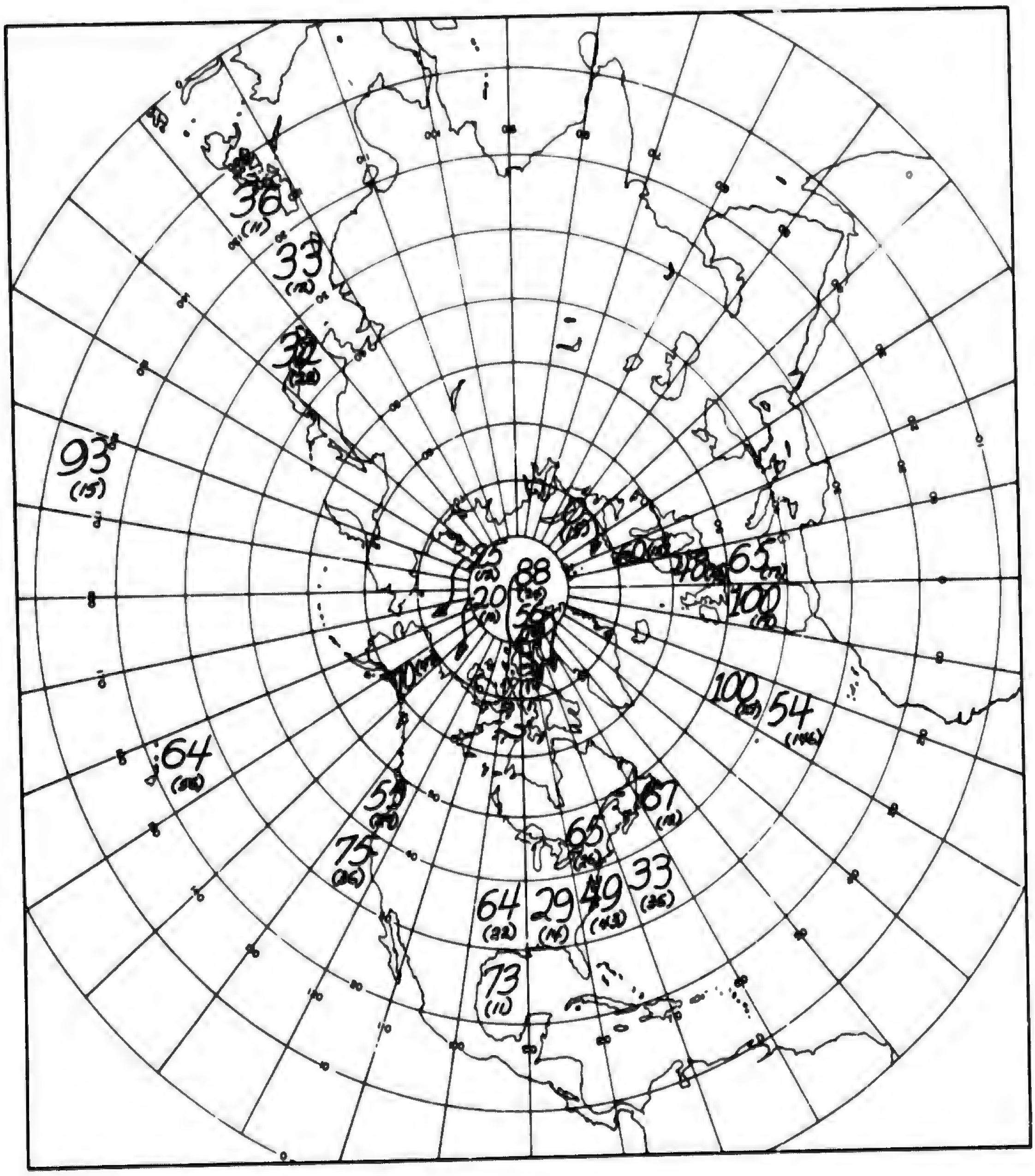

Figure C3. Estimates of the Probability of Seeing the Horizon from Altitudes up to 1800 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

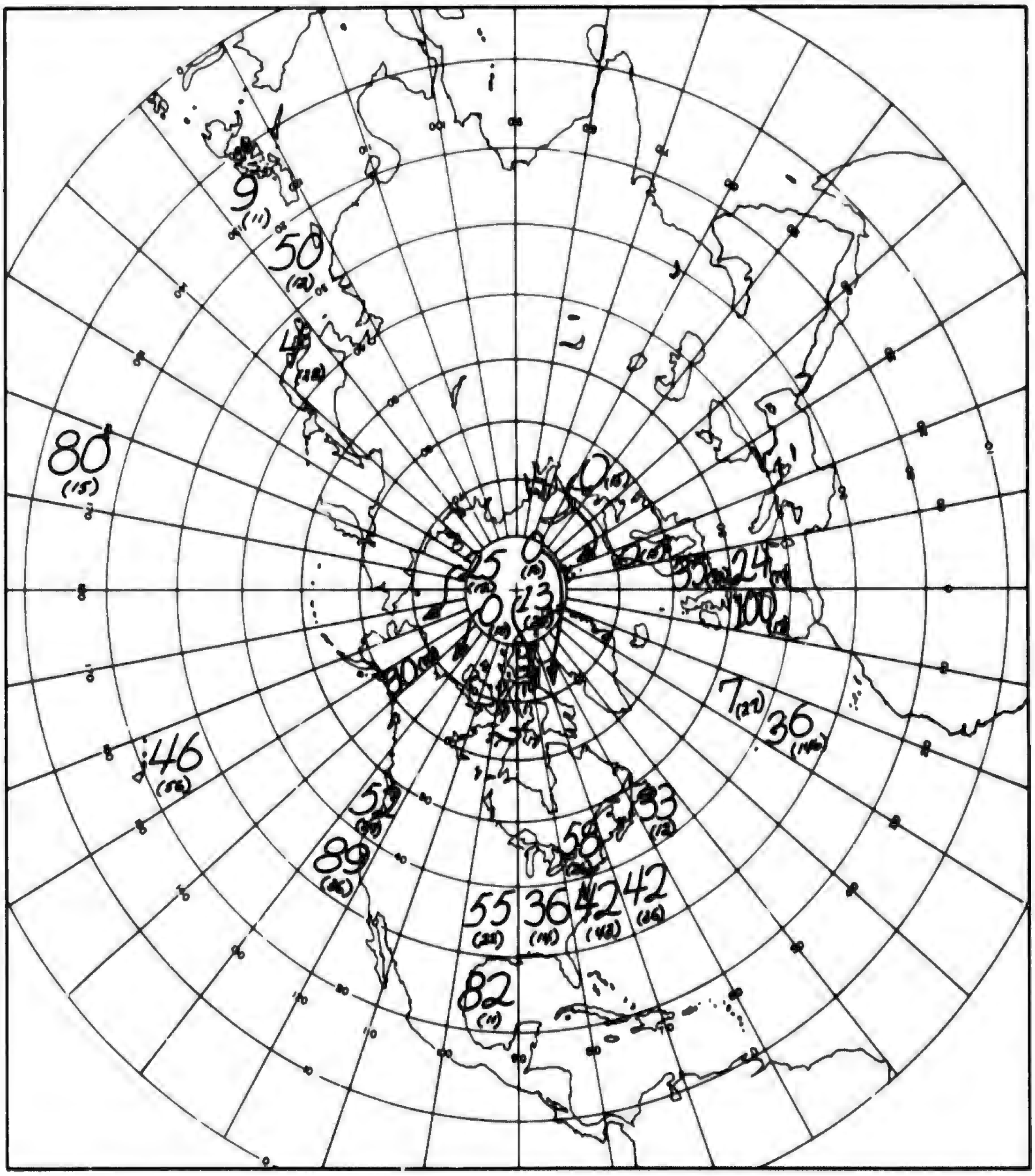

Figure C4. Estimates of the Probability of Seeing Blue Sky at 30° Above the Horizon (+ 30°) from Altitudes up to 1800 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

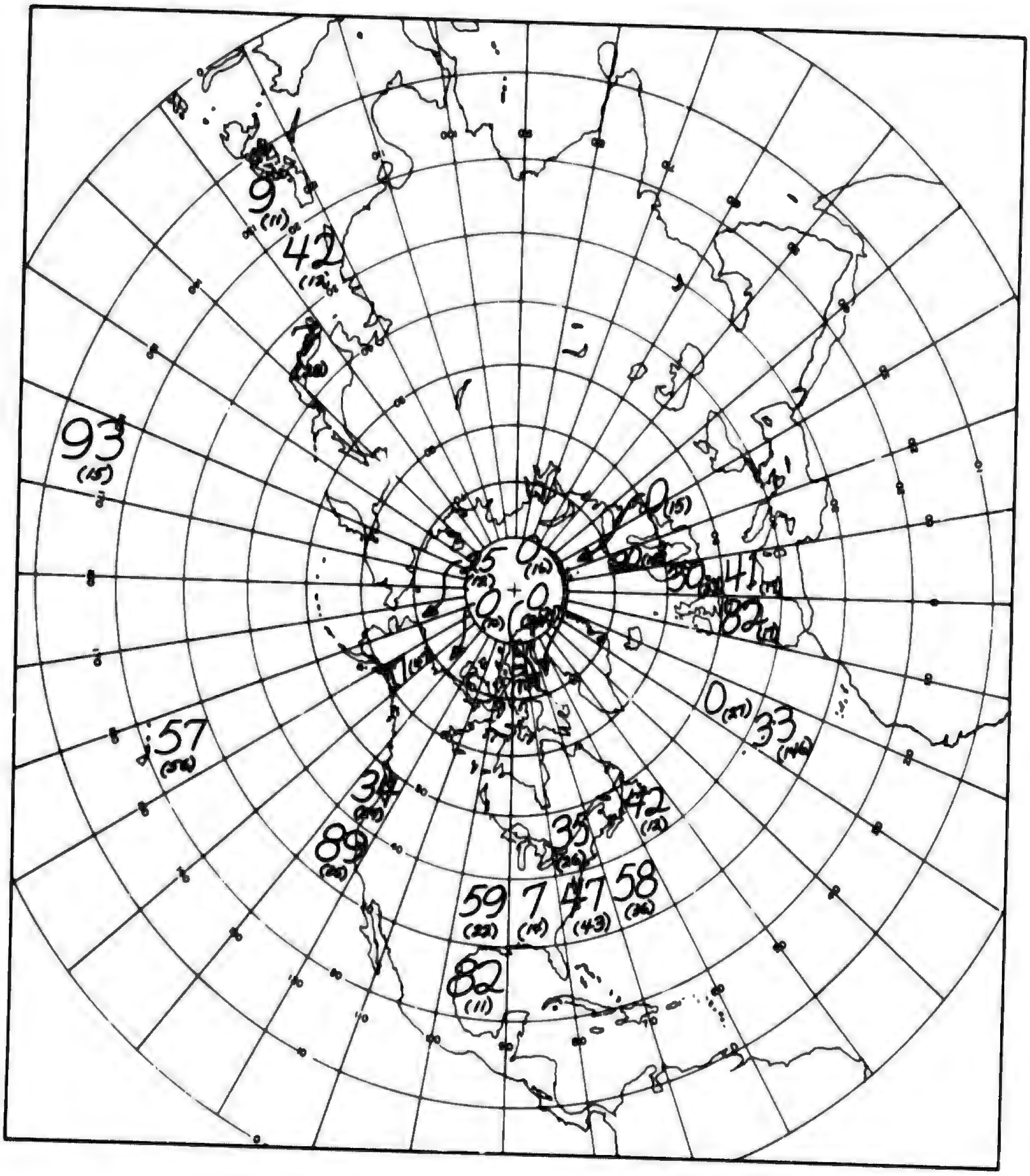

Figure C5. Estimates of the Probability of Seeing Blue Sky at 90° Above the Horizon (+ 90°) from Altitudes up to 1800 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

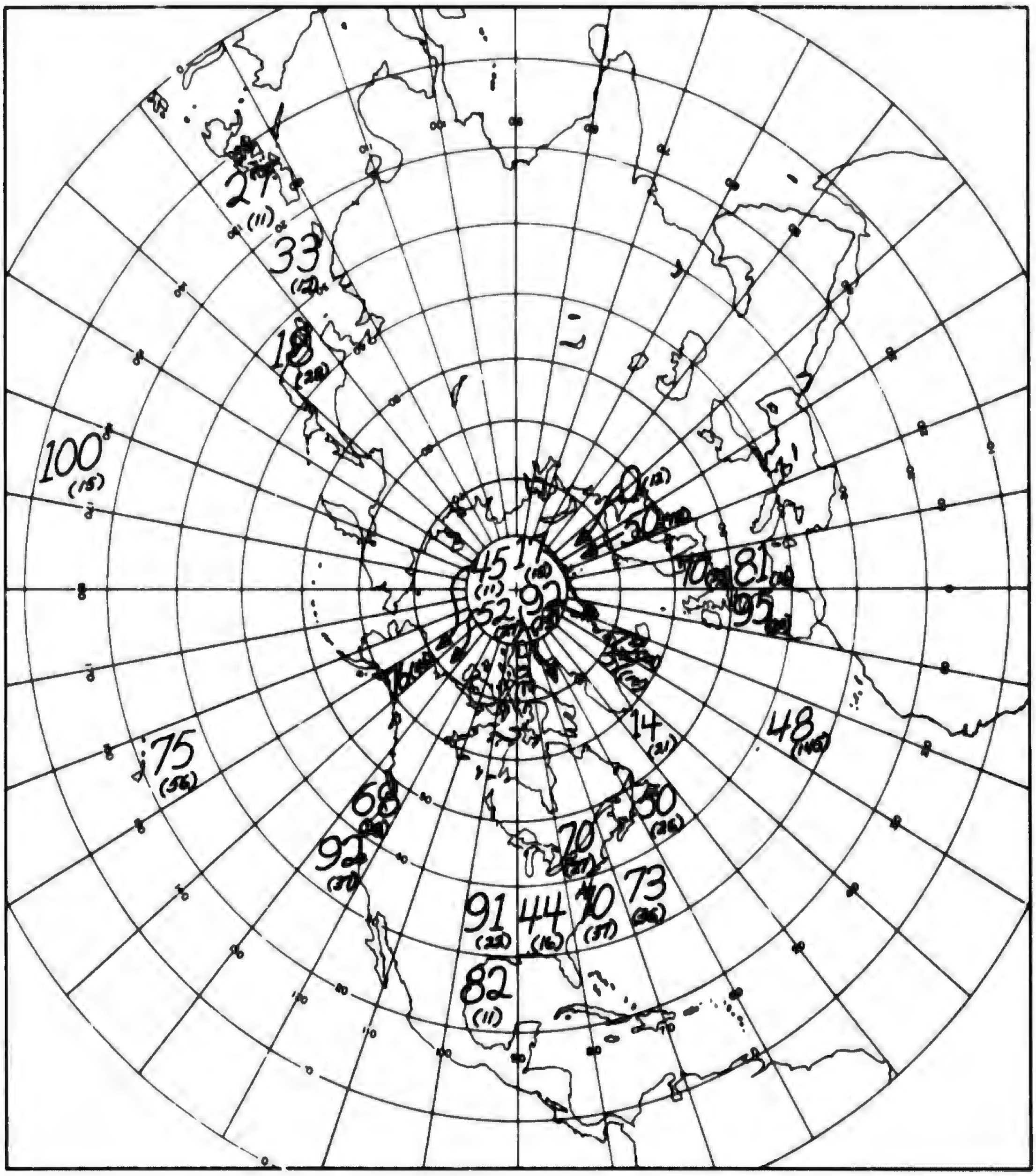

Figure C6. Estimates of the Probability of Seeing the Ground Directly Below the Aircraft (-90°) from Altitudes of 1801 to 3600 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

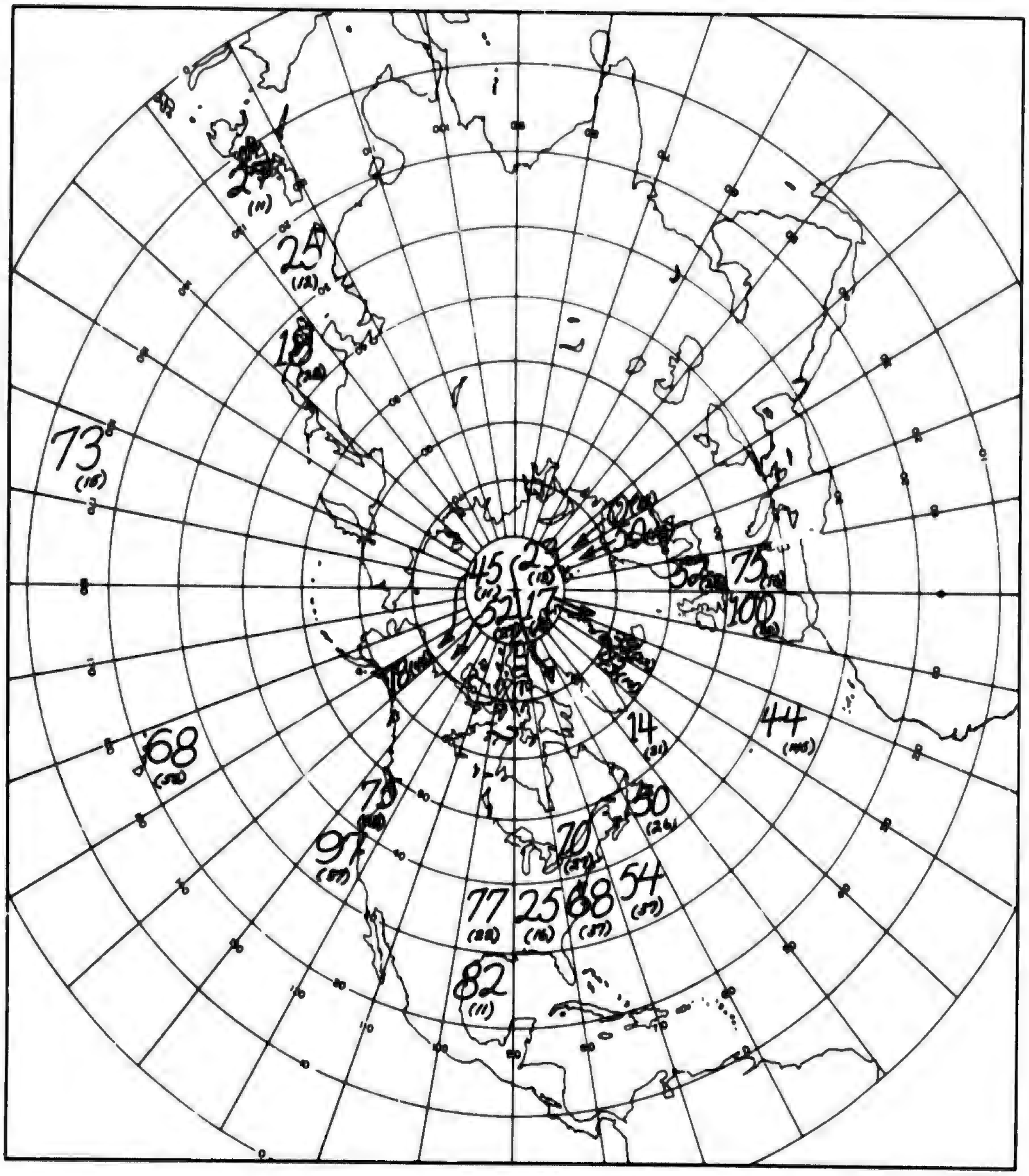

Figure C7. Estimates of the Probability of Seeing the Ground at 30° Below the Horizon (-30°) from Altitudes of 1801 to 3600 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

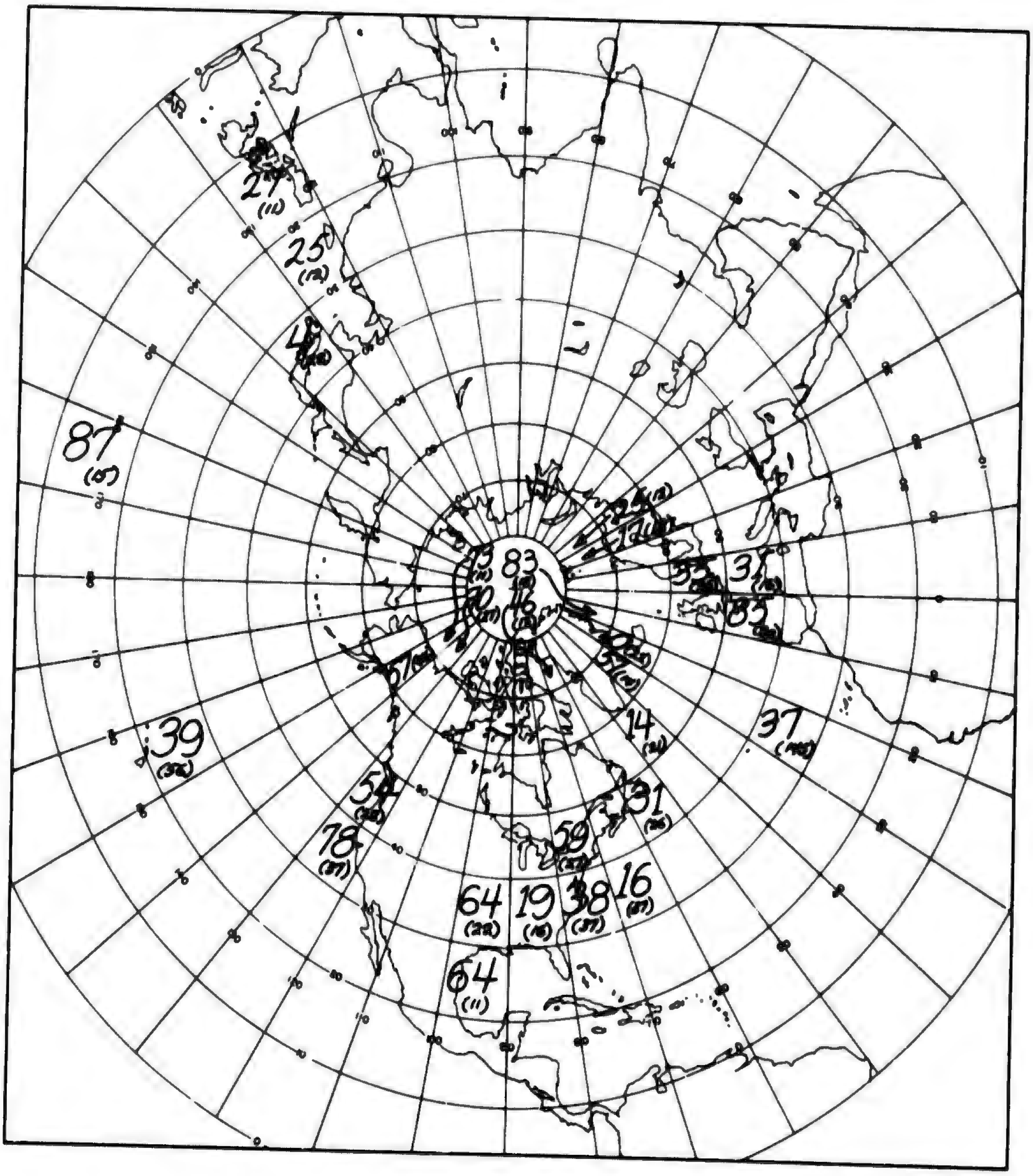

Figure C8. Estimates of the Probability of Seeing the Horizon Between Altitudes of 1801 to 3600 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

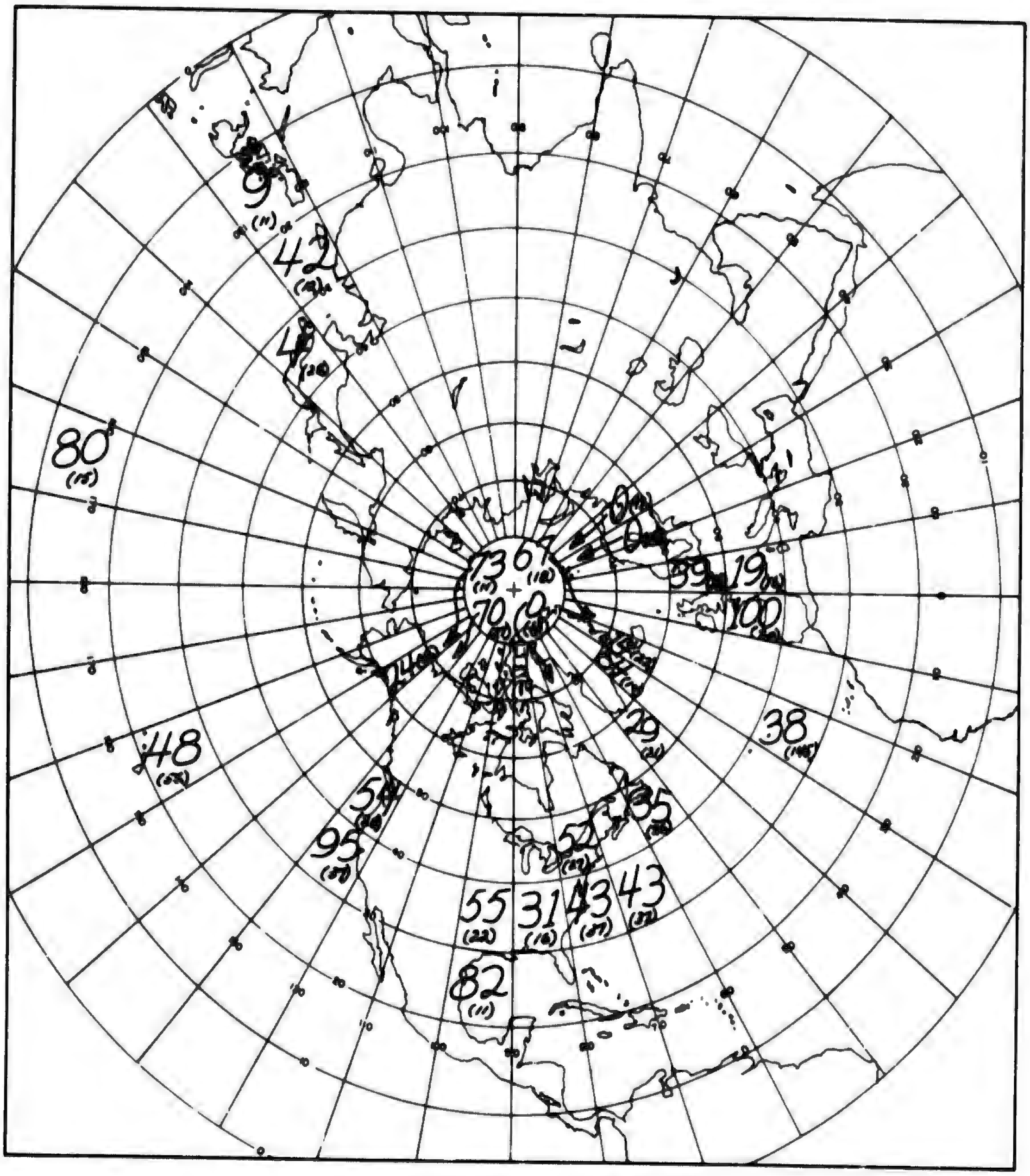

Figure C9. Estimates of the Probability of Seeing Blue Sky at 30° Above the Horizon (+ 30°) Between Altitudes of 1801 to 3600 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

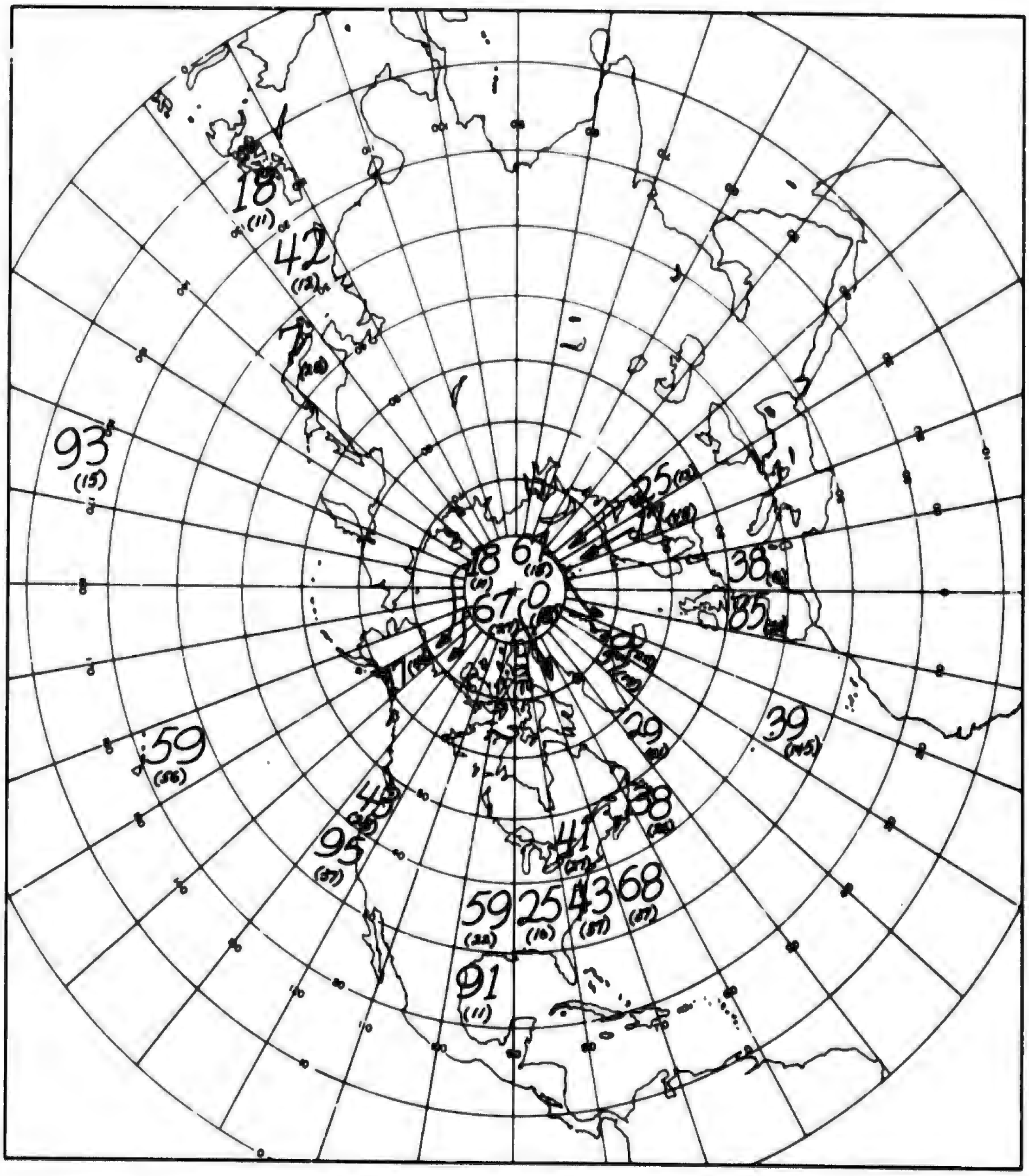

Figure C10. Estimates of the Probability of Seeing Blue Sky at 90° Above the Horizon (+ 90°) Between Altitudes of 1801 to 3600 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

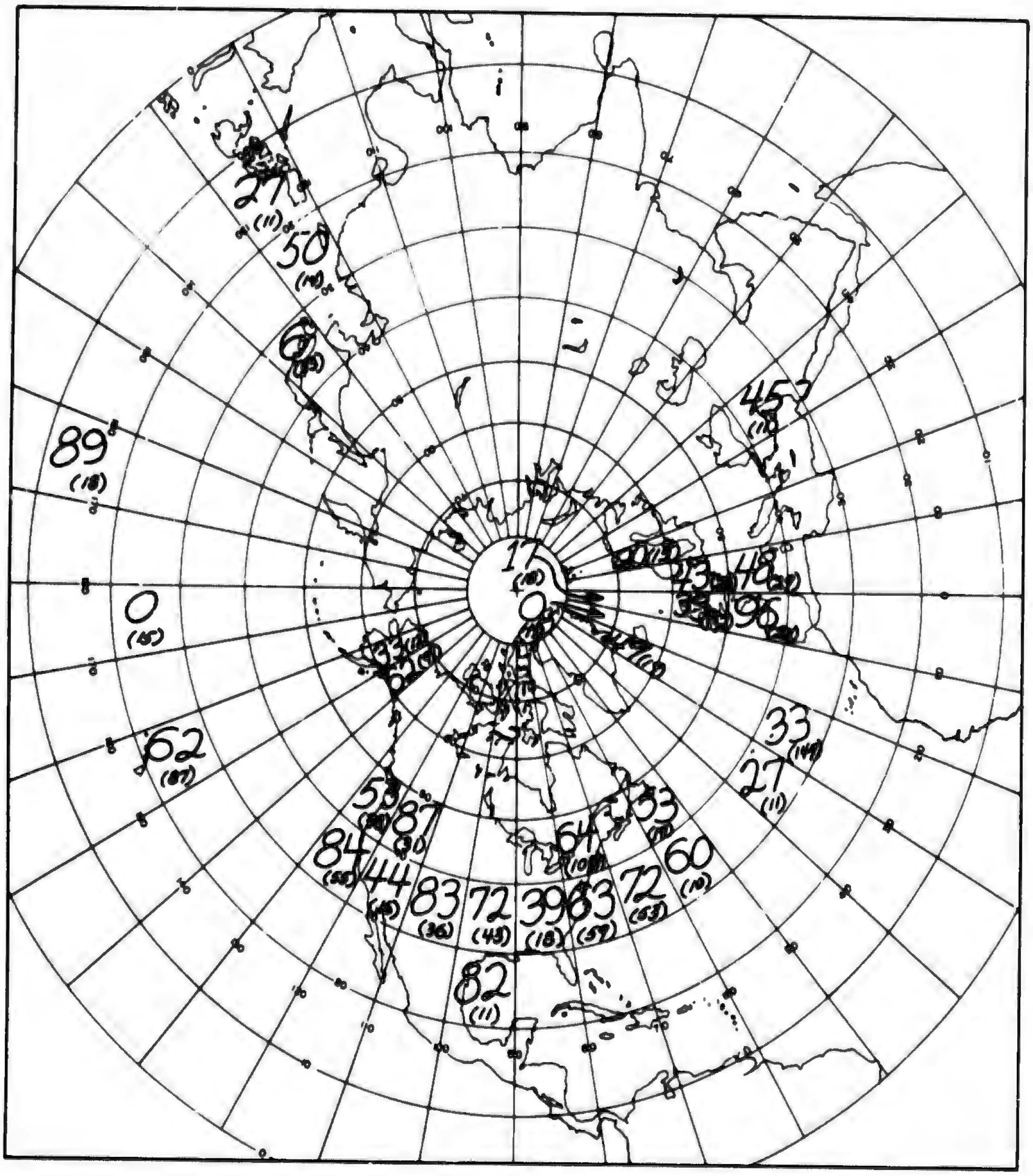

Figure C11. Estimates of the Probability of Seeing the Ground Directly Below the Aircraft (-90°) from Altitudes of 3601 to 7400 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

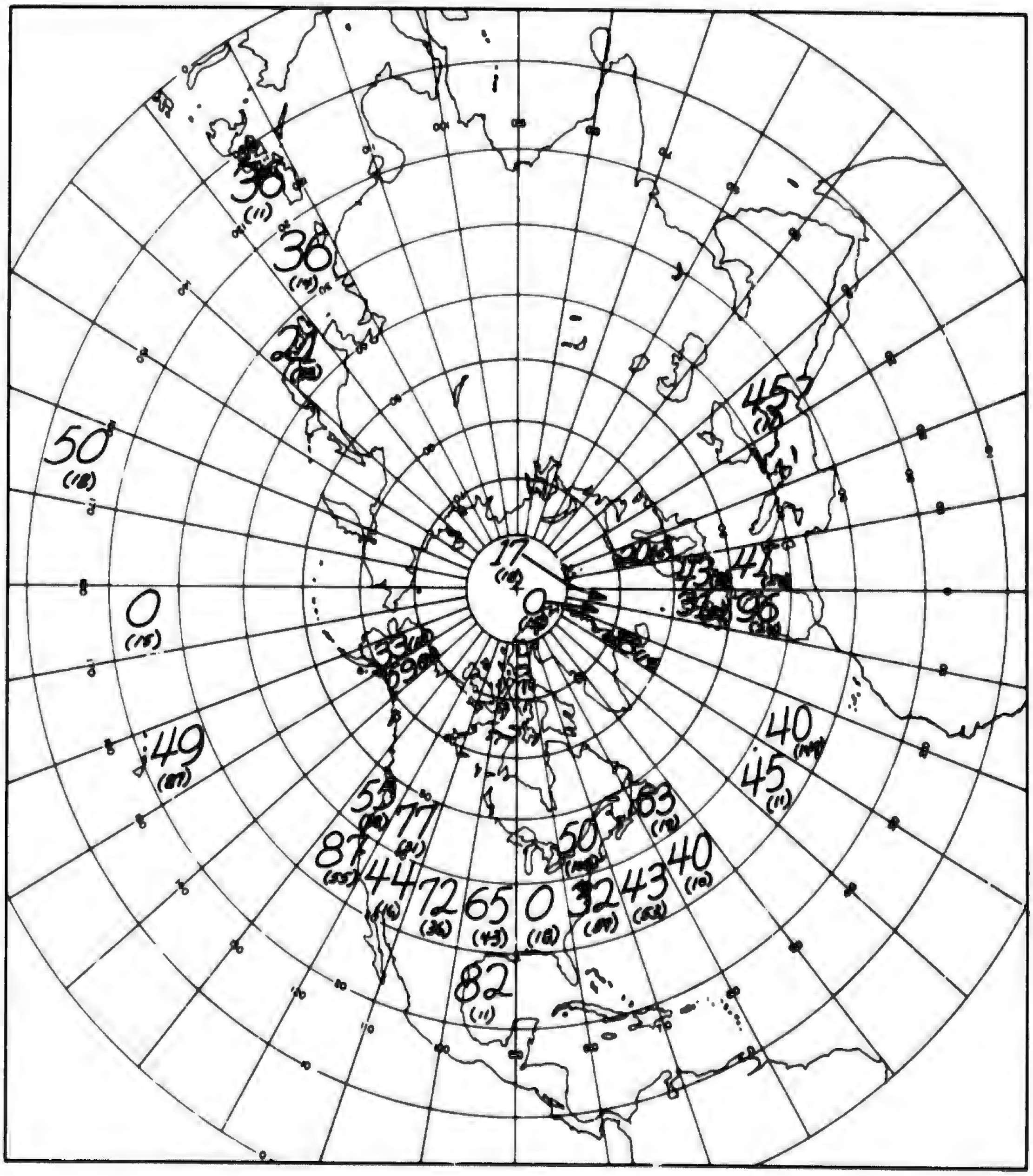

Figure C12. Estimates of the Probability of Seeing the Ground at 30° Below the Horizon (-30°) from Altitudes of 3601 to 7400 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

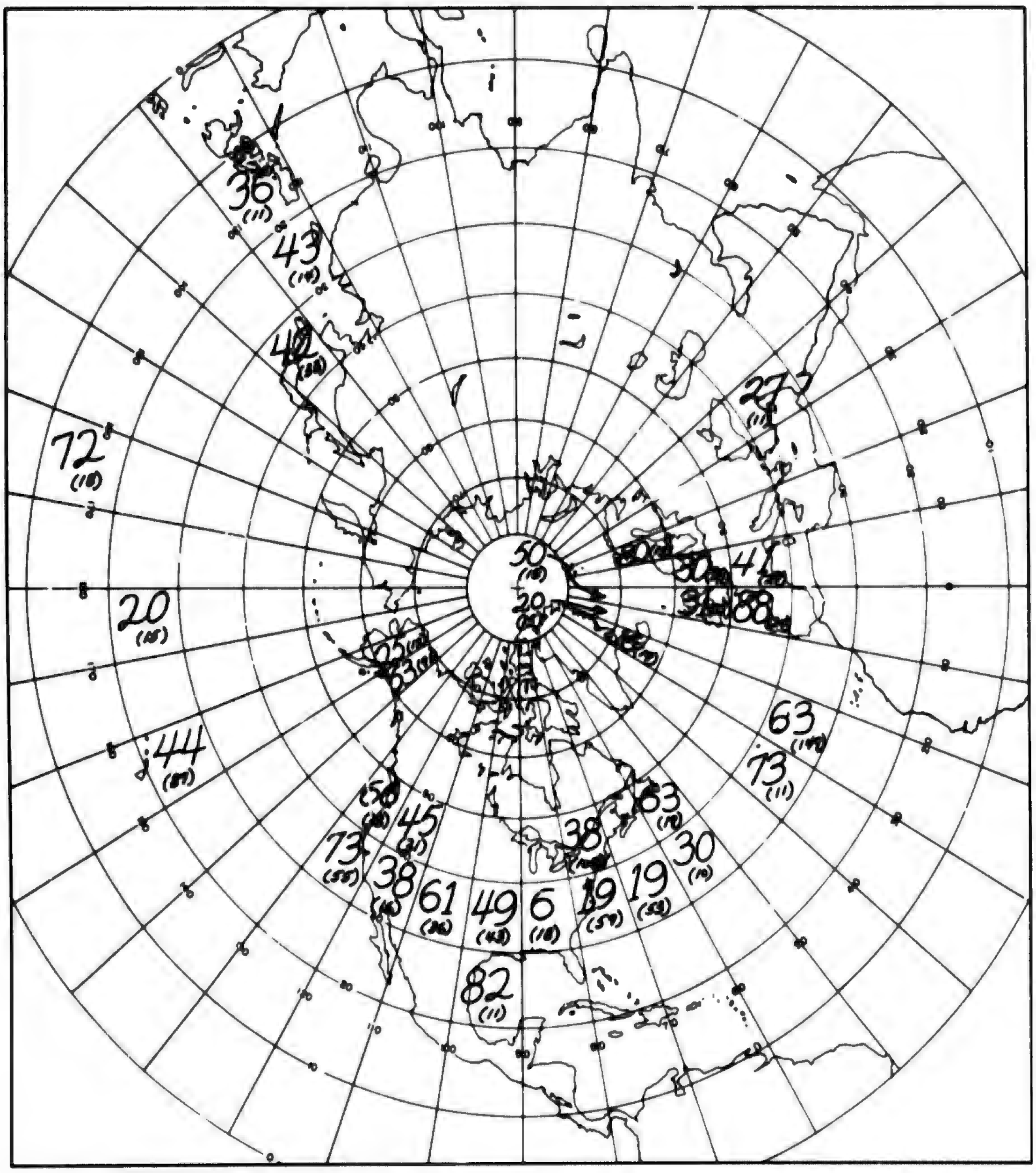

Figure C13. Estimates of the Probability of Seeing the Horizon from Altitudes of 3601 to 7400 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

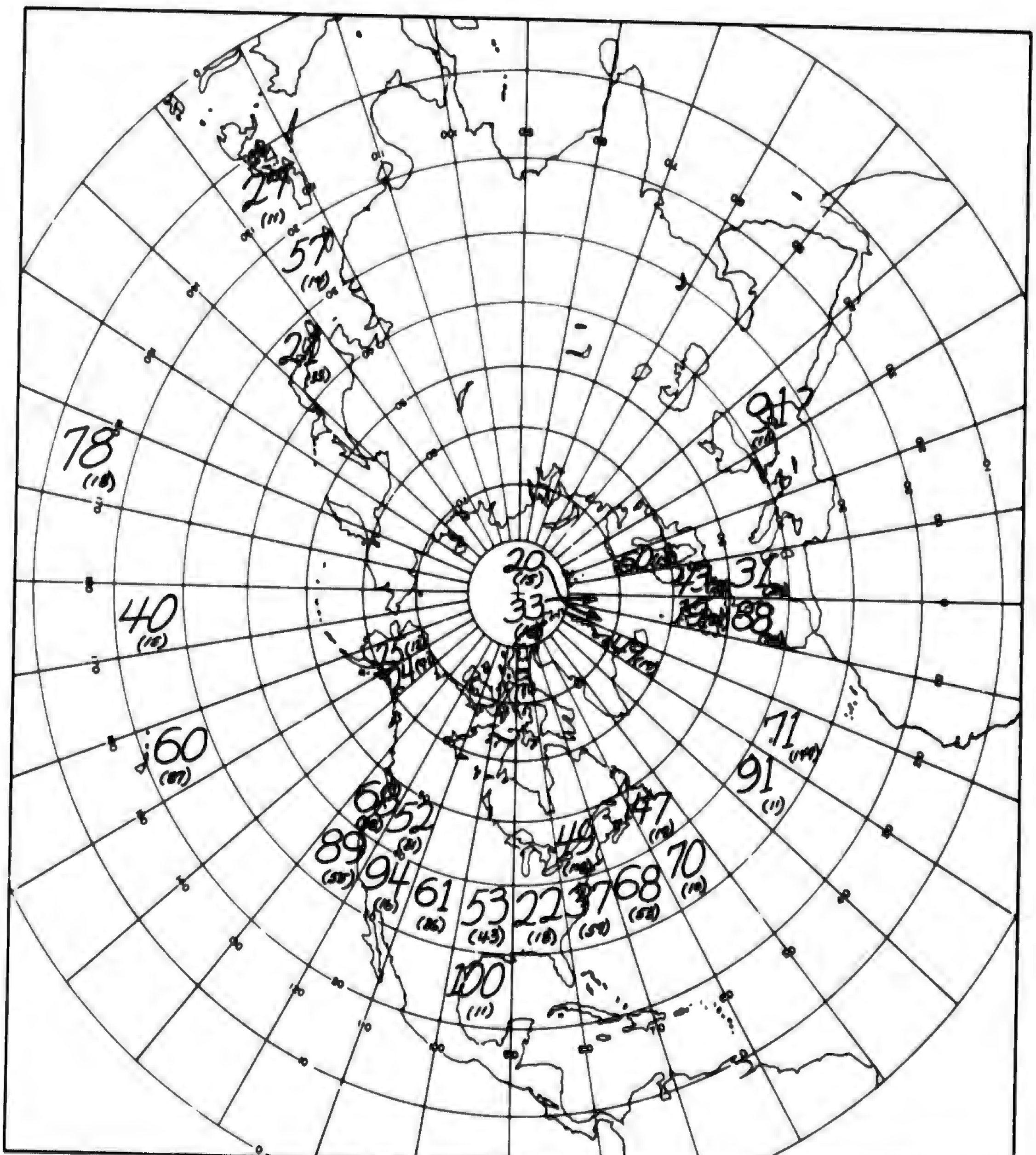

Figure C14. Estimates of the Probability of Seeing Blue Sky at 30° Above the Horizon (+ 30°) from Altitudes of 3601 to 7400 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

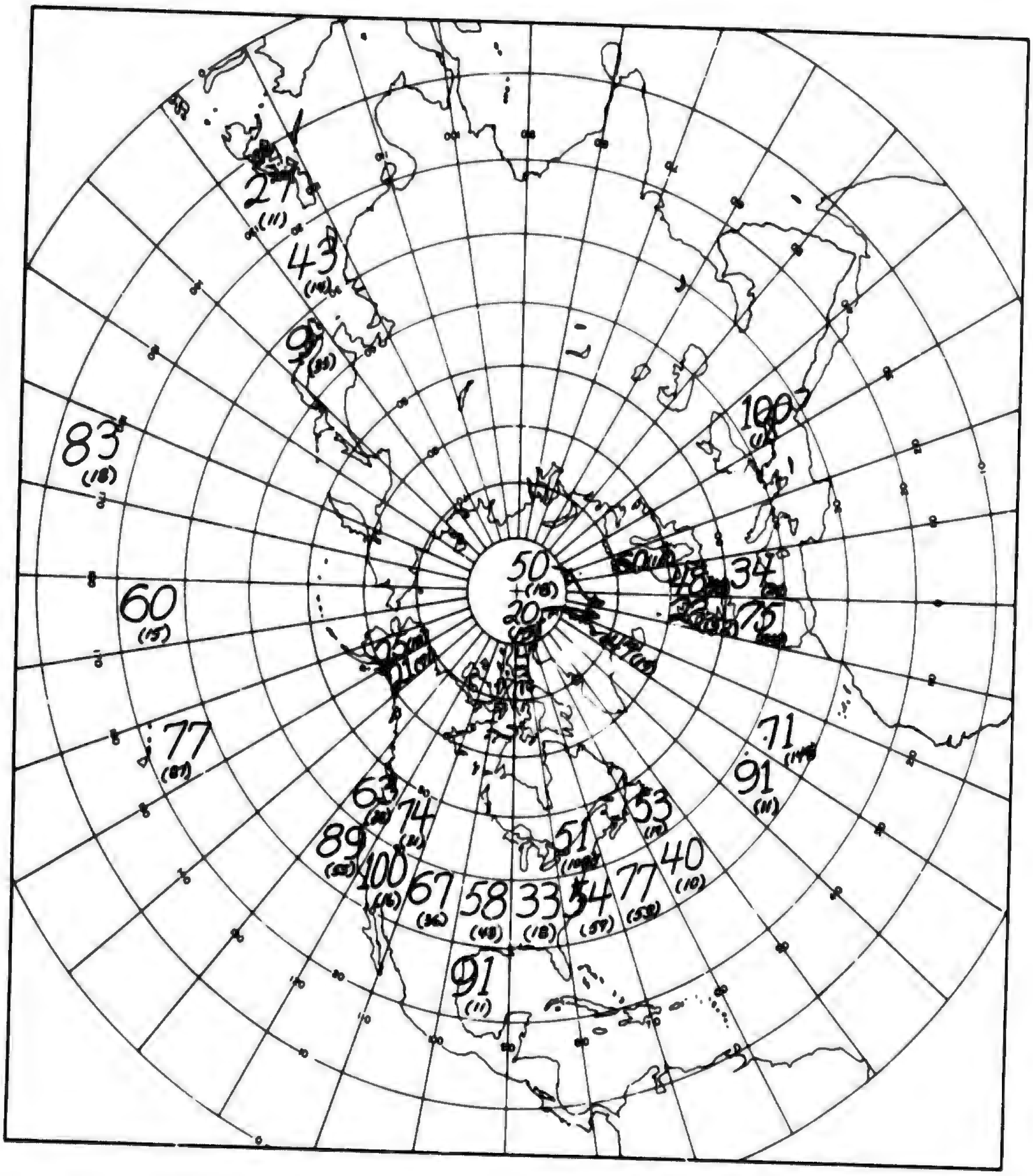

Figure C15. Estimates of the Probability of Seeing Blue Sky at 90° Above the Horizon (+ 90°) from Altitudes of 3601 to 7400 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

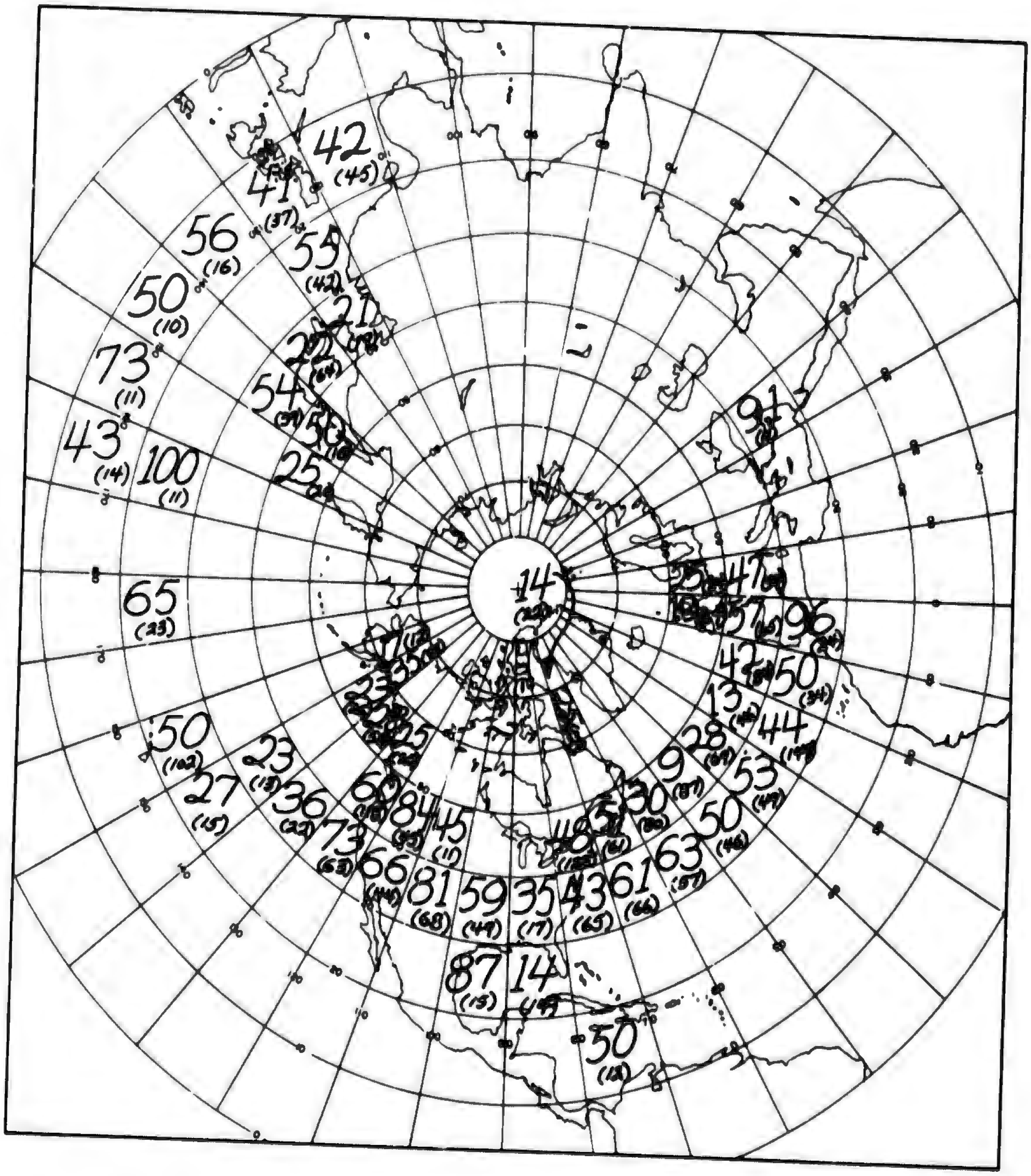

Figure C16. Estimates of the Probability of Seeing the Ground Directly Below the Aircraft (-90°) from Altitudes of 7401 to 14,999 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

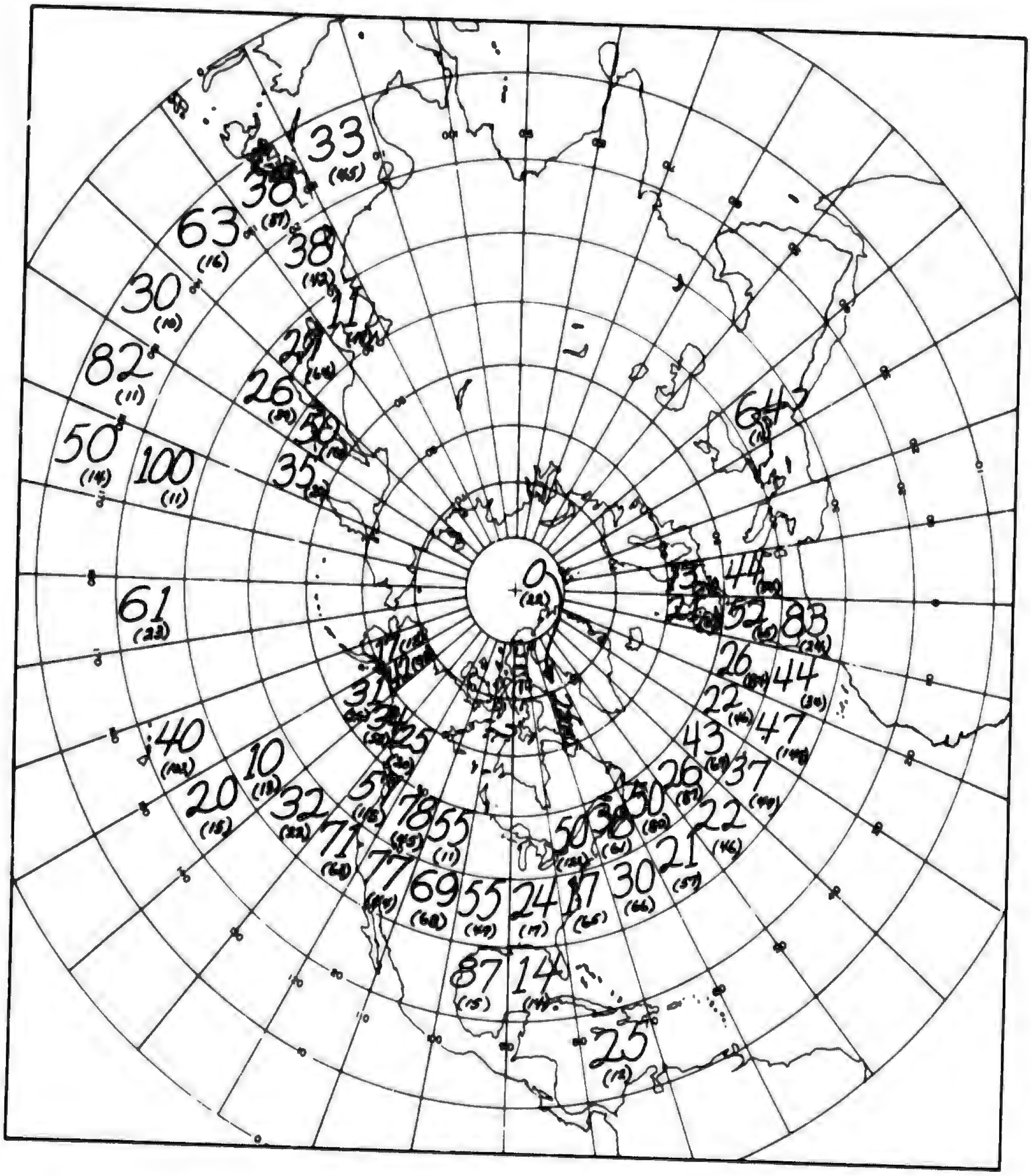

Figure C17. Estimates of the Probability of Seeing the Ground at 30° Below the Horizon (-30°) from Altitudes of 7401 to 14,999 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

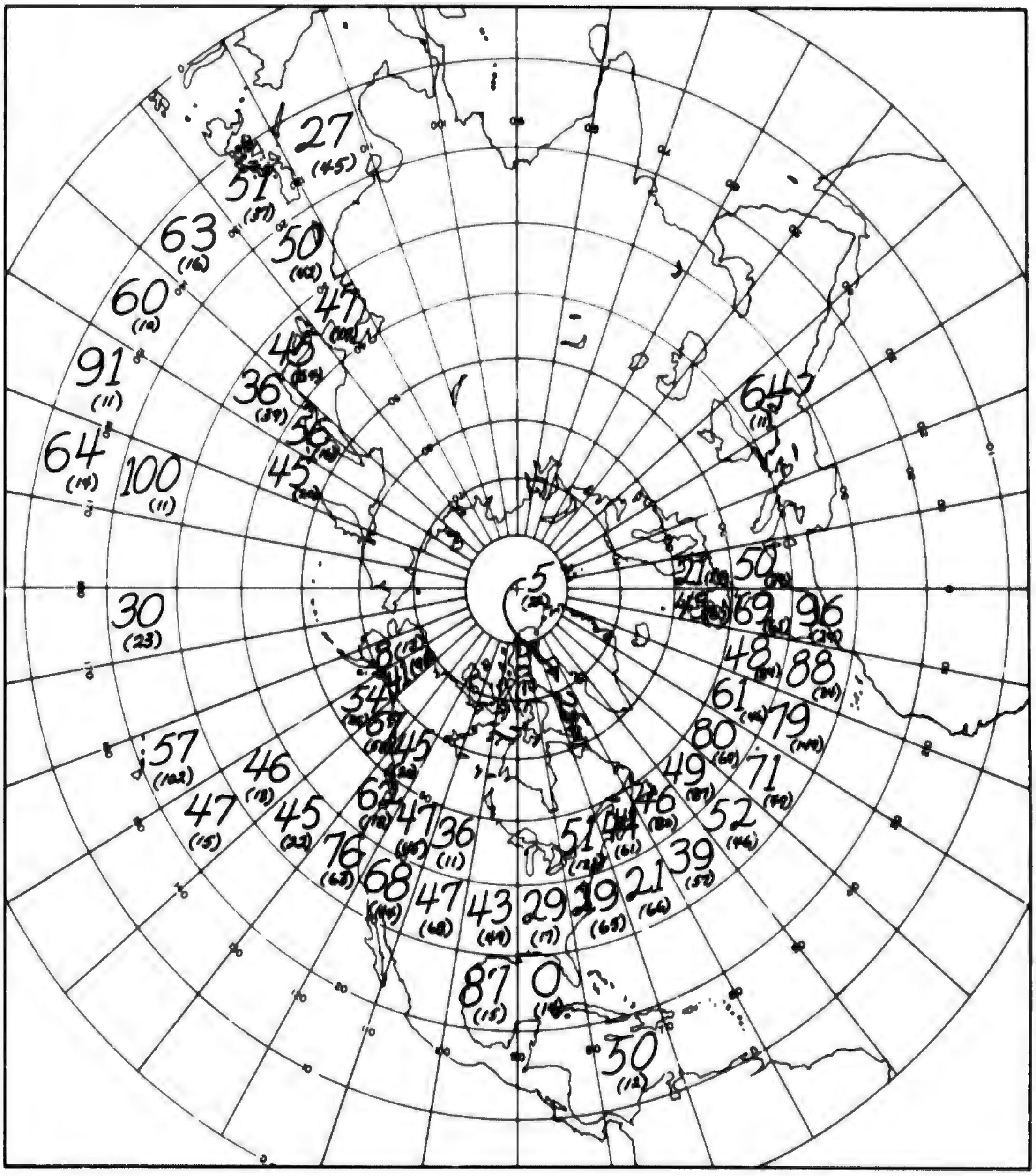

Figure C18. Estimates of the Probability of Seeing the Horizon from Altitudes of 7401 to 14,999 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

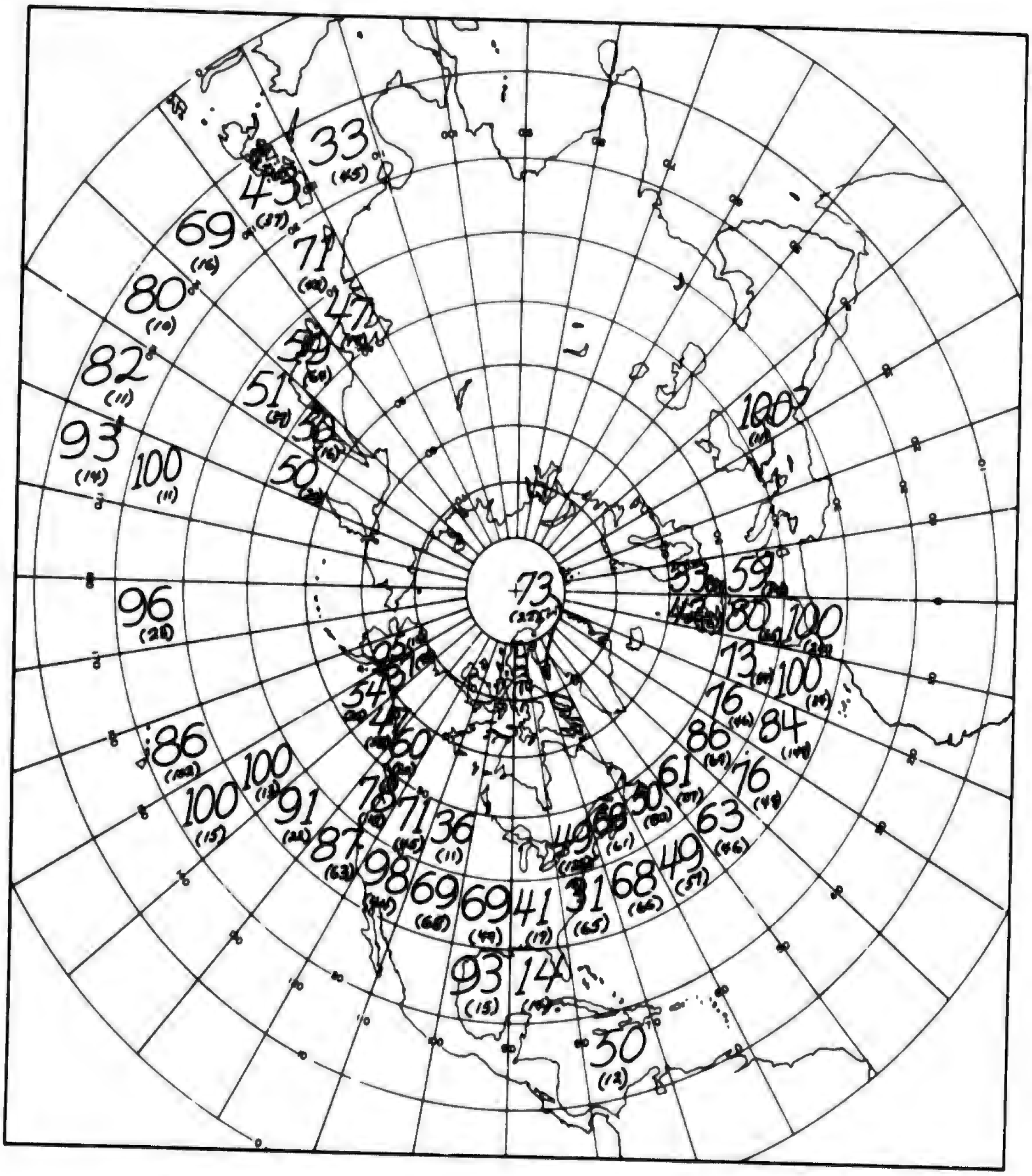

Figure C19. Estimates of the Probability of Seeing Blue Sky at 30° Above the Horizon (+ 30°) Between Altitudes of 7401 to 14,999 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

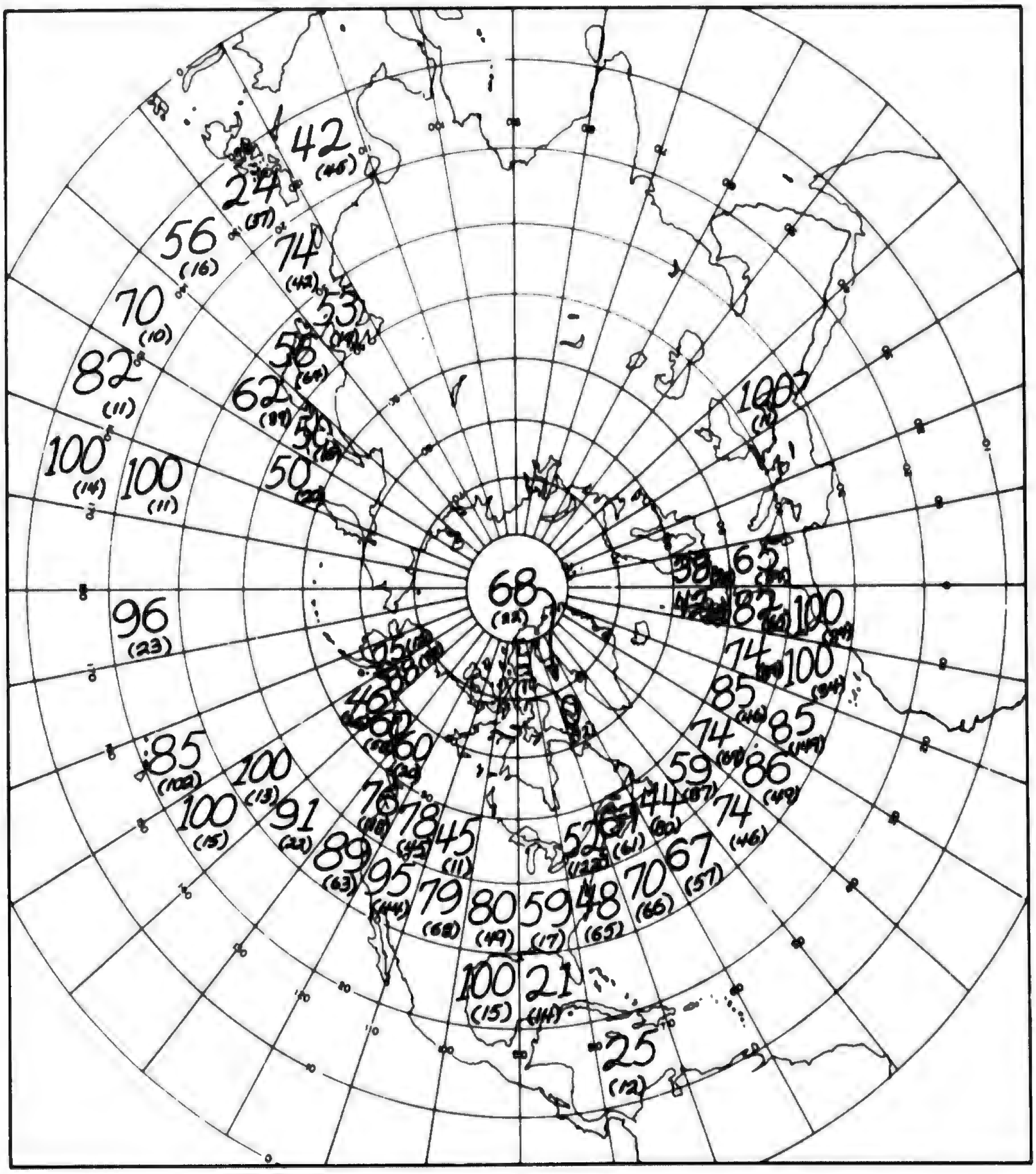

Figure C20. Estimates of the Probability of Seeing Blue Sky at 90° Above the Horizon (+ 90°) Between Altitudes of 7401 to 14,999 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

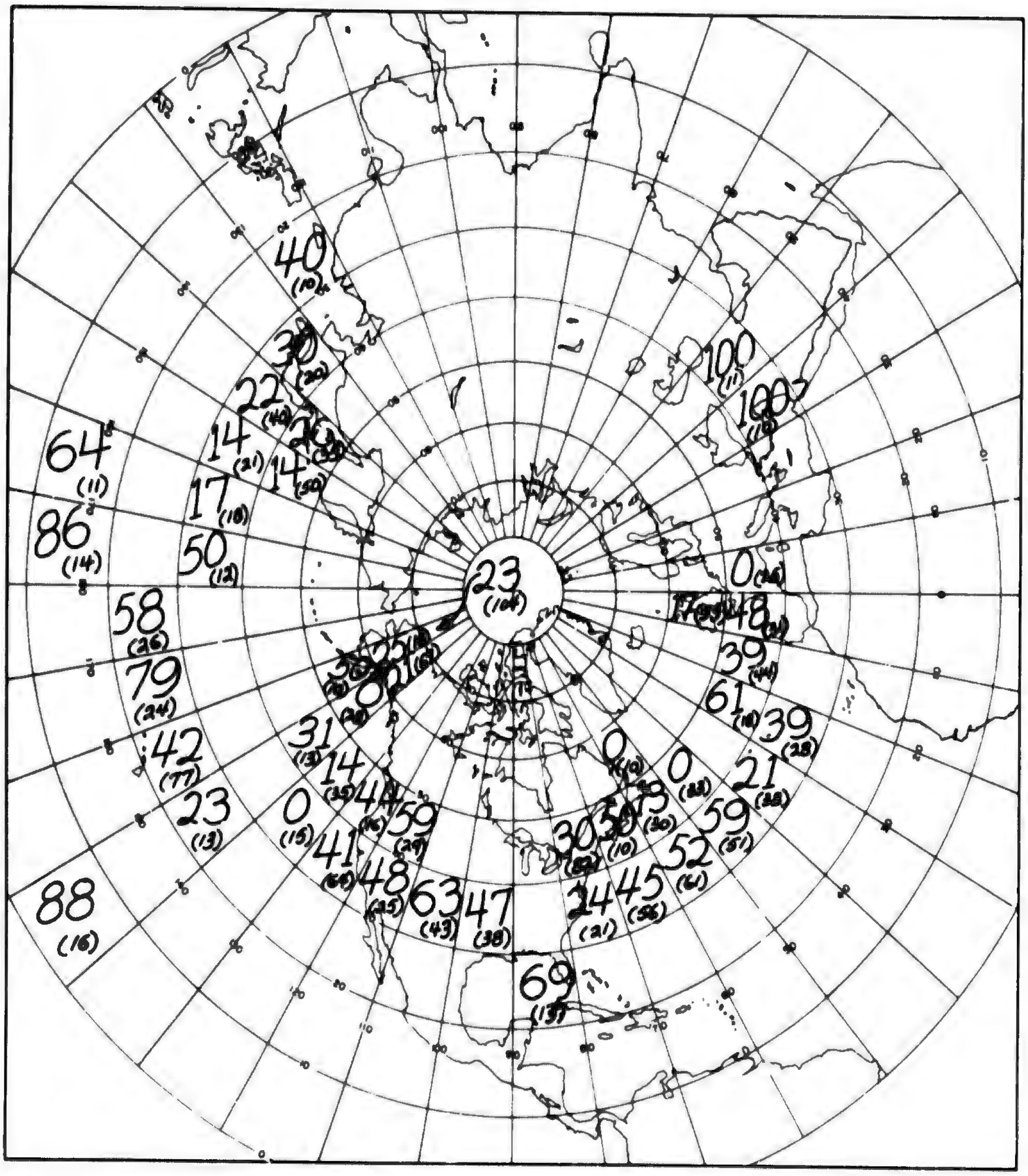

Figure C21. Estimates of the Probability of Seeing the Ground Directly Below the Aircraft (-90°) from Altitudes of 15,000 to 24,999 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

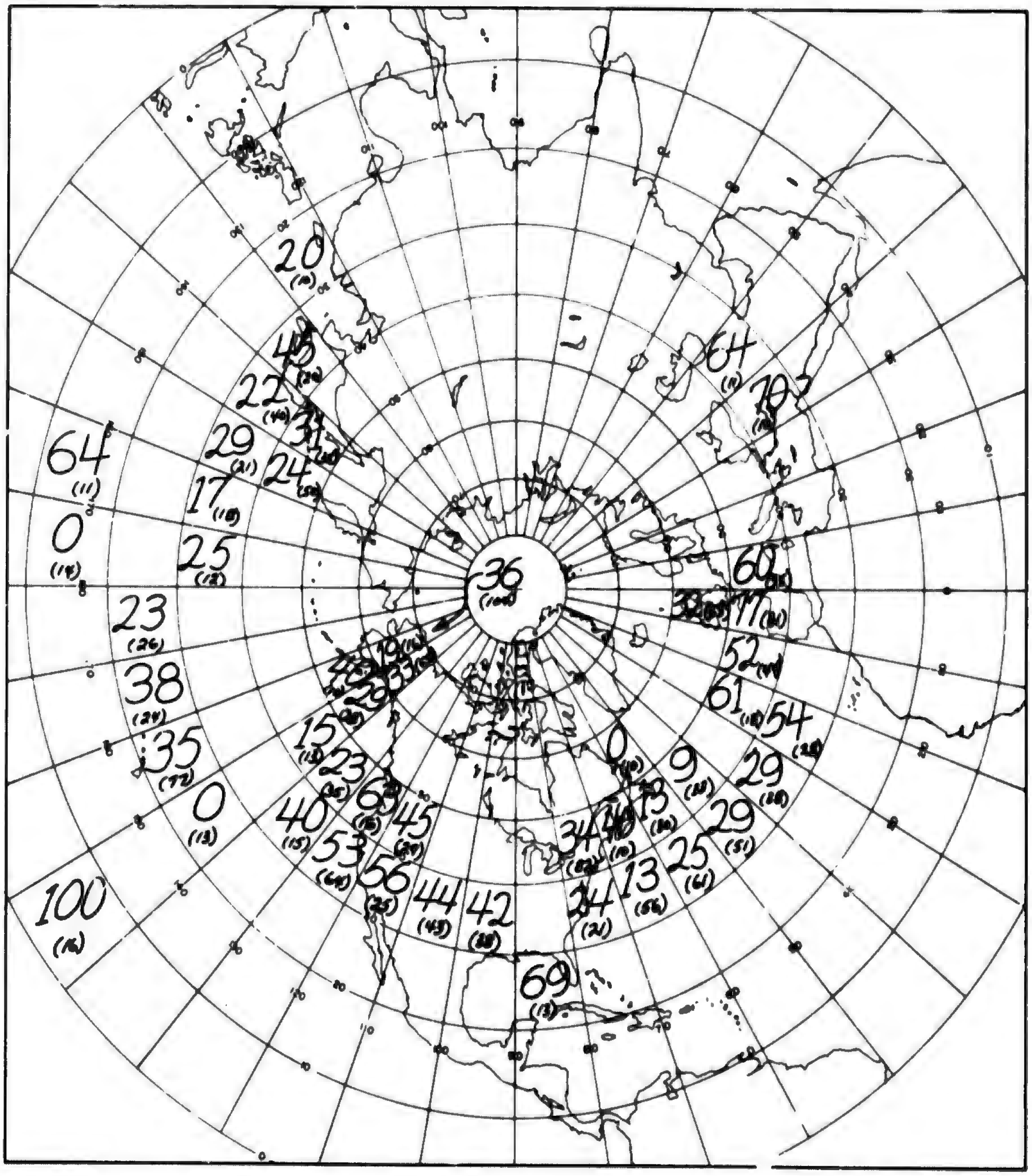

Figure C22. Estimates of the Probability of Seeing the Ground at 30° Below the Horizon (-30°) from Altitudes of 15,000 to 24,999 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

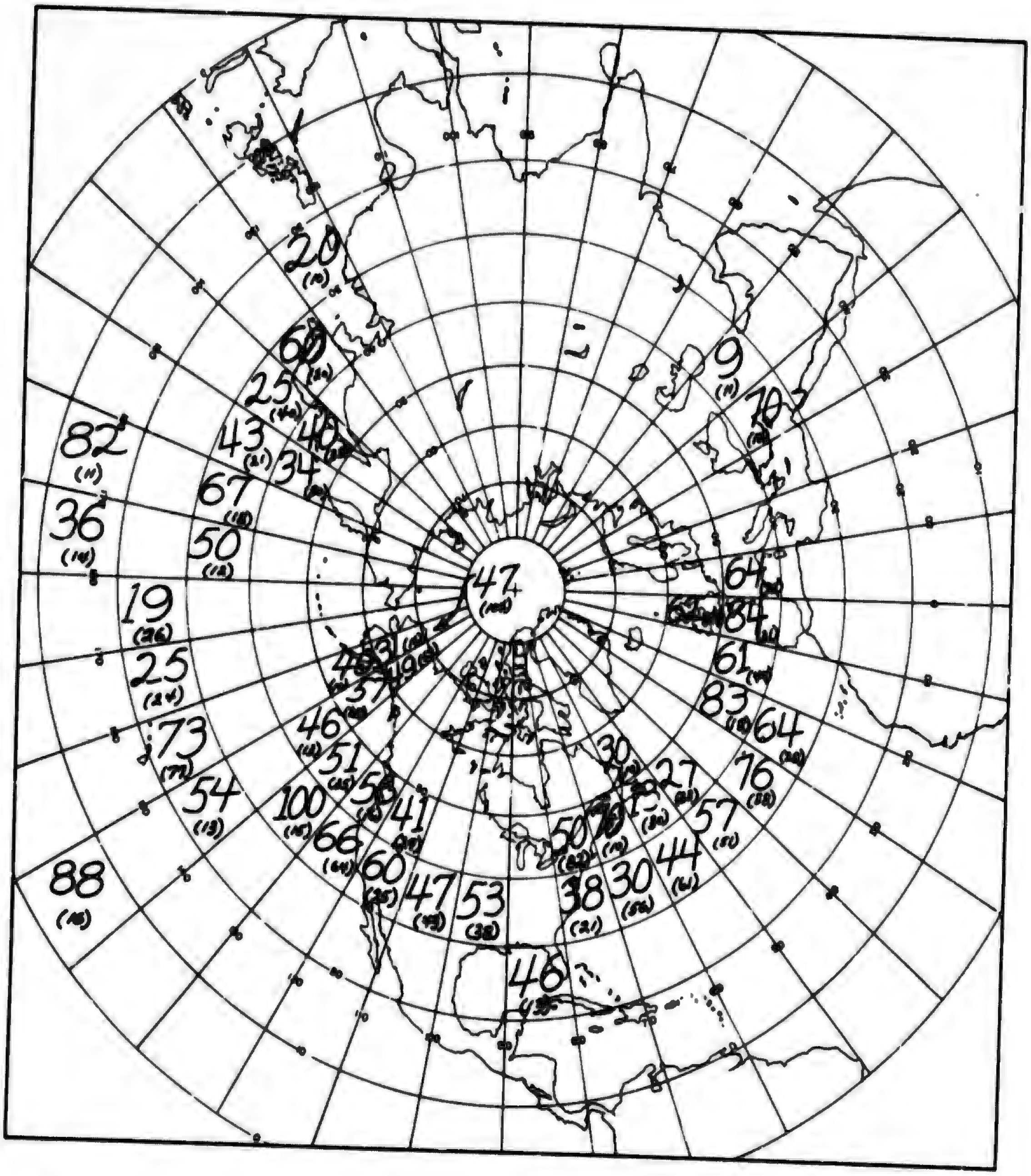

Figure C23. Estimates of the Probability of Seeing the Horizon from Altitudes of 15,000 to 24,999 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

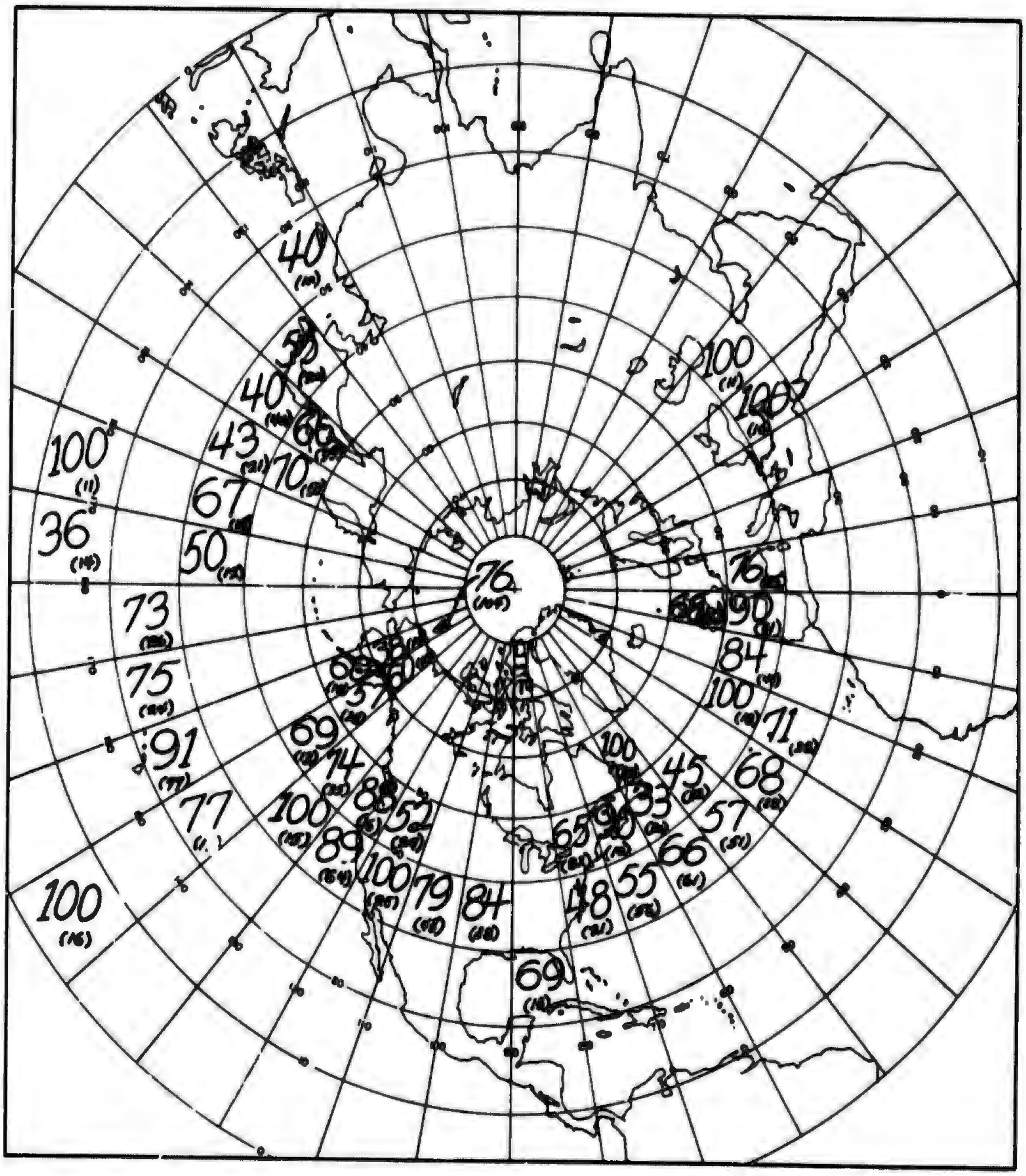

Figure C24. Estimates of the Probability of Seeing Blue Sky at 30° Above the Horizon (+ 30°) from Altitudes of 15,000 to 24,999 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

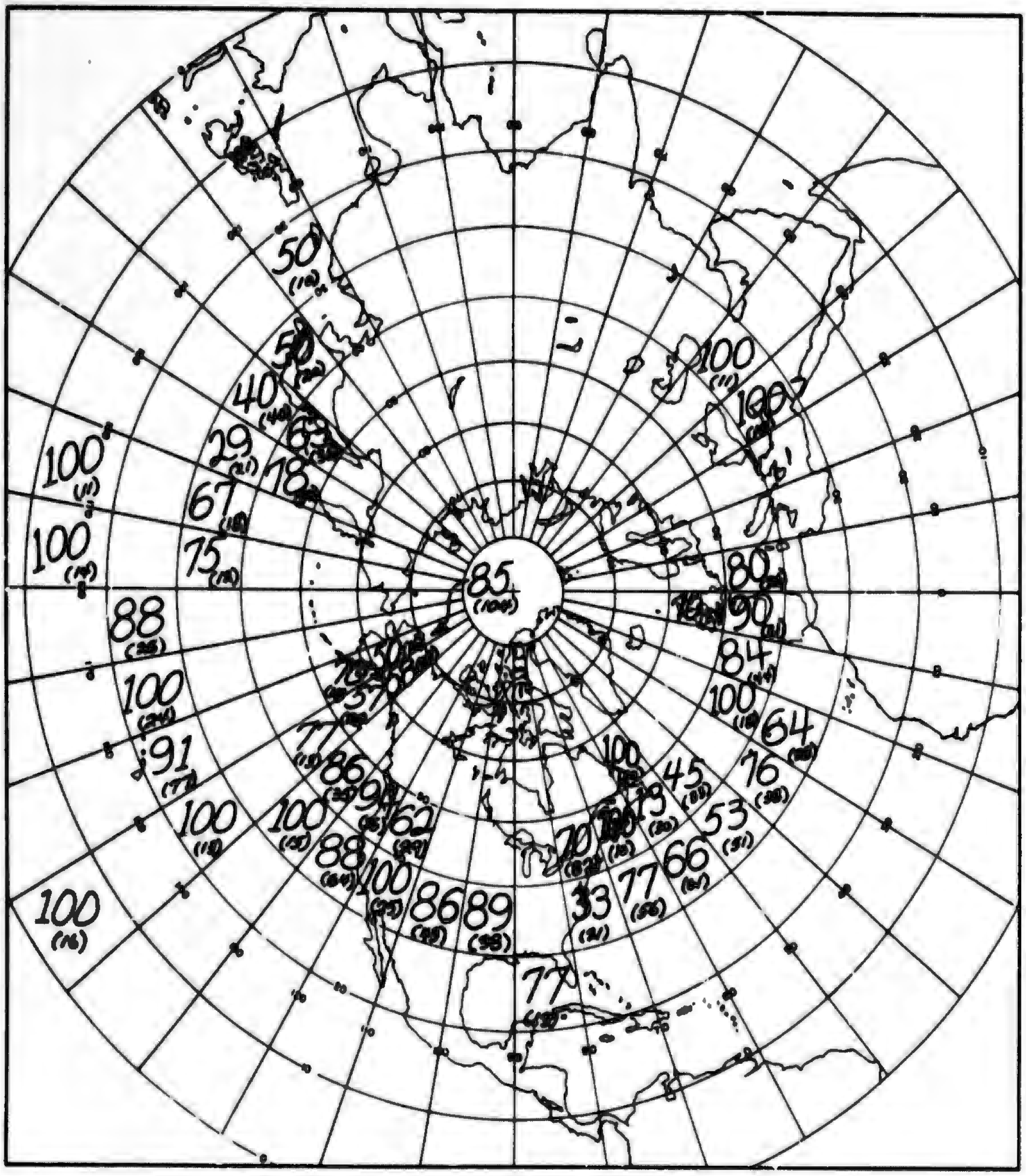

Figure C25. Estimates of the Probability of Seeing Blue Sky at 90° Above the Horizon (+ 90°) from Altitudes of 15,000 to 24,999 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

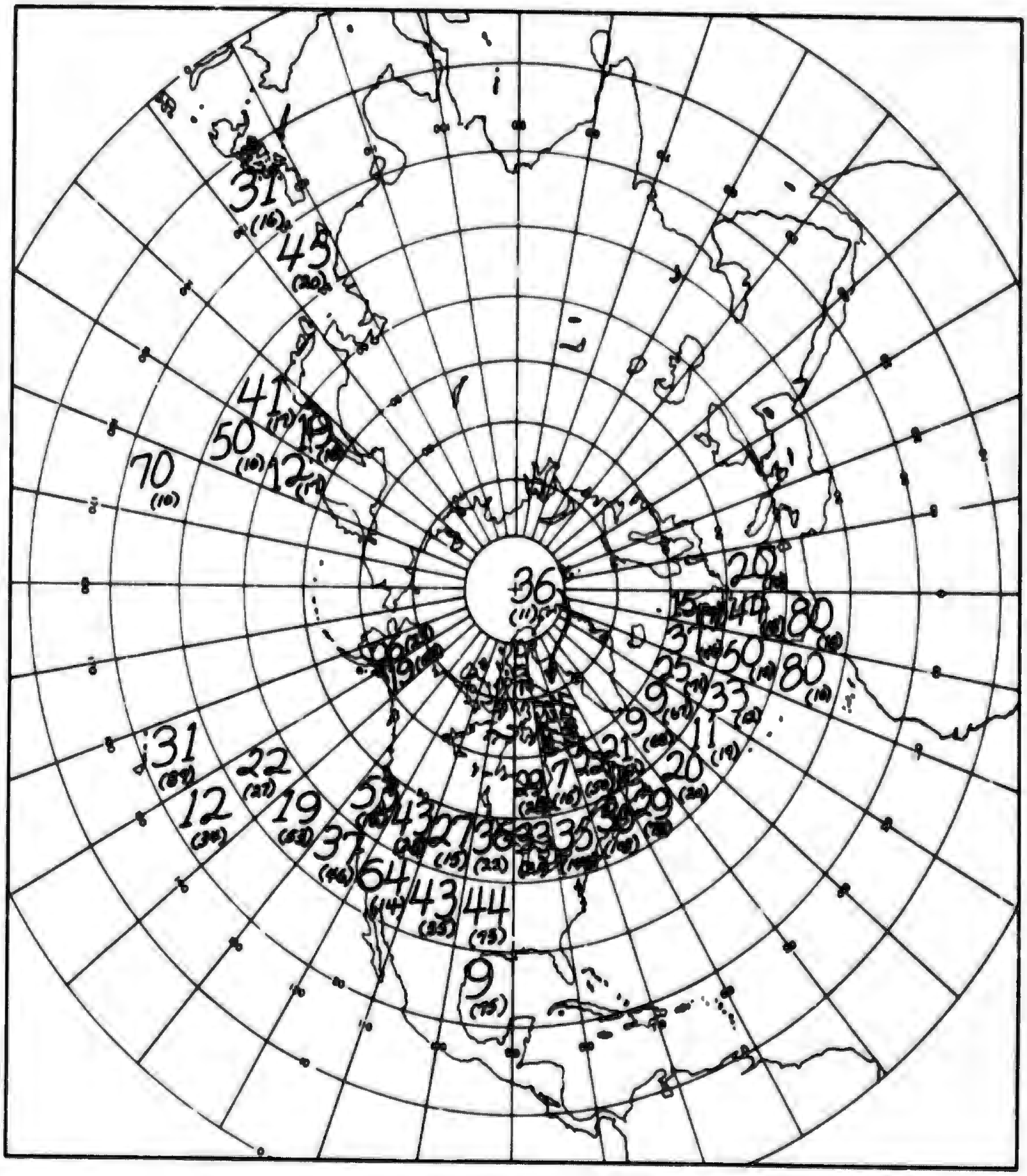

Figure C26. Estimates of the Probability of Seeing the Ground Directly Below the Aircraft (-90°) from Altitudes of 25,000 to 34,999 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

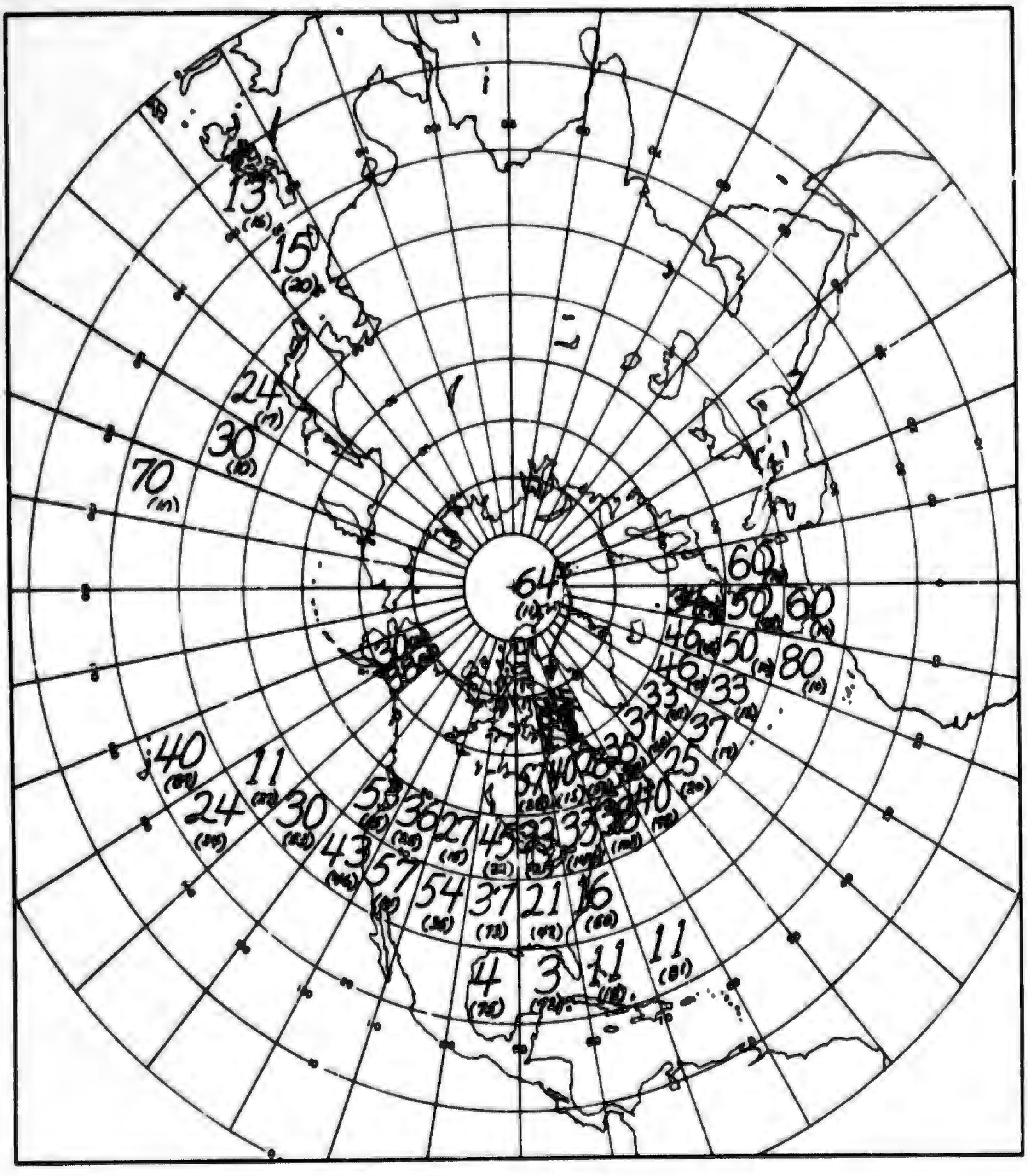

Figure C27. Estimates of the Probability of Seeing the Ground at 30° Below the Horizon (-30°) from Altitudes of 25,000 to 34,999 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

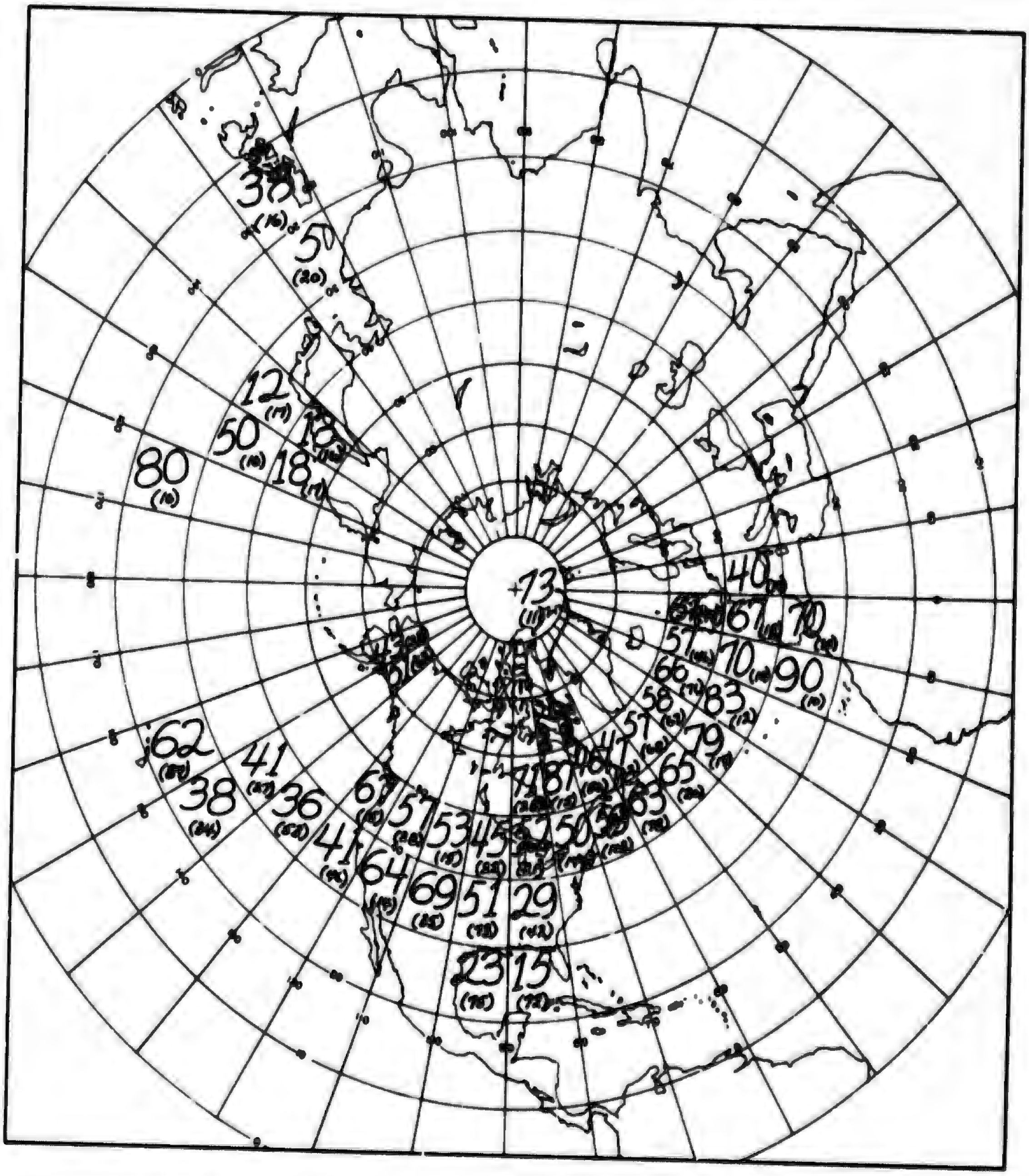

Figure C28. Estimates of the Probability of Seeing the Horizon from Altitudes of 25,000 to 34,999 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

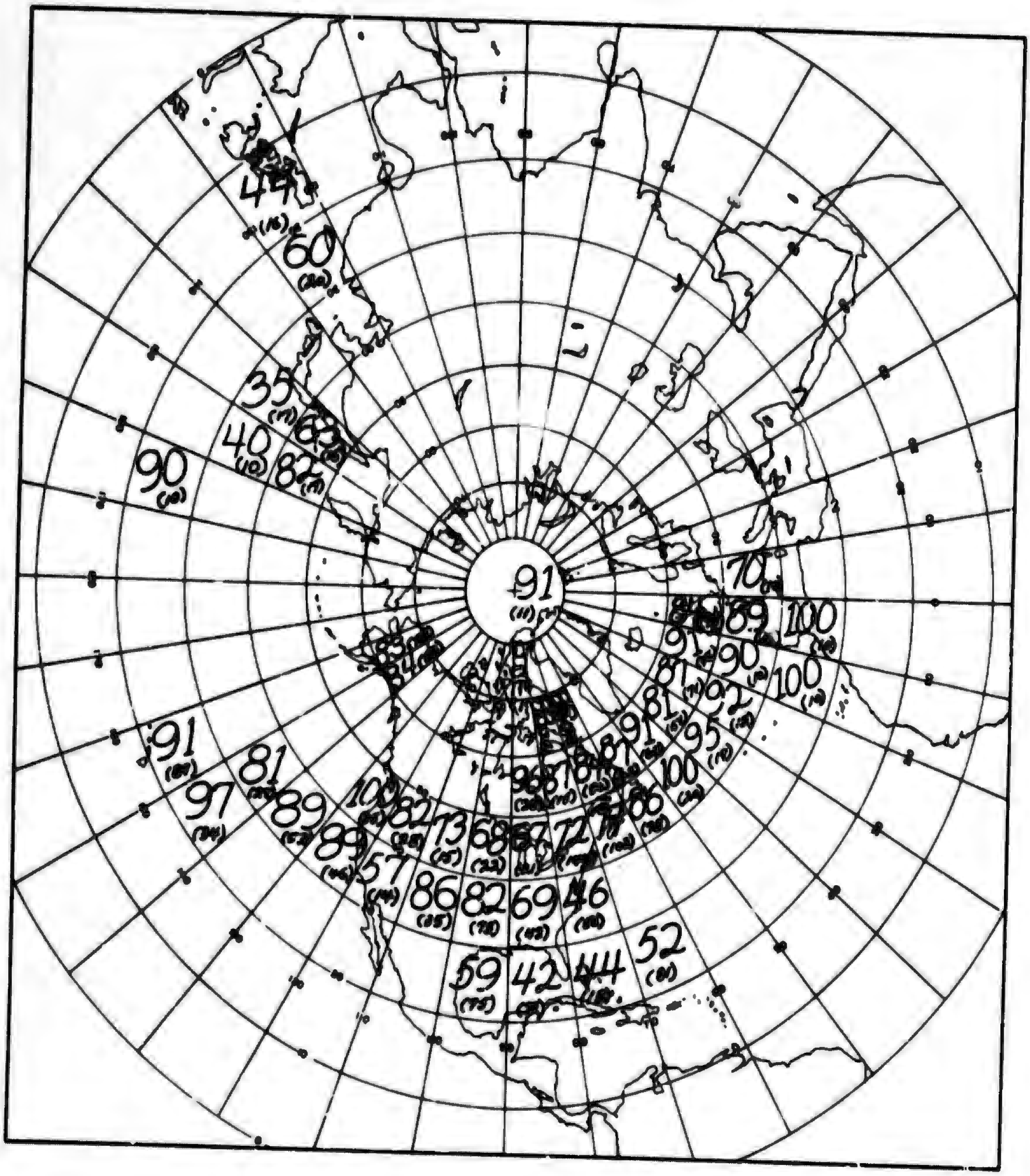

Figure C29. Estimates of the Probability of Seeing Blue Sky at 30° Above the Horizon (+ 30°) from Altitudes of 25,000 to 34,999 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

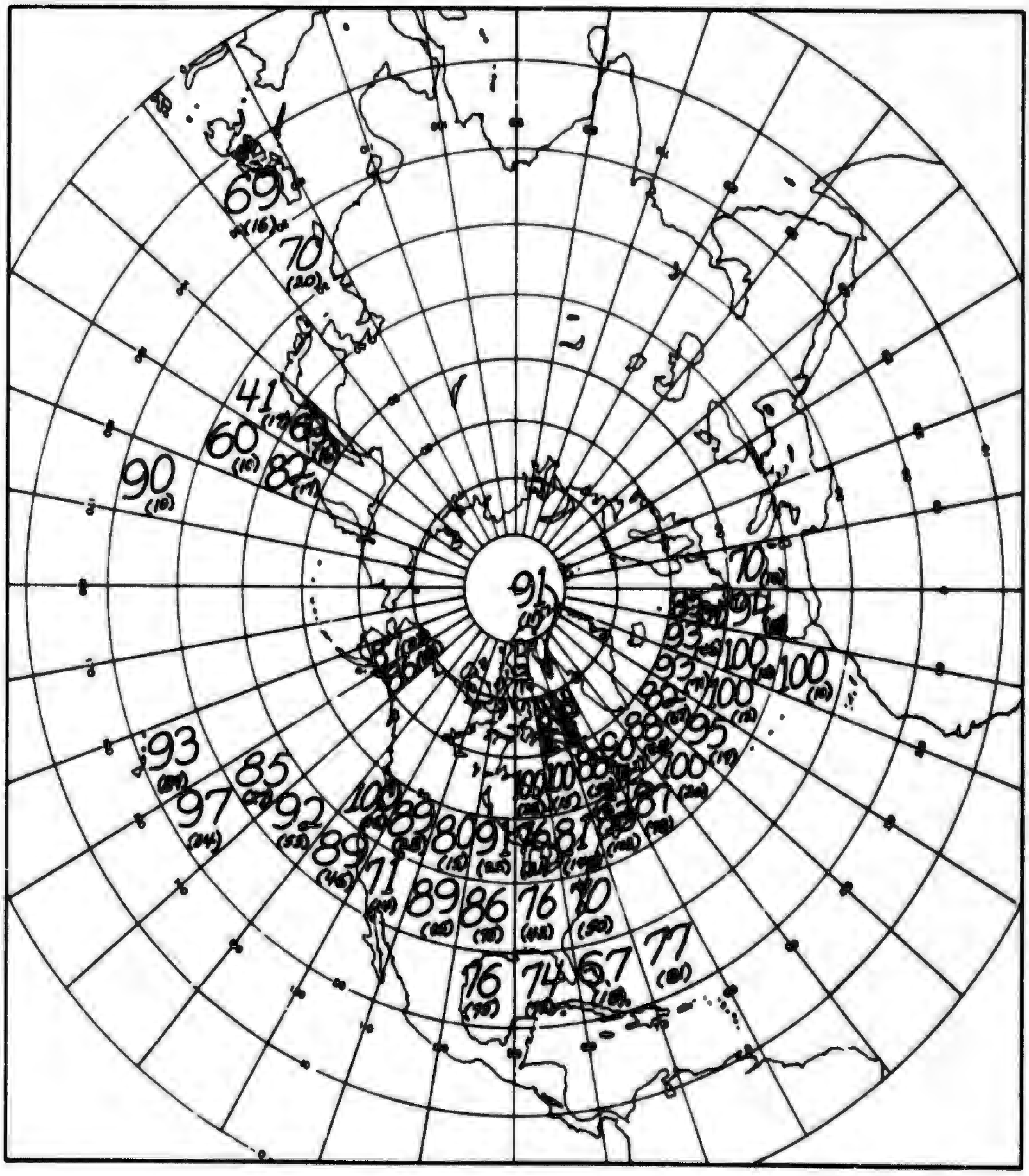

Figure C30. Estimates of the Probability of Seeing Blue Sky at 90° Above the Horizon (+90°) from Altitudes of 25,000 to 34,999 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

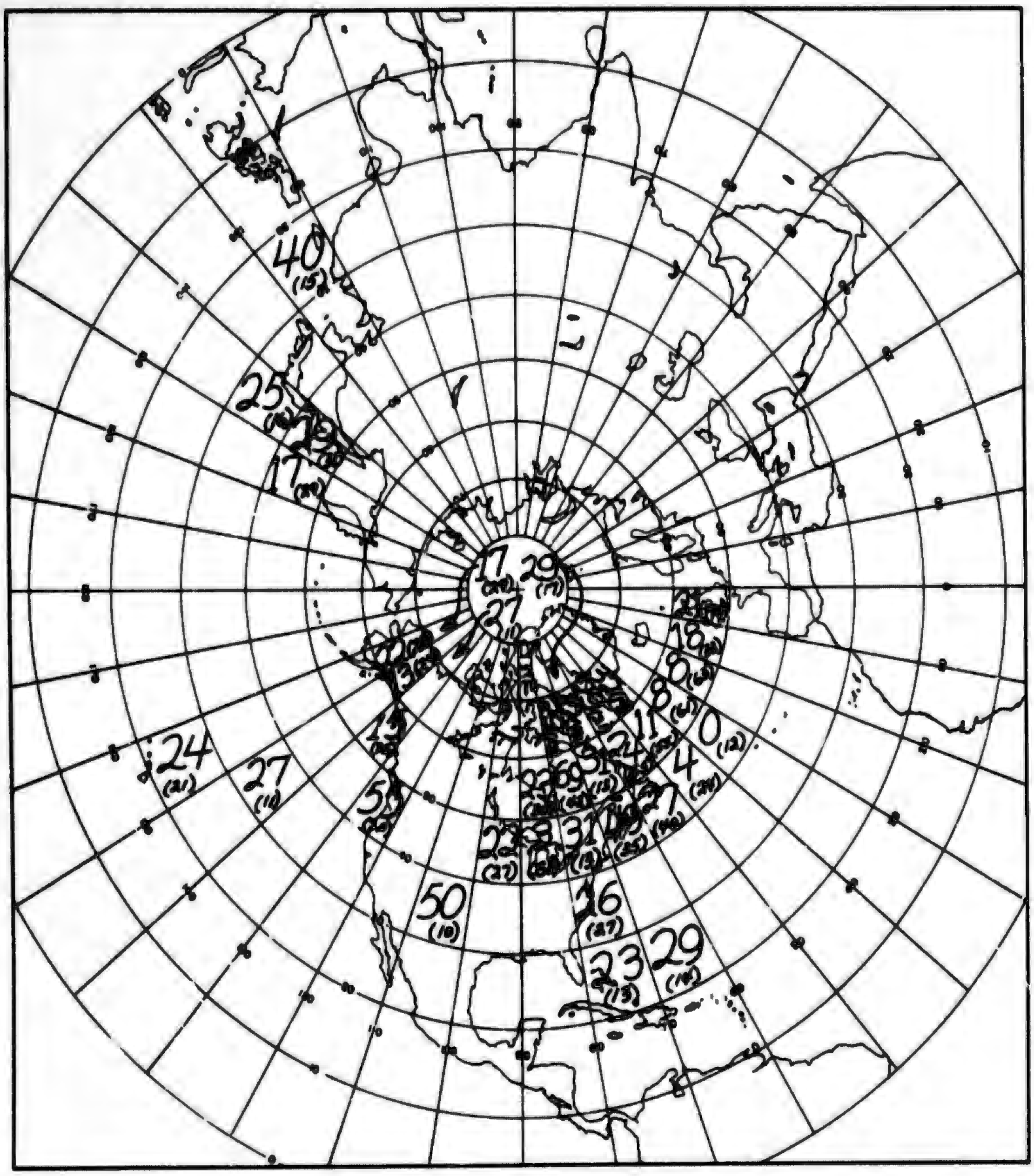

Figure C31. Estimates of the Probability of Seeing the Ground Directly Below the Aircraft (-90°) from Altitudes of 35,000 to 44,999 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

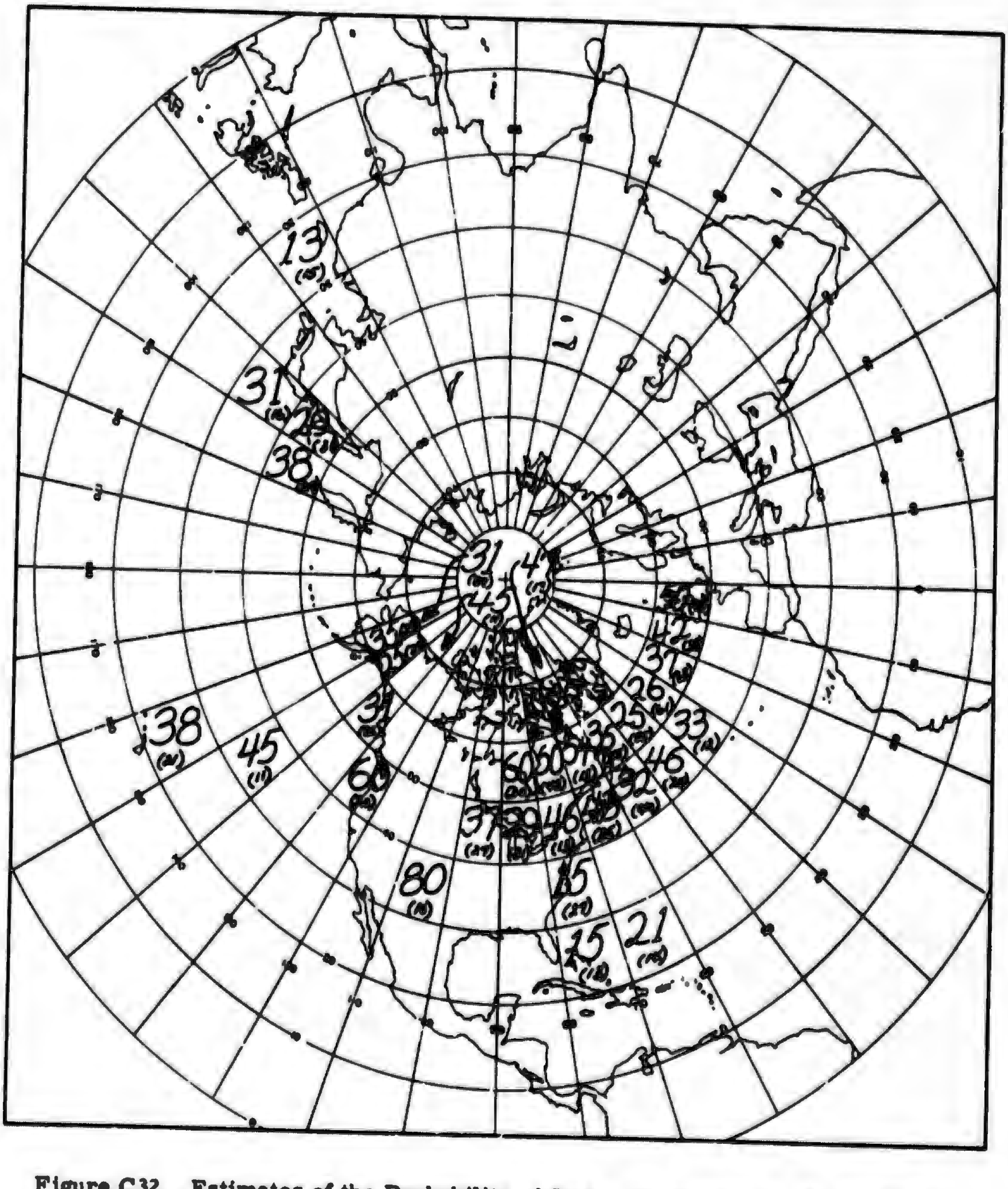

Figure C32. Estimates of the Probability of Seeing the Ground at 30° Below the Horizon (-30°) from Altitudes of 35,000 to 44,999 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

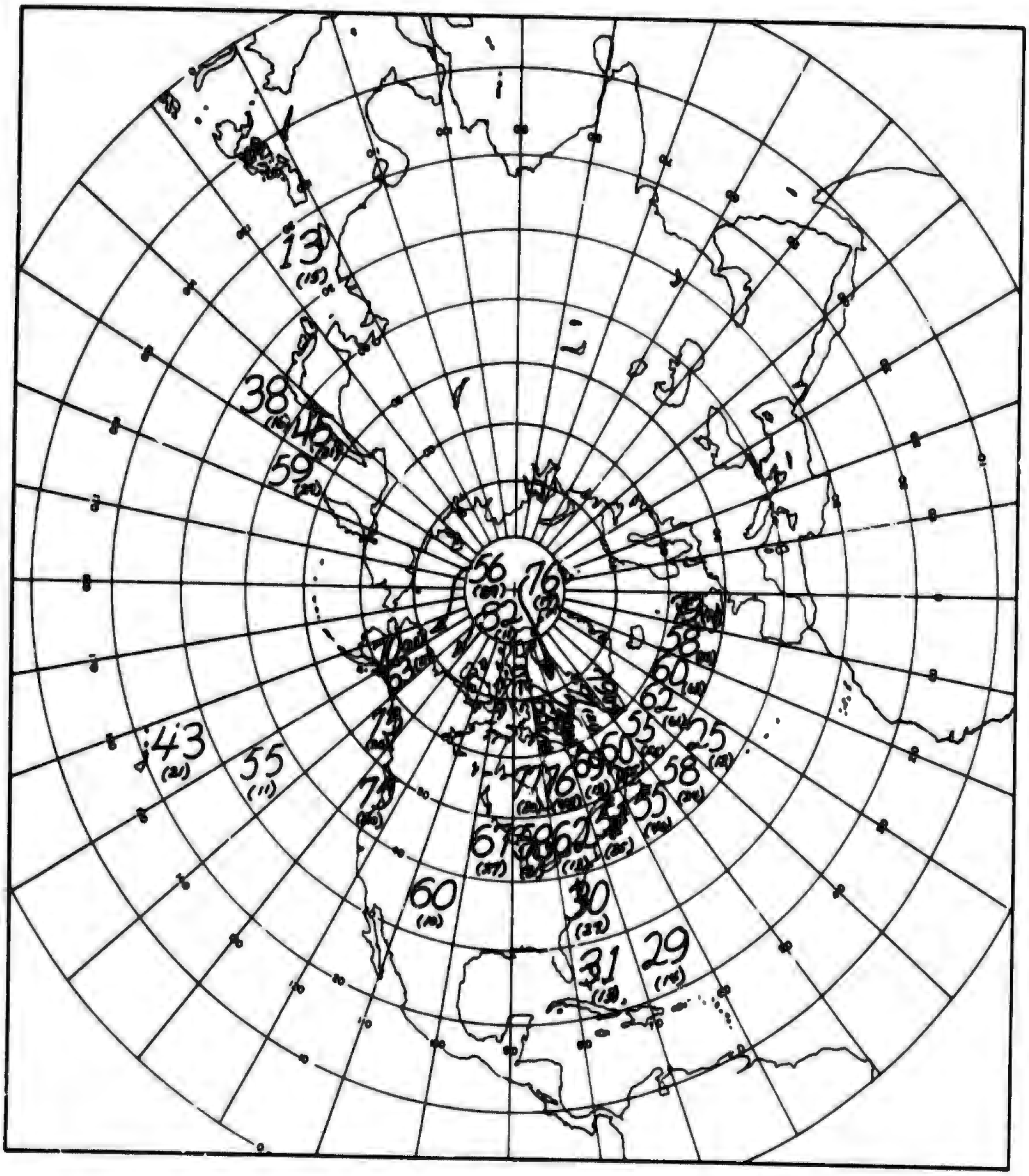

Figure C33. Estimates of the Probability of Seeing the Horizon from Altitudes of 35,000 to 44,999 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

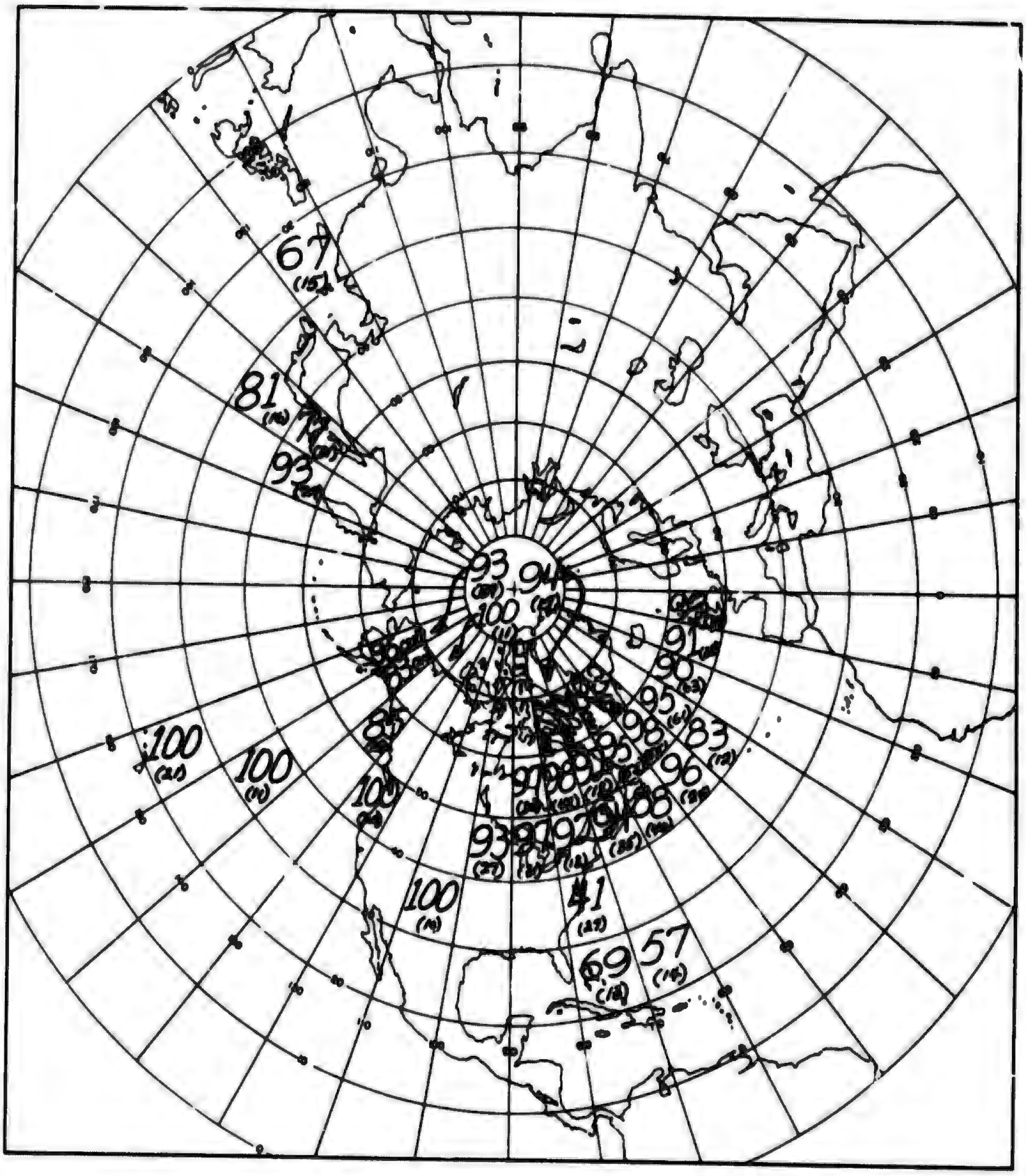

Figure C34. Estimates of the Probability of Seeing Blue Sky at 30° Above the Horizon (+ 30°) from Altitudes of 35,000 to 44,999 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

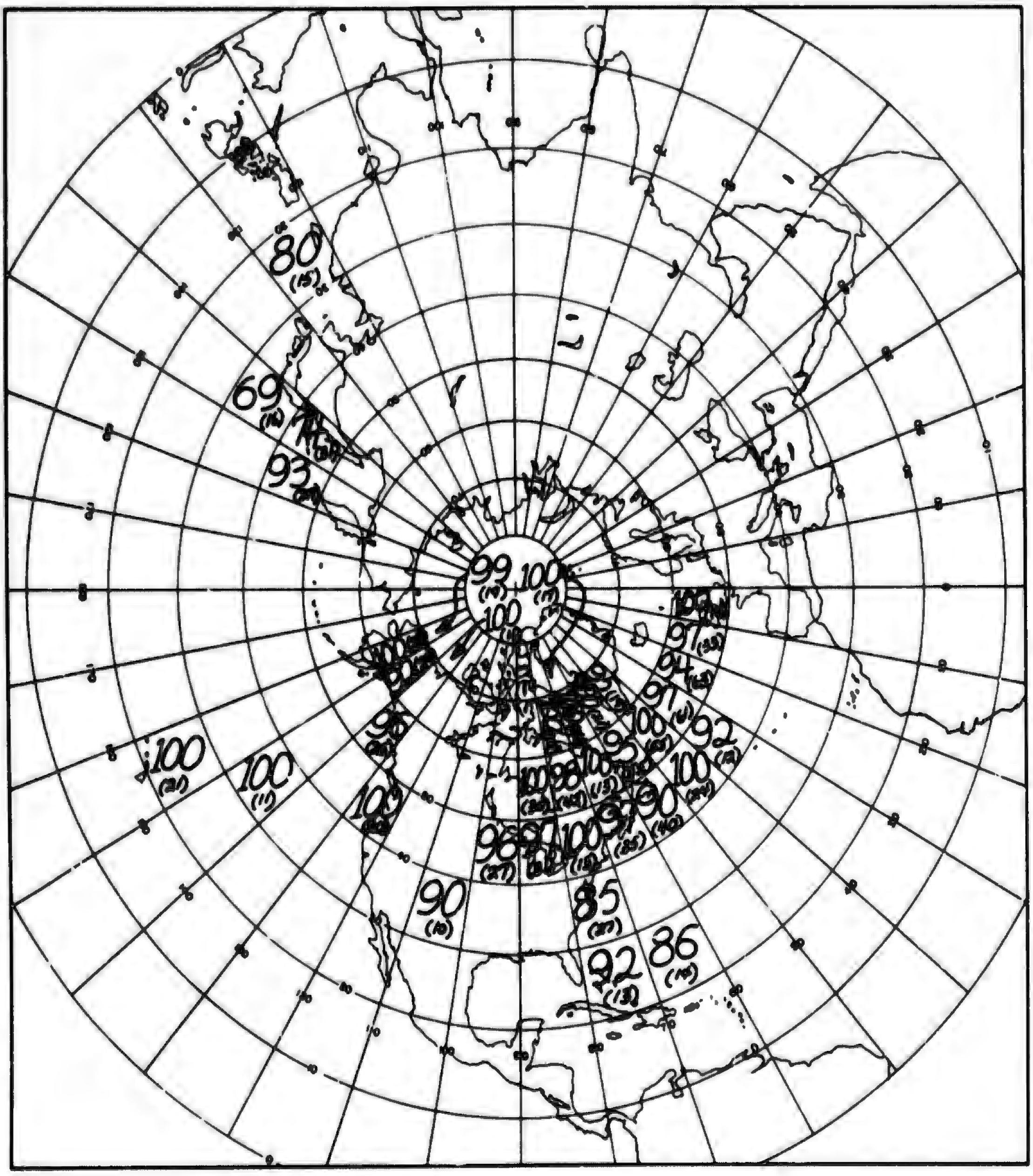

Figure C35. Estimates of the Probability of Seeing Blue Sky at 90° Above the Horizon (+ 90°) from Altitudes of 35,000 to 44,999 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

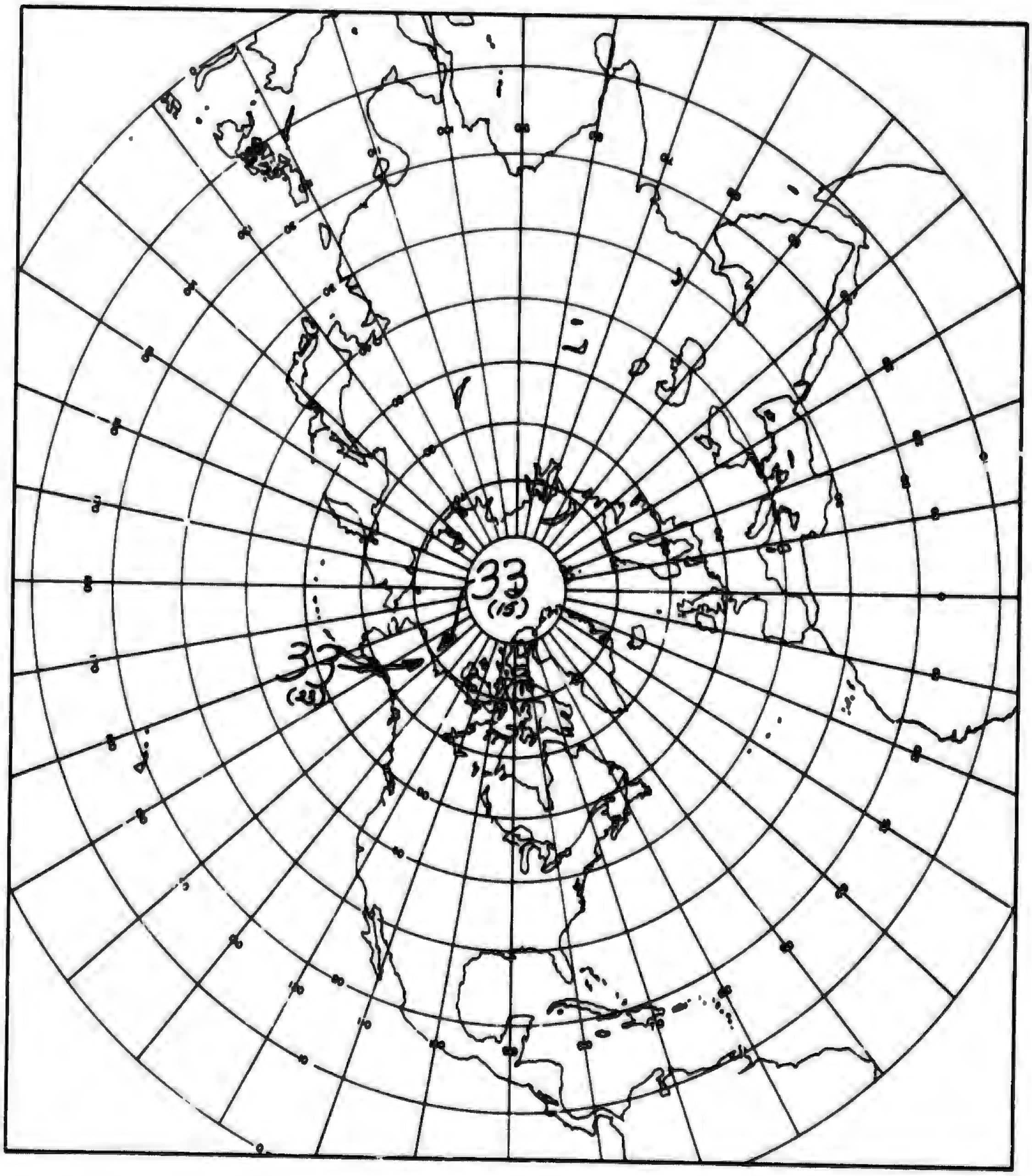

Figure C36. Estimates of the Probability of Seeing the Ground Directly Below the Aircraft (-90°) from Altitudes Above 45,000 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

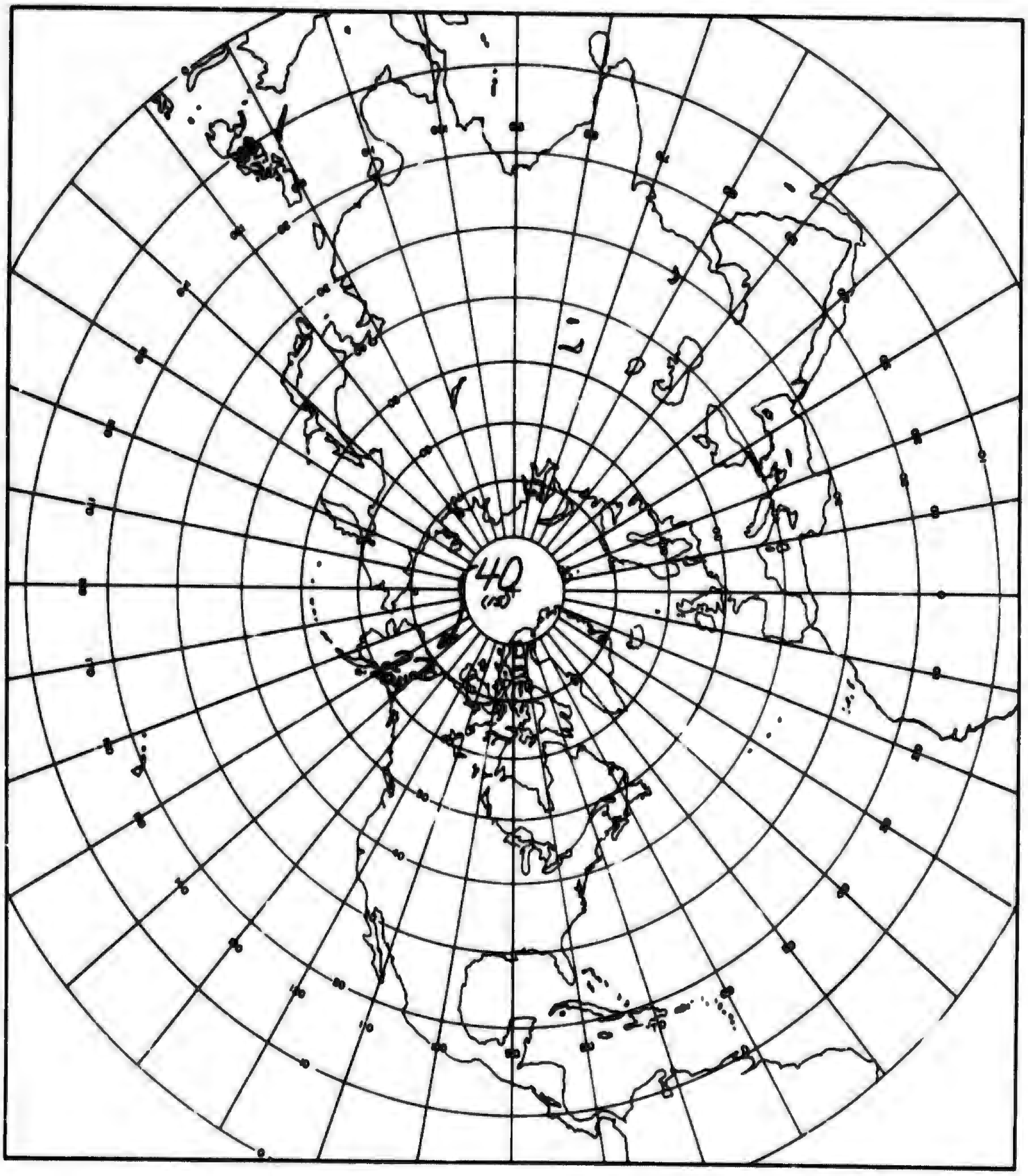

Figure C37. Estimates of the Probability of Seeing the Ground at 30° Below the Horizon (-30°) from Altitudes Above 45,000 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

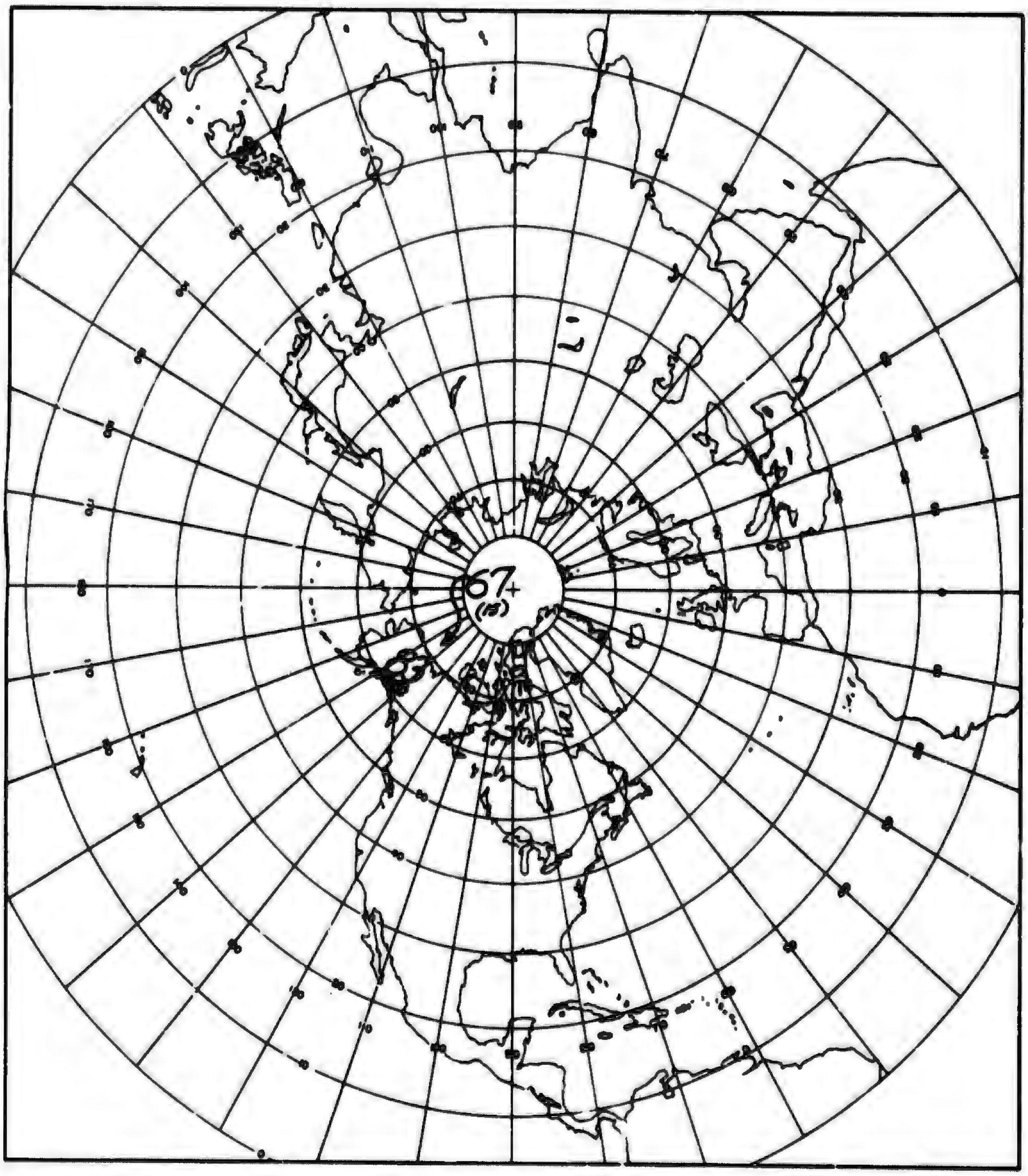

Figure C38. Estimates of the Probability of Seeing the Horizon from Altitudes Above 45,000 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

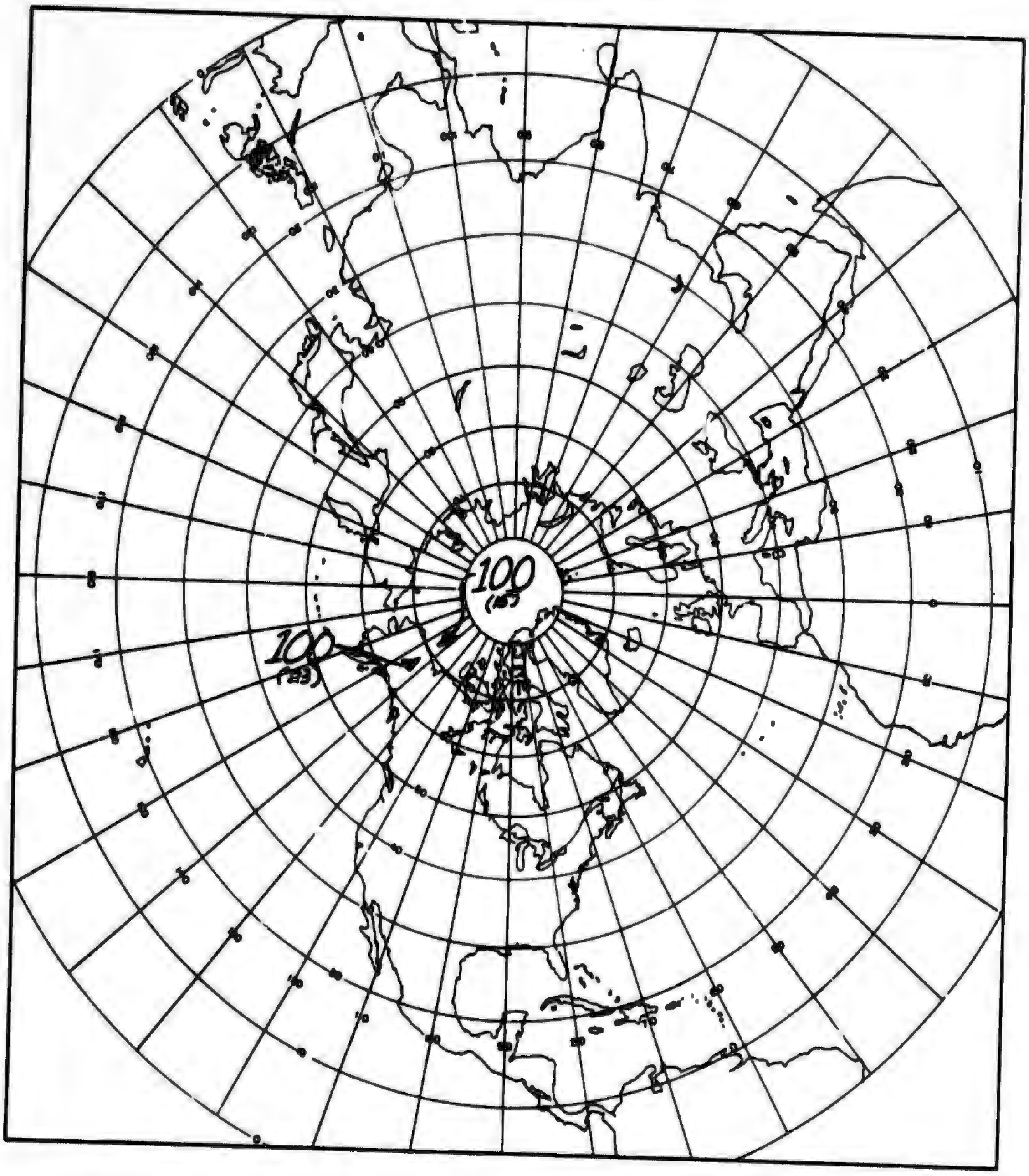

Figure C39. Estimates of the Probability of Seeing Blue Sky at 30° Above the Horizon (+ 30°) from Altitudes Above 45,000 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

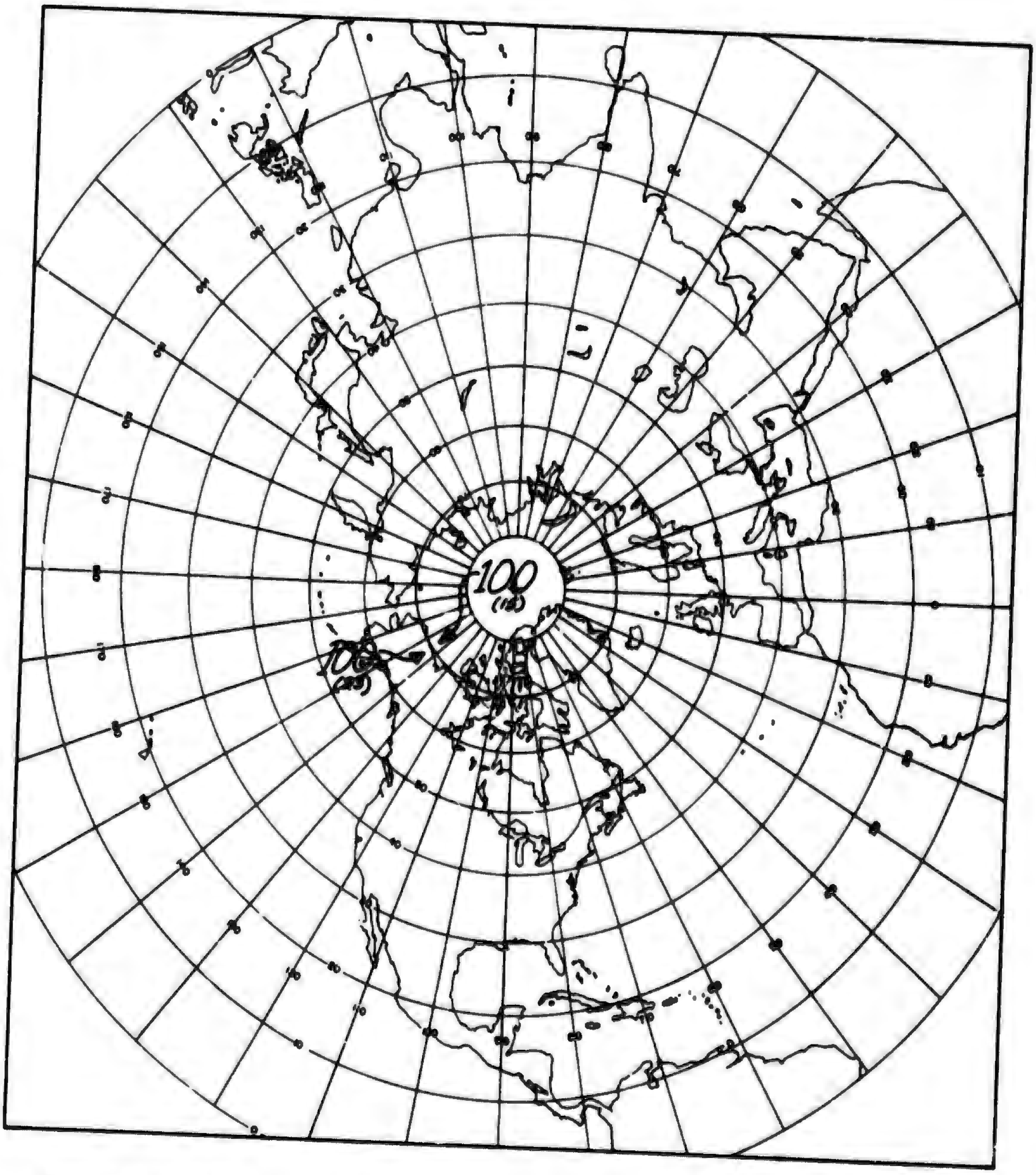

Figure C40. Estimates of the Probability of Seeing Blue Sky at 90° Above the Horizon (+ 90°) from Altitudes Above 45,000 ft, in Summer. (Estimates are based on the number of observations shown in parentheses)

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Appendix D

Fall Estimates of Probability of a Clear Line-of-Sight

In this appendix are given Northern Hemisphere maps of estimates of the probability of a clear line-of-sight for fall (September, October, November) at five selected angles of vision: (a) ground at 90 degrees below the horizon (-90°); (b) ground at 30 degrees below the horizon (-30°); (c) horizon; (d) sky at 30 degrees above the horizon (+30°); (e) sky at 90 degrees above the horizon (+90°), and for eight altitude layers: below 1800 ft; 1801 to 3600 ft; 3601 to 7400 ft; 7401 to 14,999 ft; 15,000 to 24,999 ft; 25,000 to 34,999 ft; 35,000 to 44,999 ft; and above 45,000 ft. The Northern Hemisphere is divided into 10° latitude-longitude sectors. The values given in these sectors are estimates of the probability of a clear line-of-sight. Values in parentheses indicate the number of observations taken in that sector. Probabilities were not computed for sectors that reported less than 10 observations.

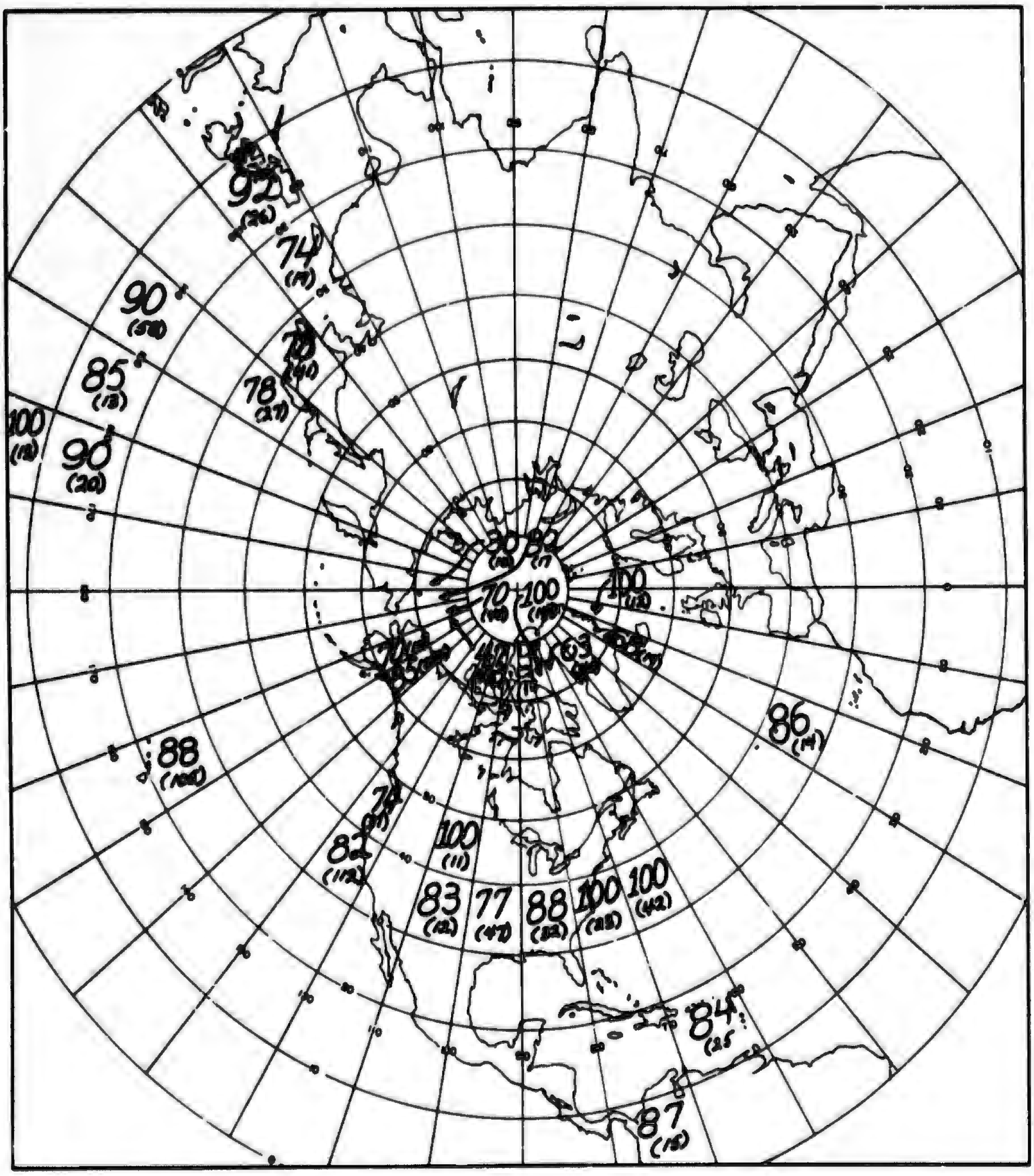

Figure D1. Estimates of the Probability of Seeing the Ground Directly Below the Aircraft (-90°) from Altitudes up to 1800 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

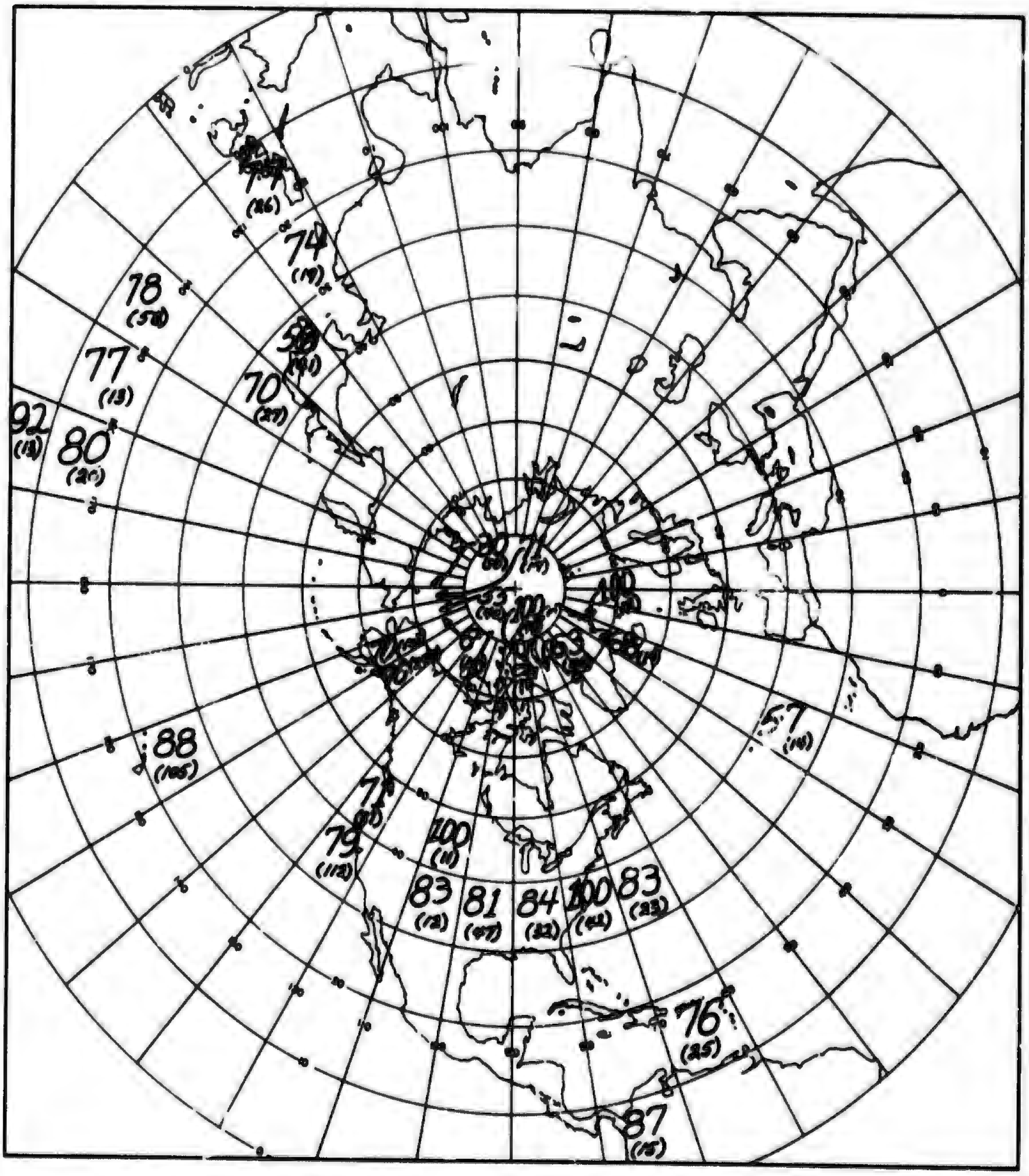

Figure D2. Estimates of the Probability of Seeing the Ground at 30° Below the Horizon (-30°) from Altitudes up to 1800 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

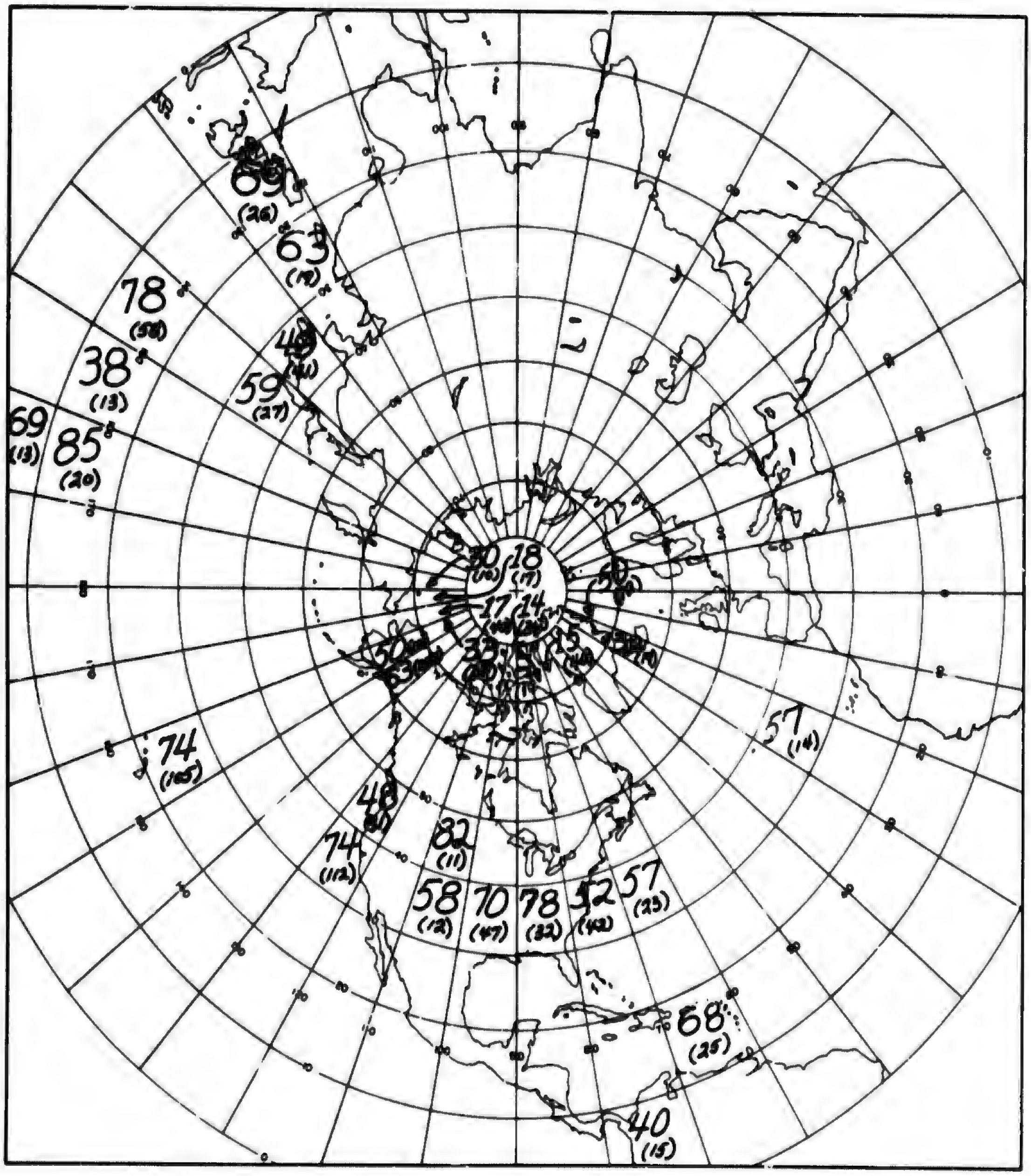

Figure D3. Estimates of the Probability of Seeing the Horizon from Altitudes up to 1800 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

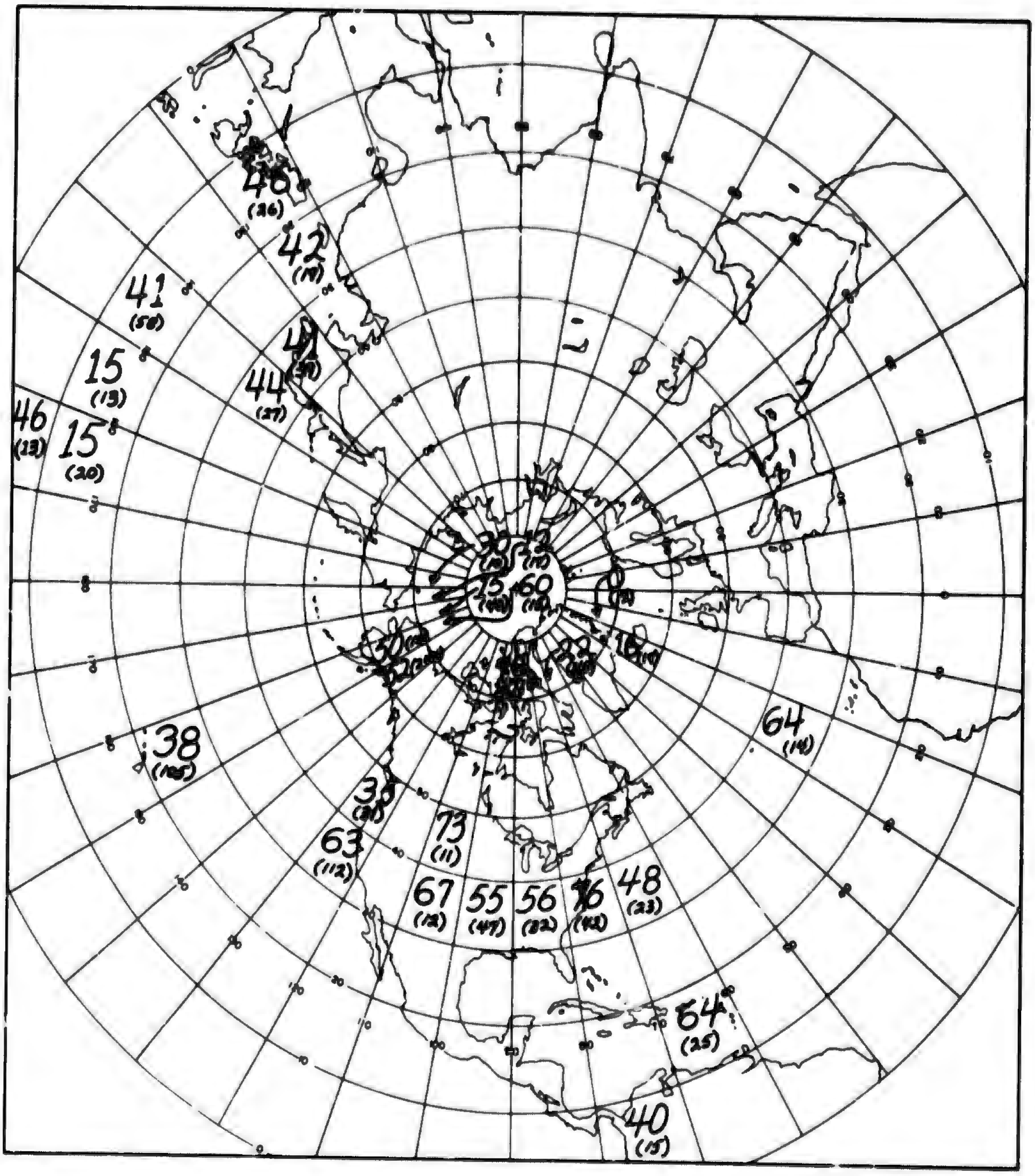

Figure D4. Estimates of the Probability of Seeing Blue Sky at 30° Above the Horizon (+ 30°) from Altitudes up to 1800 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

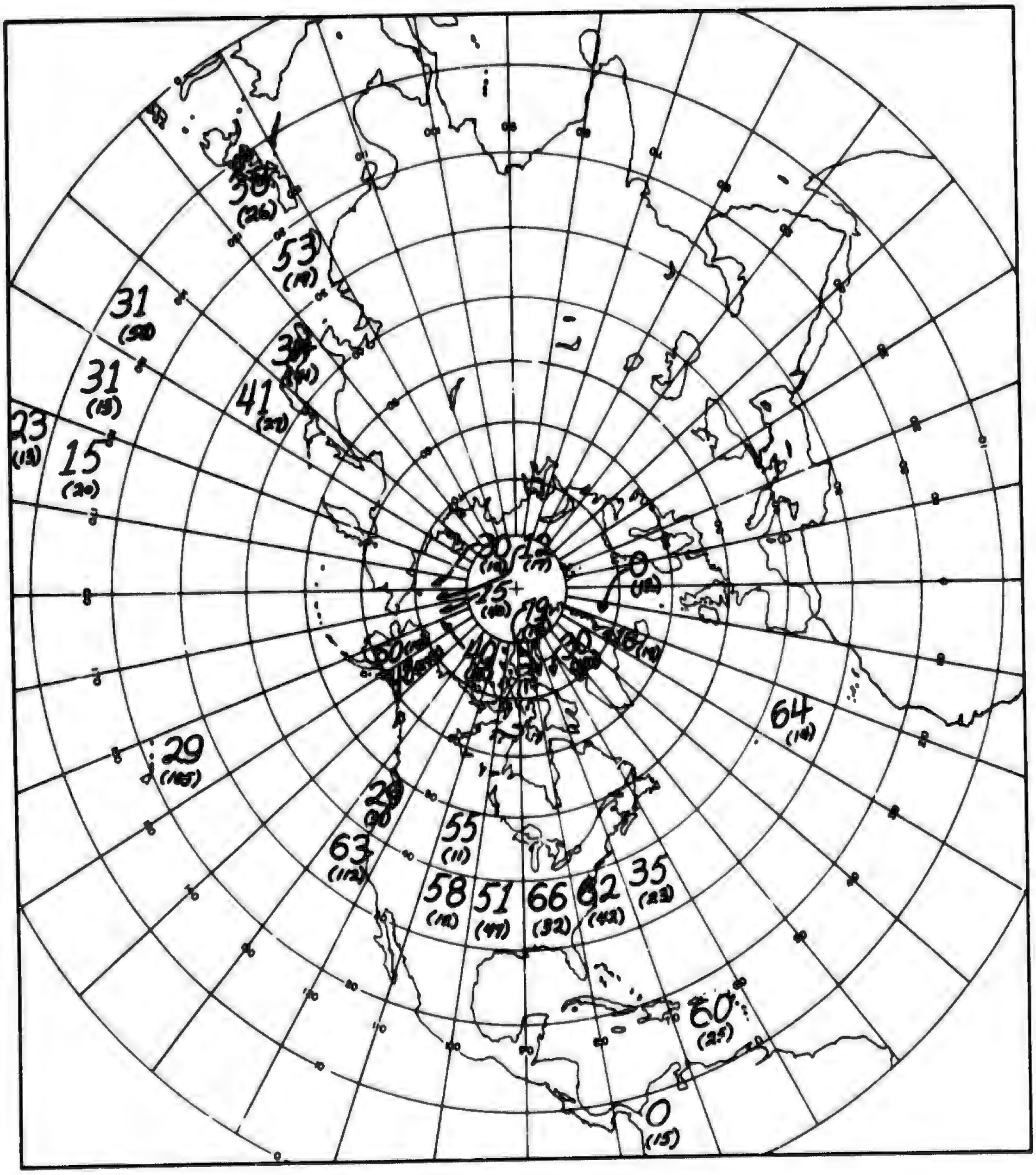

Figure D5. Estimates of the Probability of Seeing Blue Sky at 90° Above the Horizon (+ 90°) from Altitudes up to 1800 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

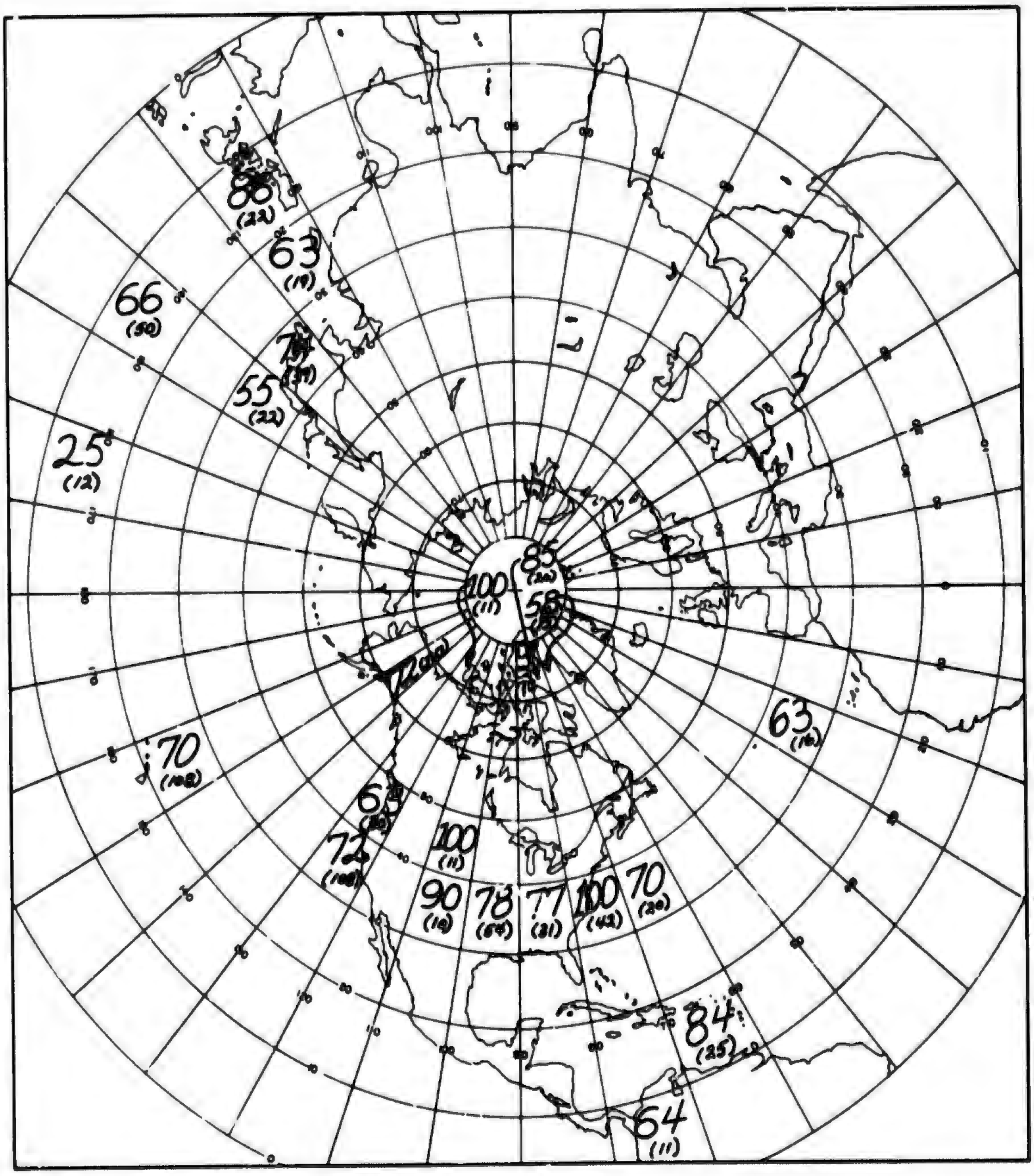

Figure D6. Estimates of the Probability of Seeing the Ground Directly Below the Aircraft (-90°) from Altitudes of 1801 to 3600 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

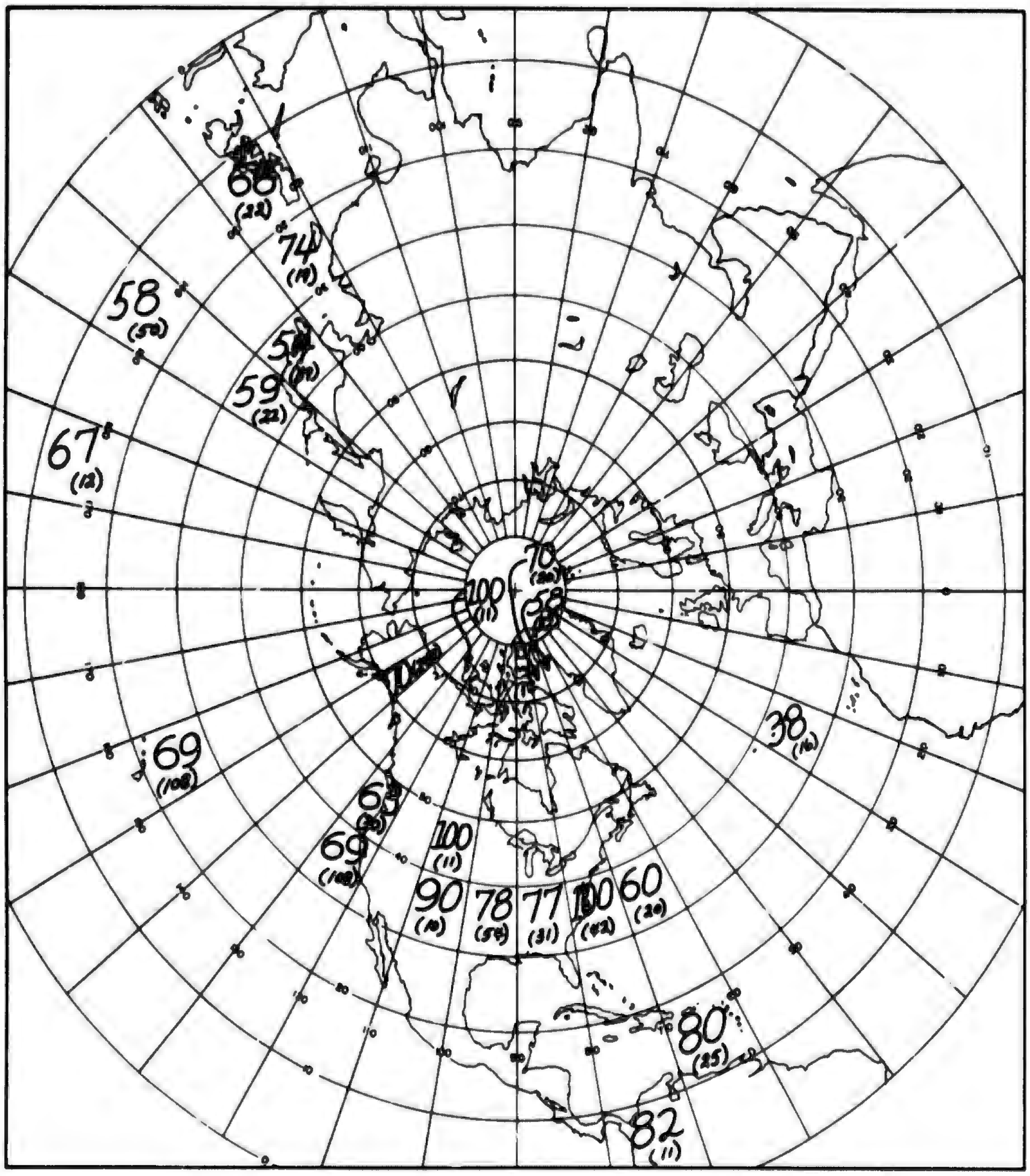

Figure D7. Estimates of the Probability of Seeing the Ground at 30° Below the Horizon (-30°) from Altitudes of 1801 to 3600 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

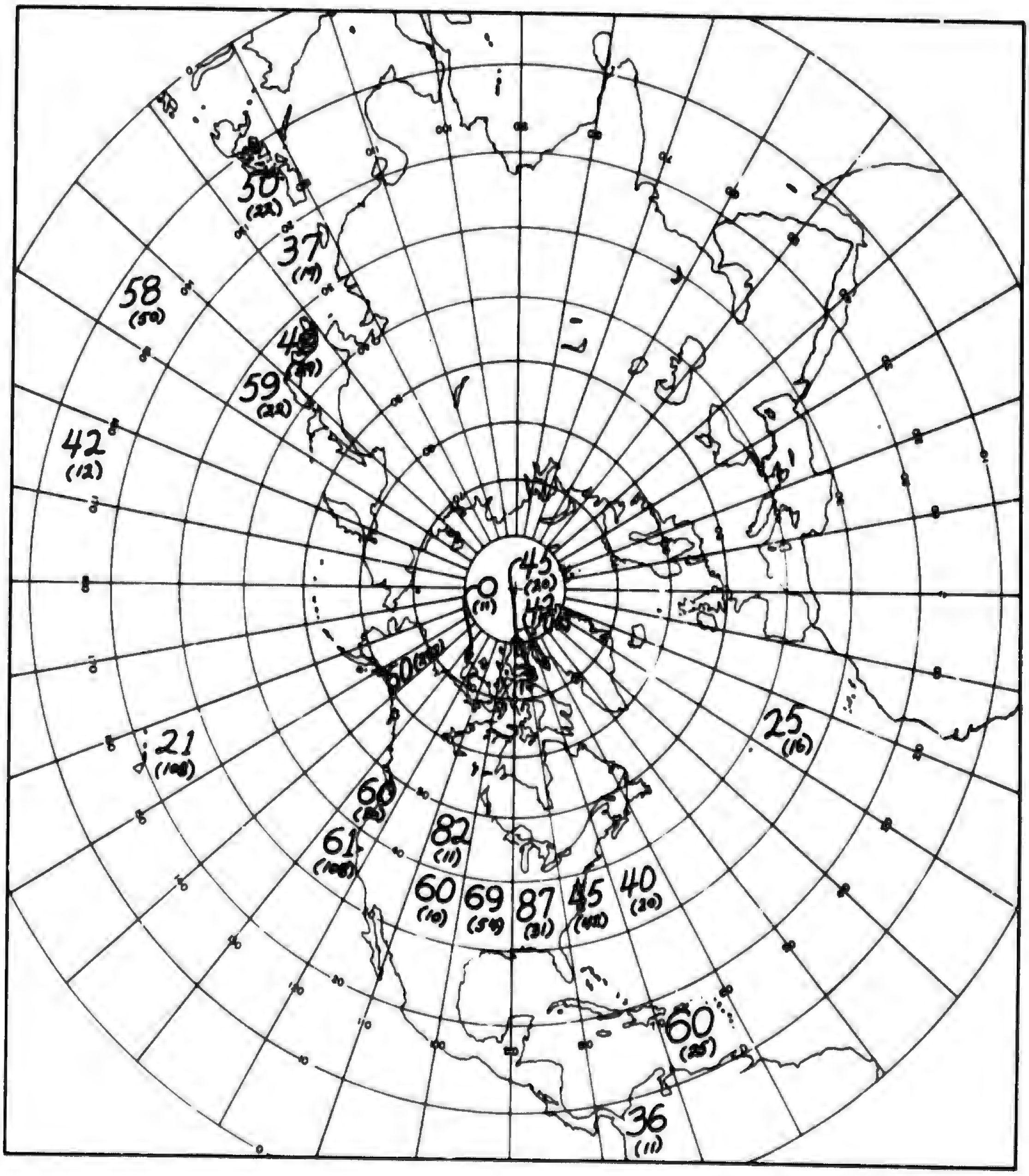

Figure D8. Estimates of the Probability of Seeing the Horizon from Altitudes of 1801 to 3600 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

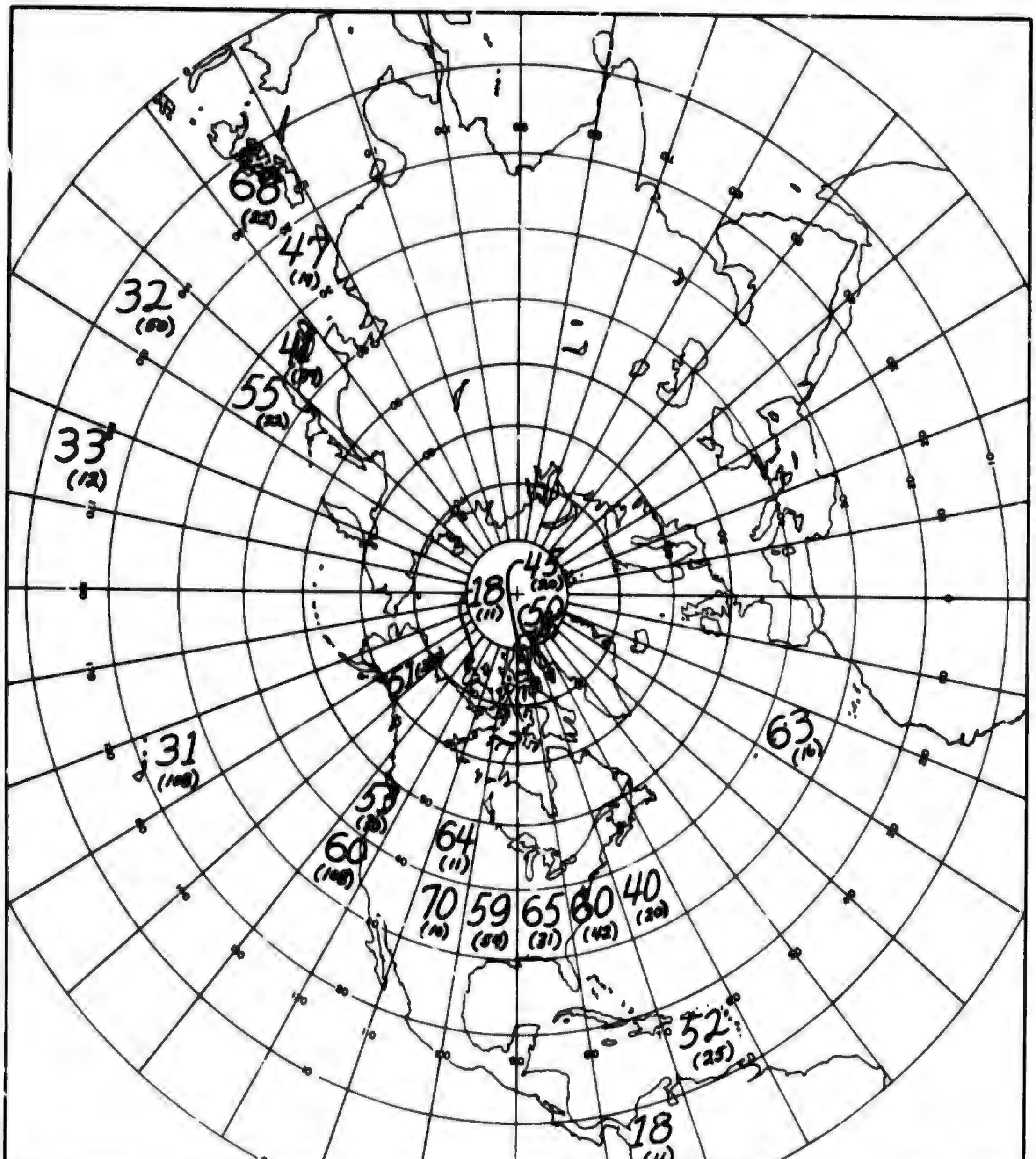

Figure D9. Estimates of the Probability of Seeing Blue Sky at 30° Above the Horizon (+ 30°) from Altitudes of 1801 to 3600 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

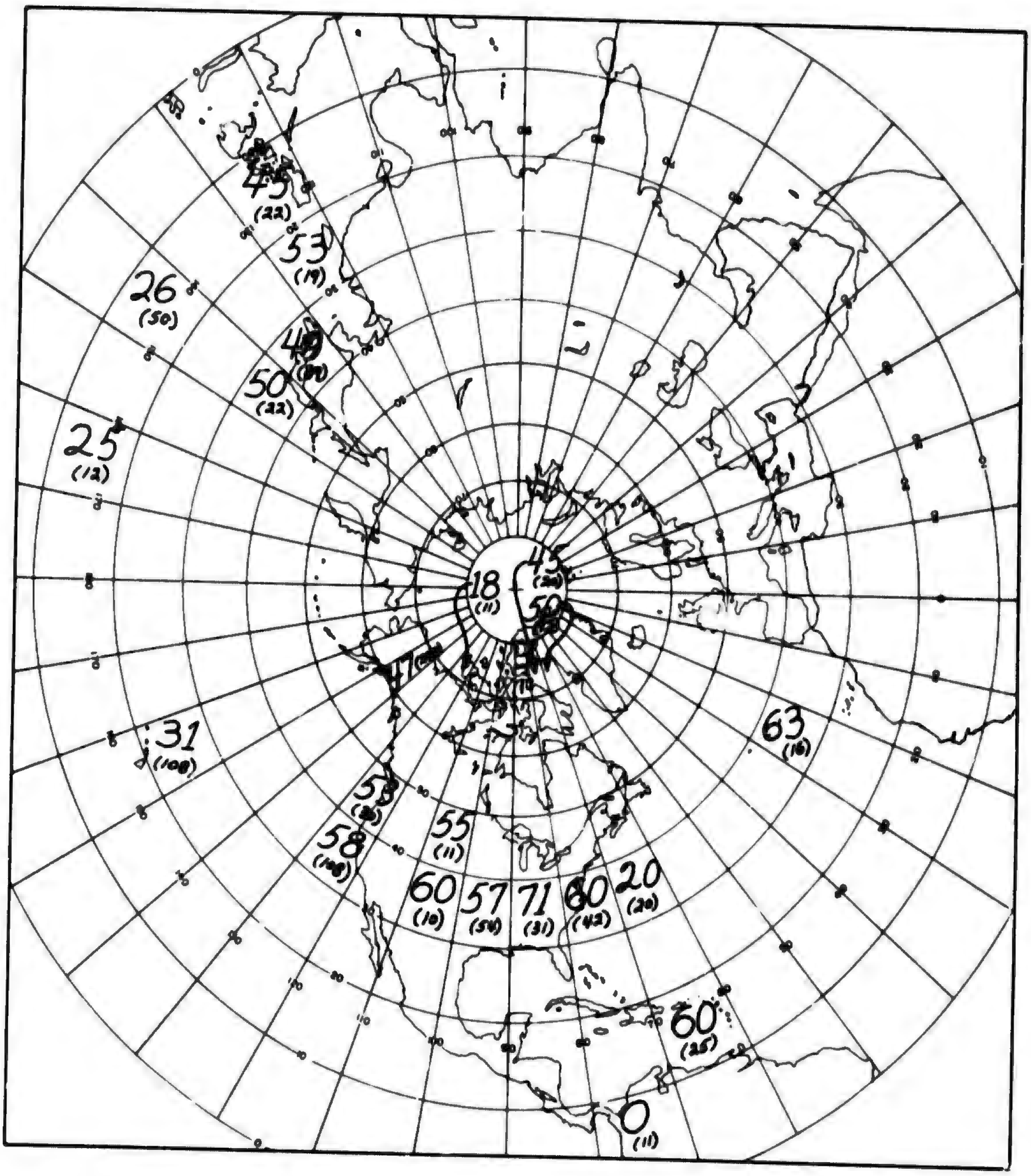

Figure D10. Estimates of the Probability of Seeing Blue Sky at 90° Above the Horizon (+ 90°) from Altitudes of 1801 to 3600 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

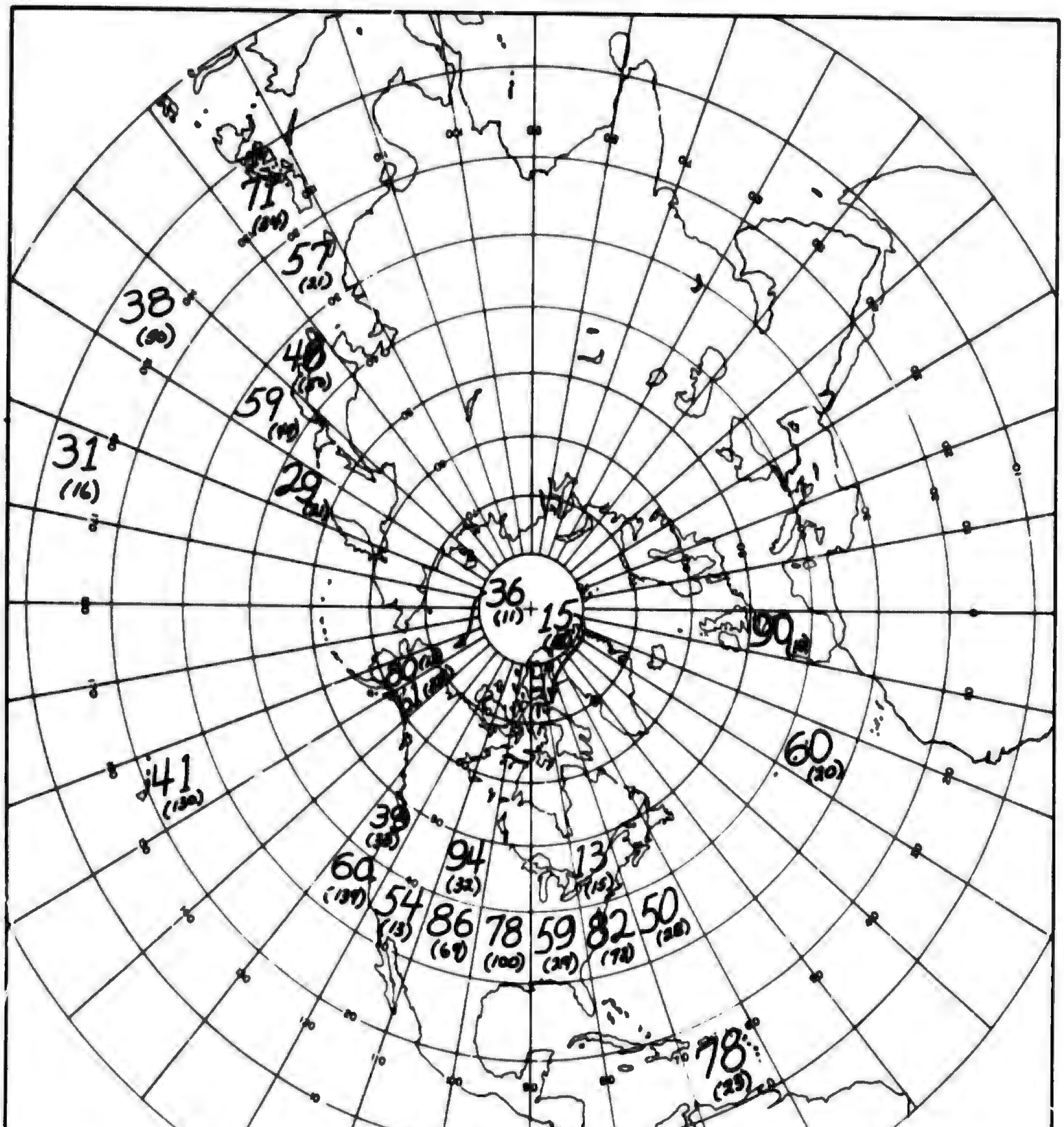

Figure D11. Estimates of the Probability of Seeing the Ground Directly Below the Aircraft (-90°) from Altitudes of 3601 to 7400 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

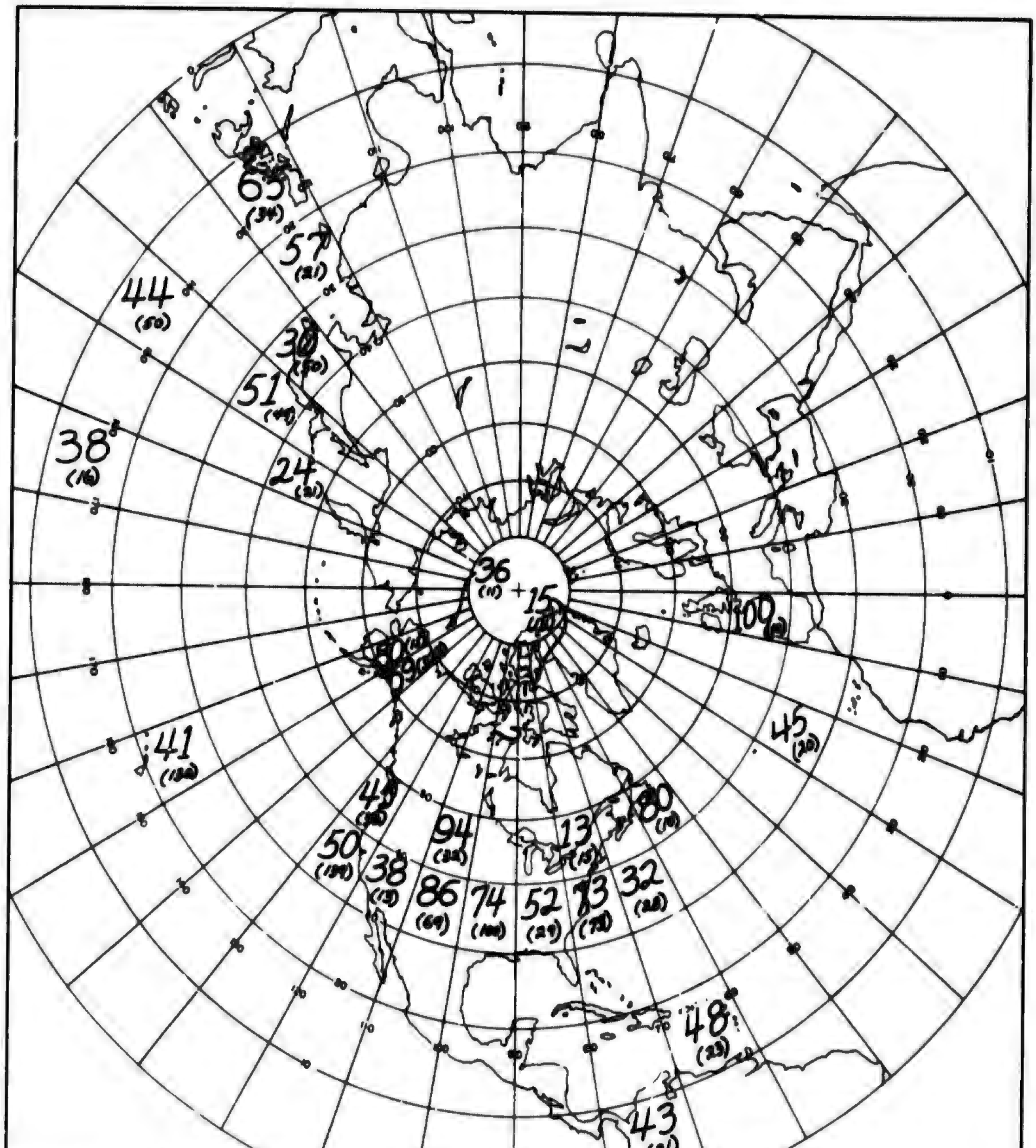

Figure D12. Estimates of the Probability of Seeing the Ground at 30° Below the Horizon (-30°) from Altitudes of 3601 to 7400 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

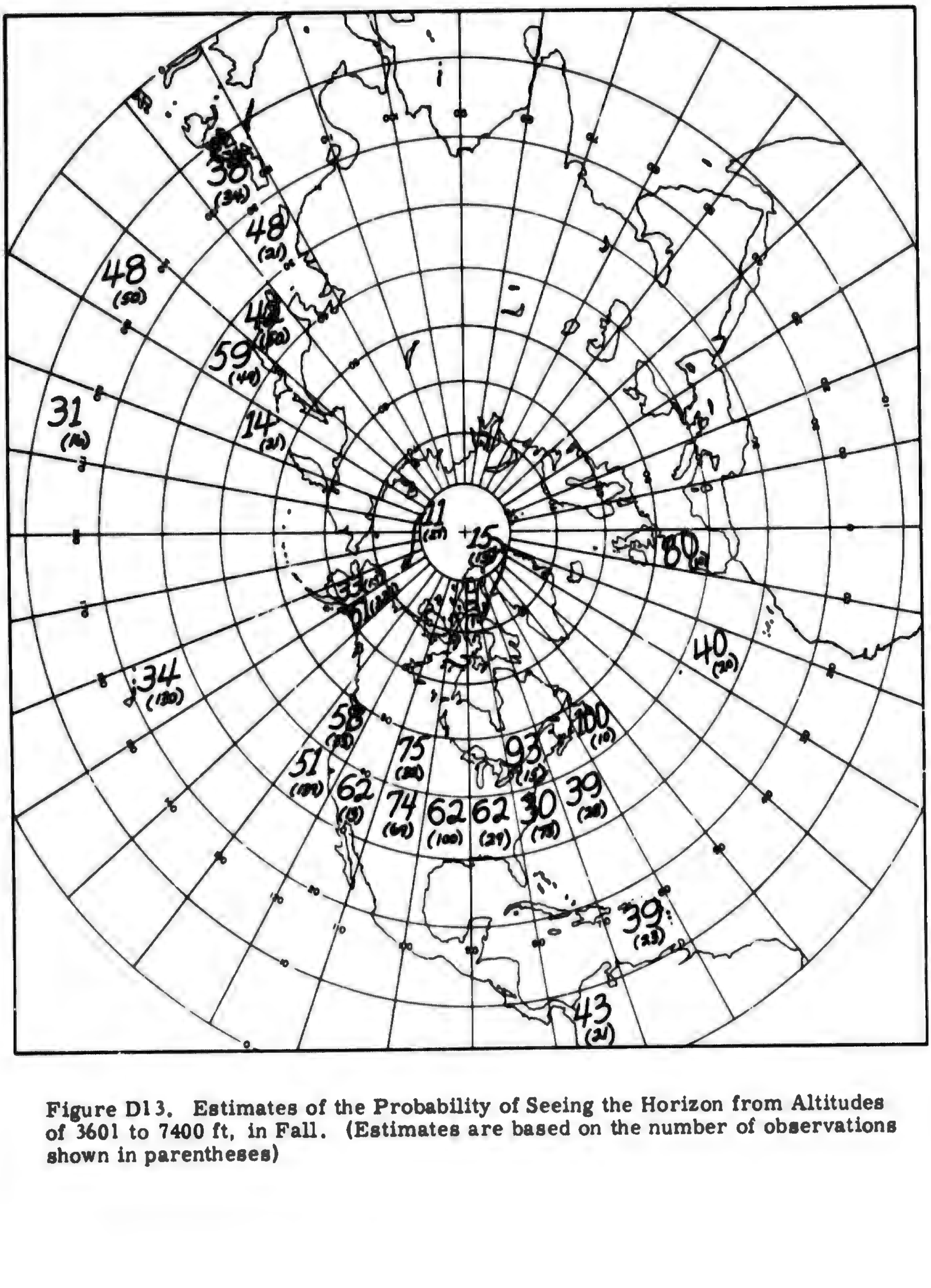

Figure D13. Estimates of the Probability of Seeing the Horizon from Altitudes of 3601 to 7400 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

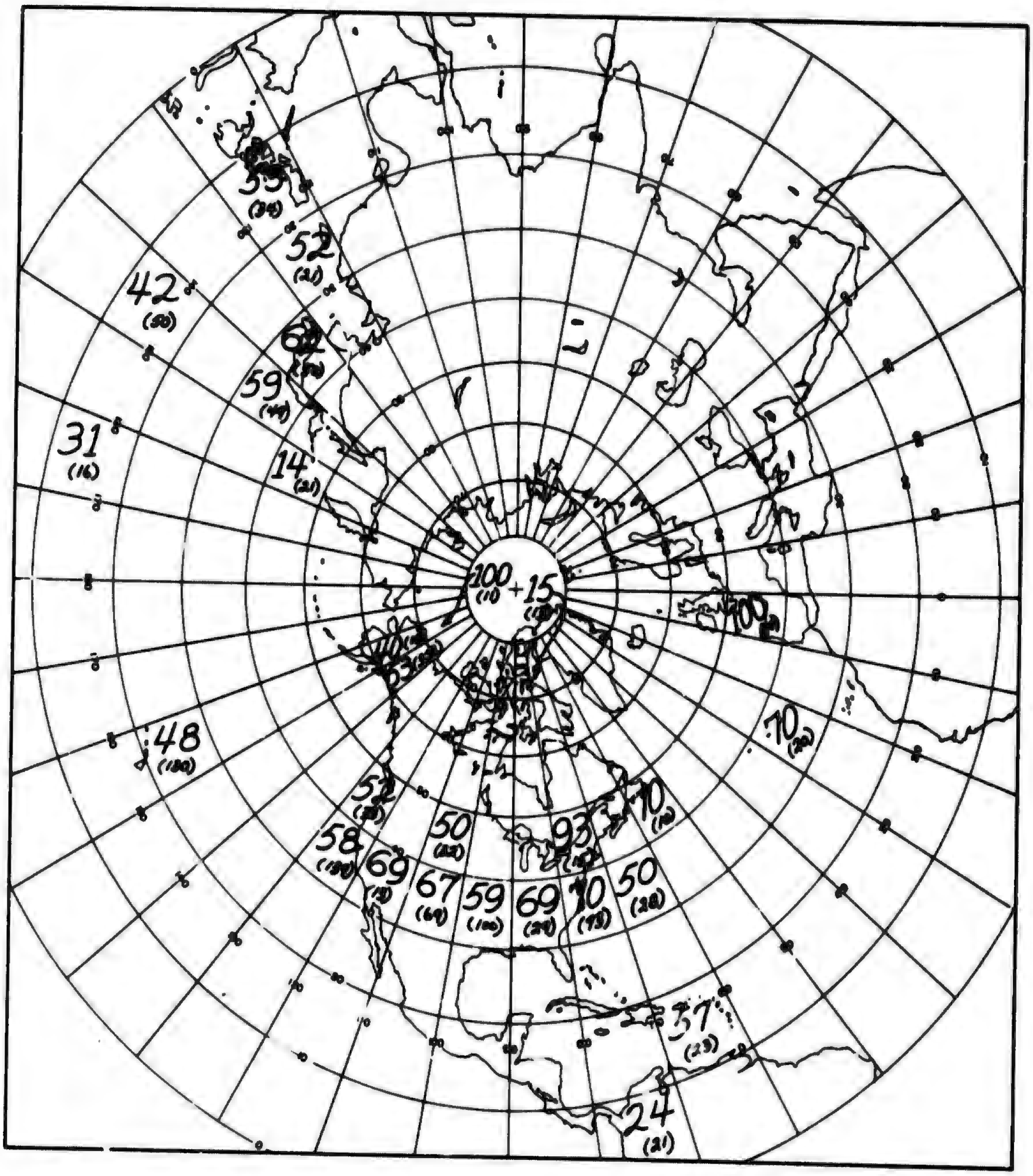

Figure D14. Estimates of the Probability of Seeing Blue Sky at 30° Above the Horizon (+ 30°) from Altitudes of 3601 to 7400 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

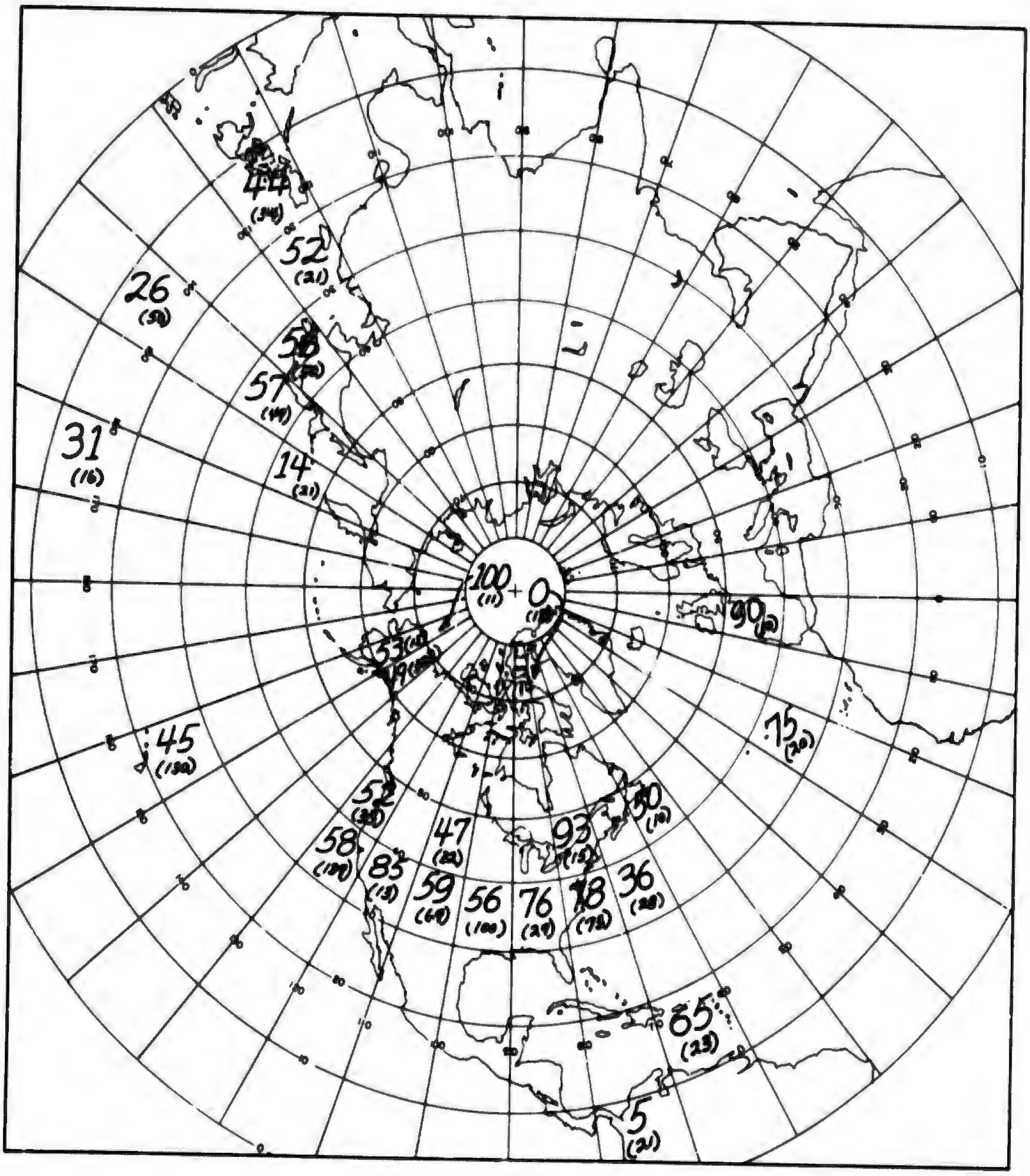

Figure D15. Estimates of the Probability of Seeing Blue Sky at 90° Above the Horizon (+ 90°) from Altitudes of 3601 to 7400 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

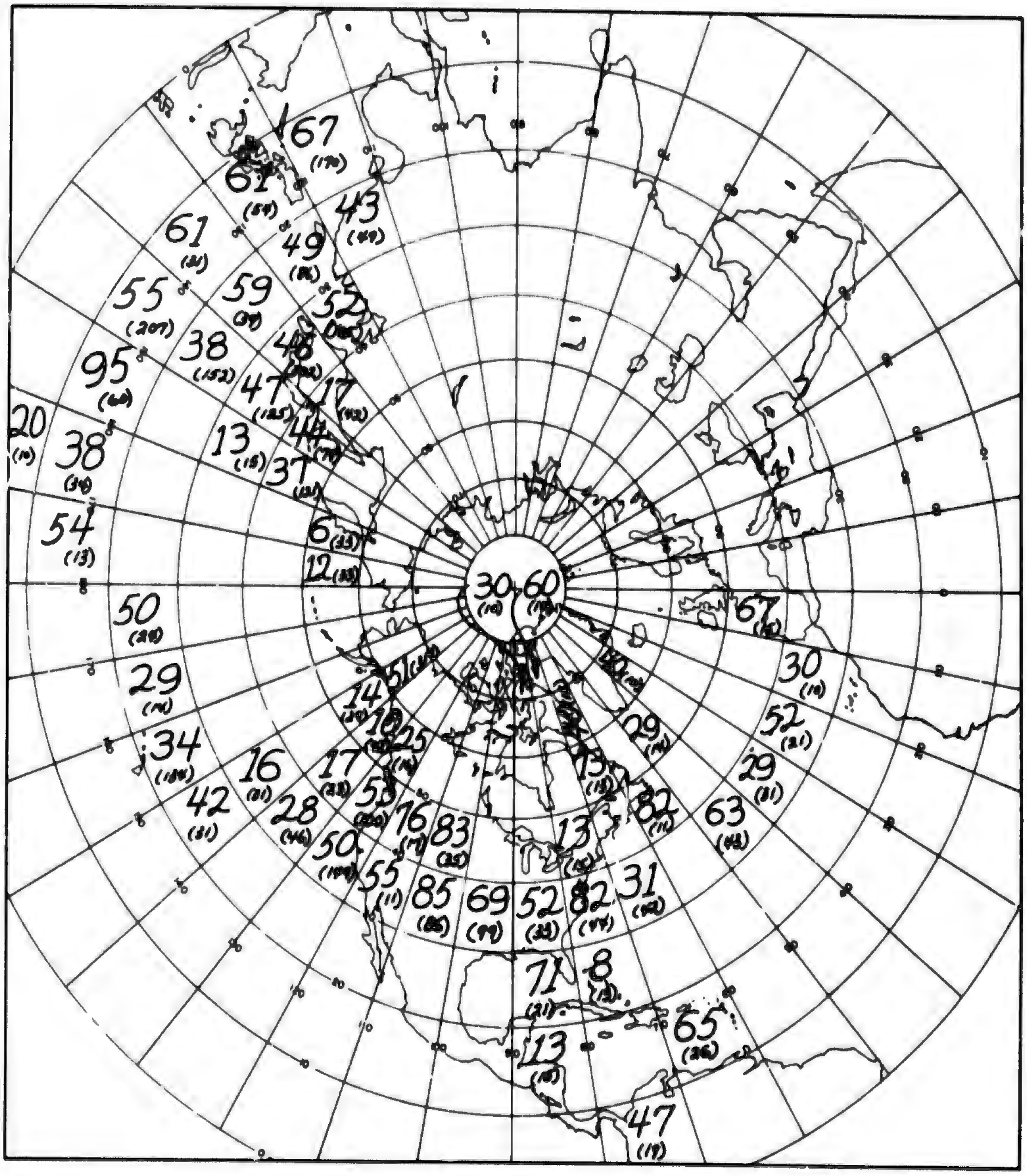

Figure D16. Estimates of the Probability of Seeing the Ground Directly Below the Aircraft (-90°) from Altitudes of 7401 to 14,999 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

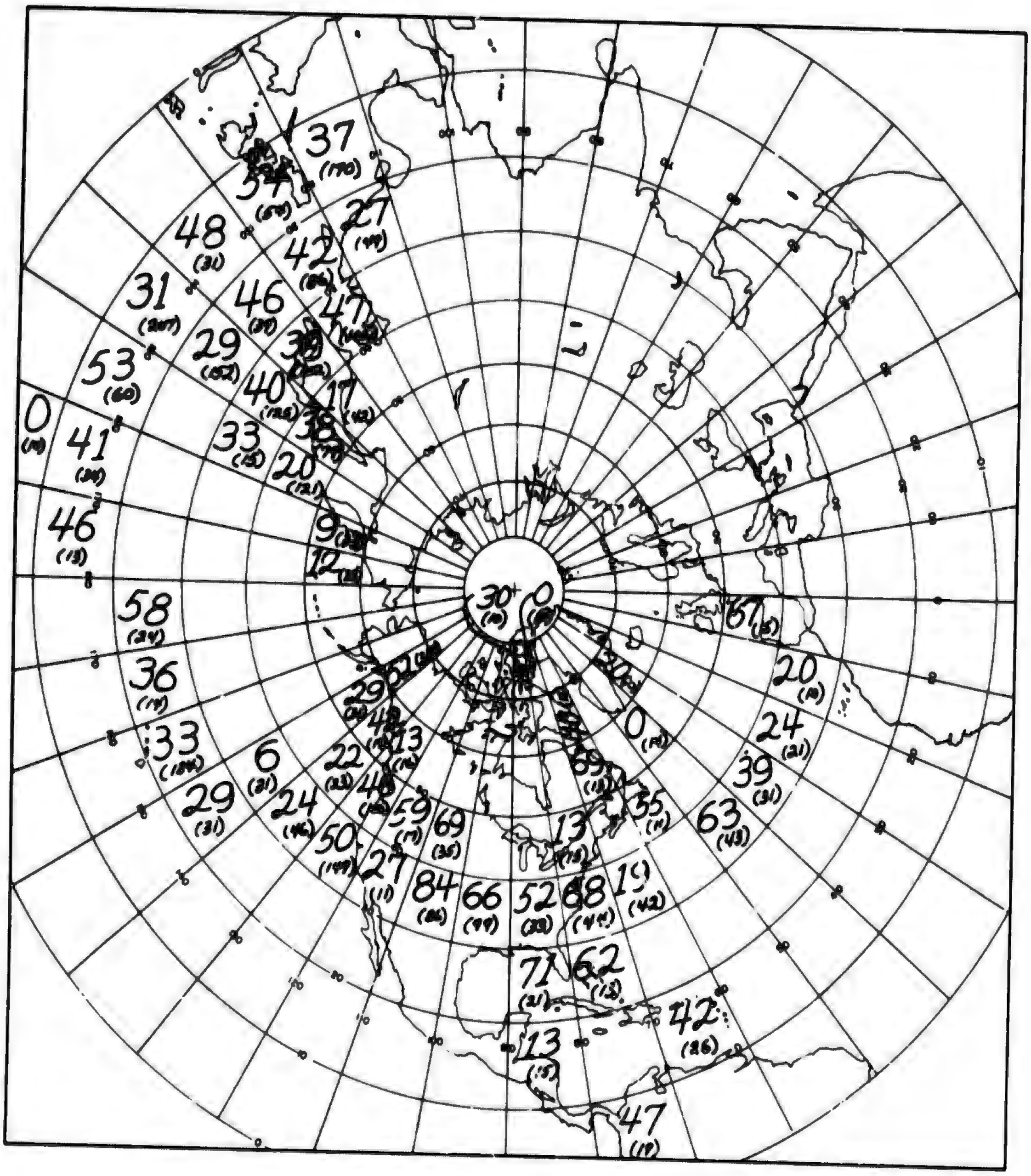

Figure D17. Estimates of the Probability of Seeing the Ground at 30° Below the Horizon (-30°) from Altitudes of 7401 to 14,999 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

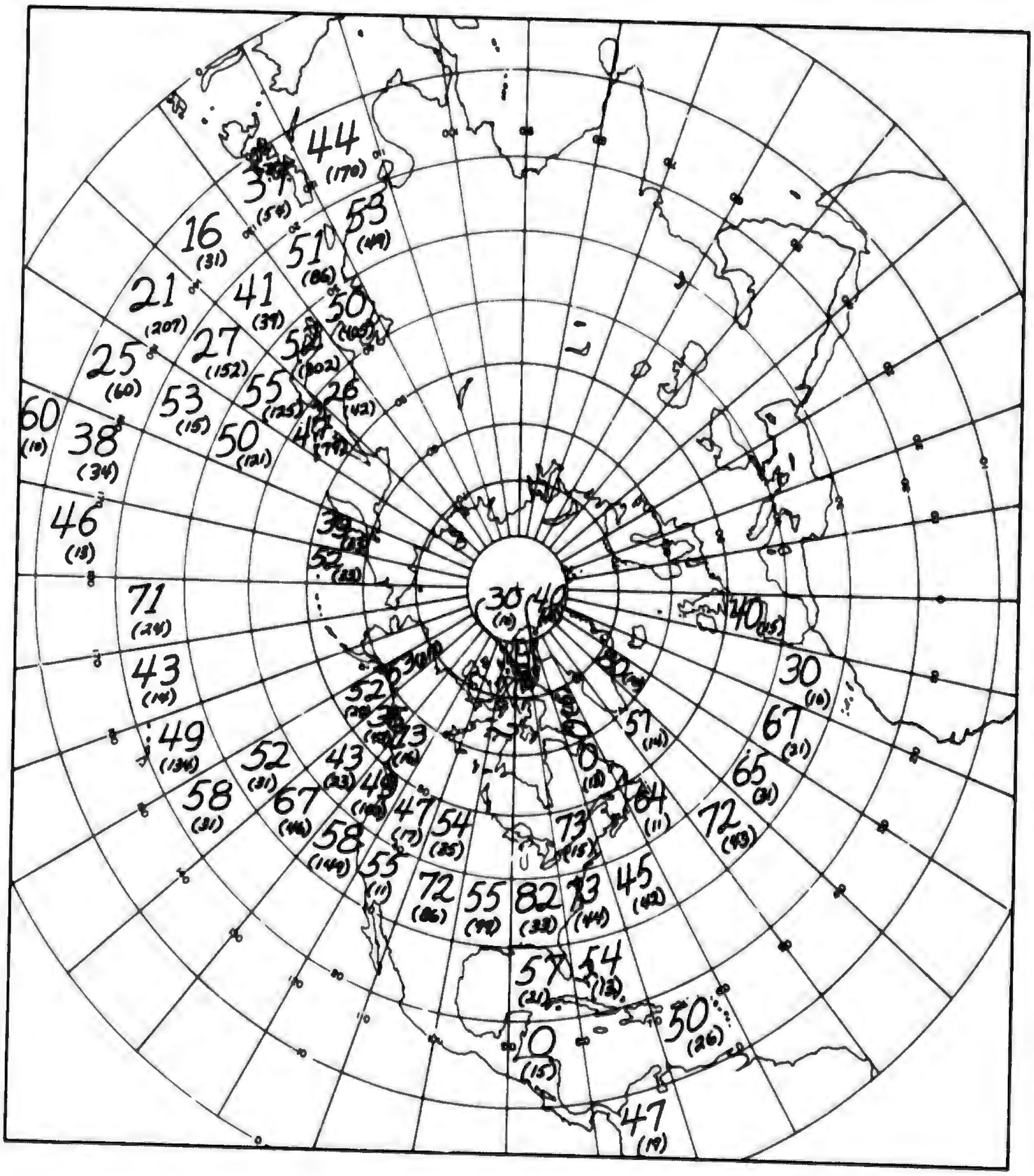

Figure D18. Estimates of the Probability of Seeing the Horizon from Altitudes of 7401 to 14,999 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

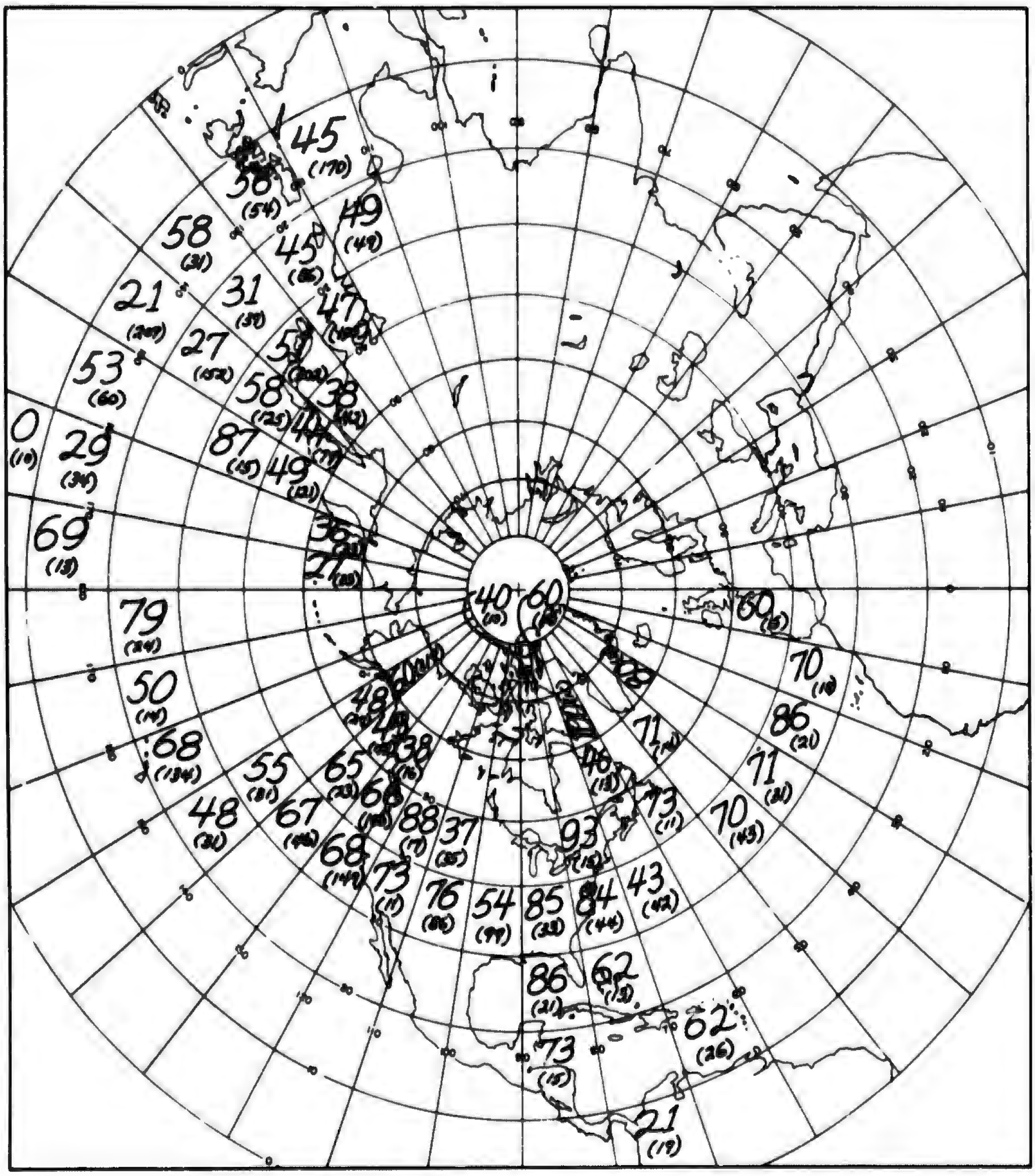

Figure D19. Estimates of the Probability of Seeing Blue Sky at 30° Above the Horizon (+ 30°) from Altitudes of 7401 to 14,999 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

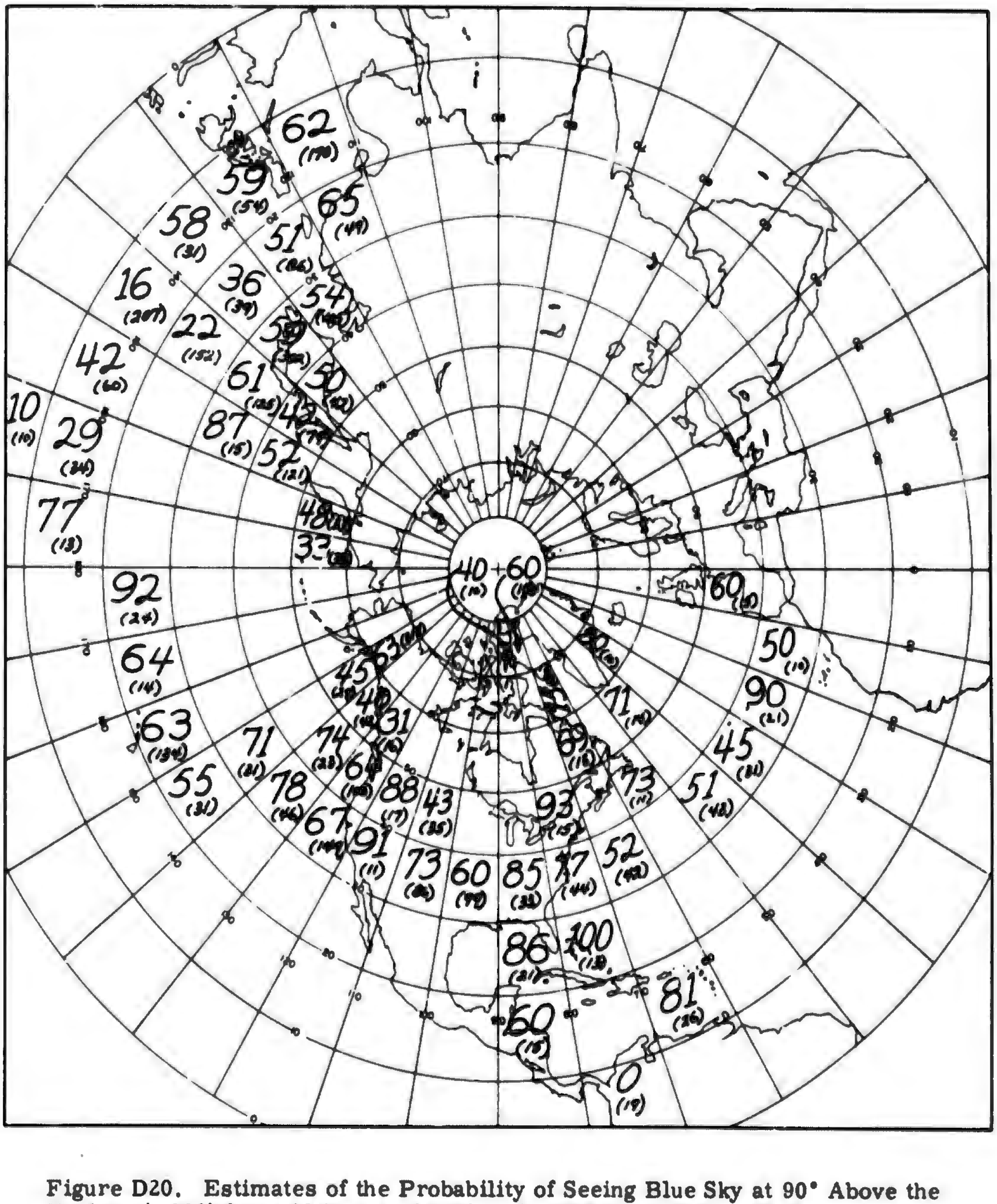

Figure D20. Estimates of the Probability of Seeing Blue Sky at 90° Above the Horizon (+ 90°) from Altitudes of 7401 to 14,999 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

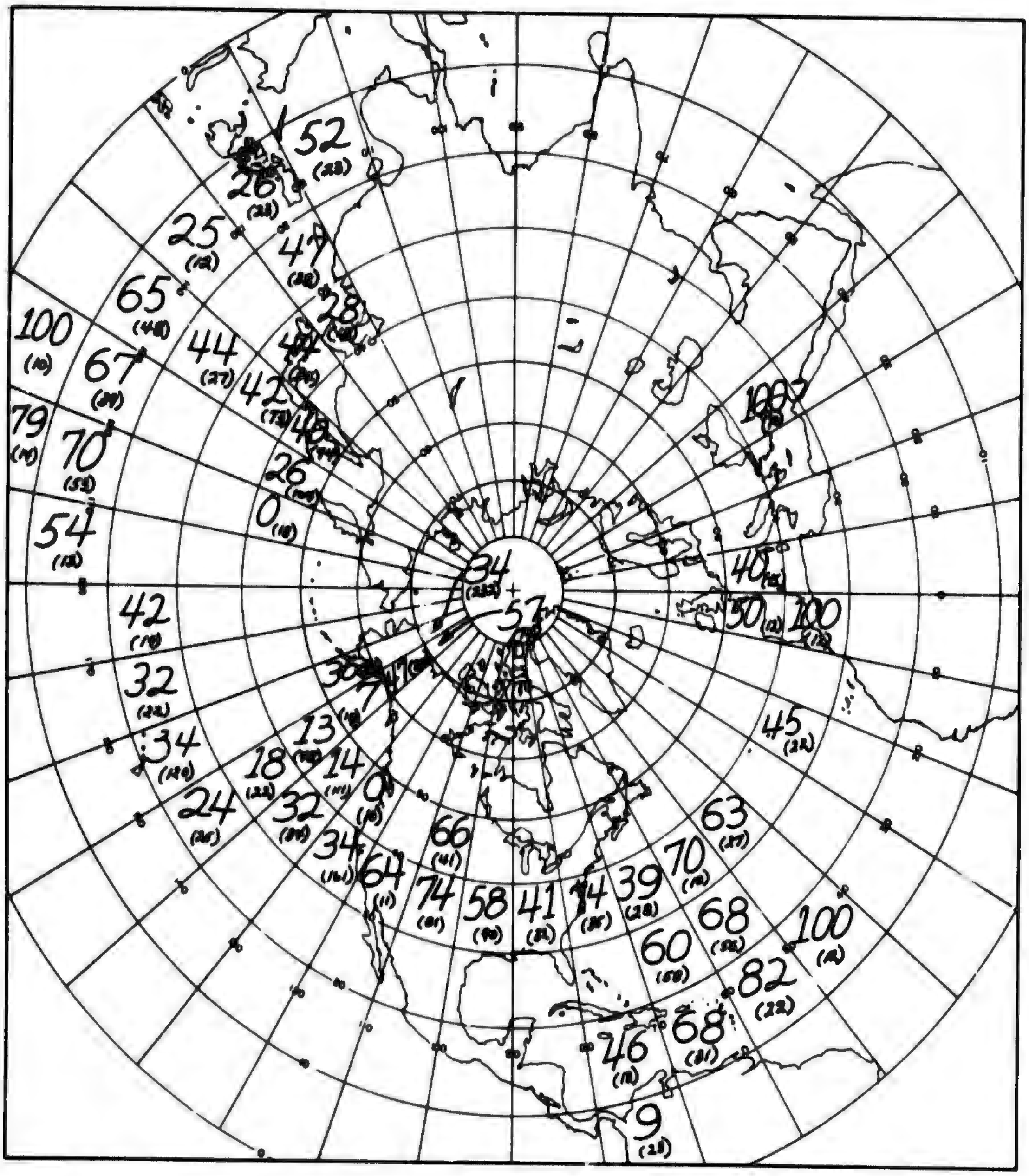

Figure D21. Estimates of the Probability of Seeing the Ground Directly Below the Aircraft (-90°) from Altitudes of 15,000 to 24,999 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

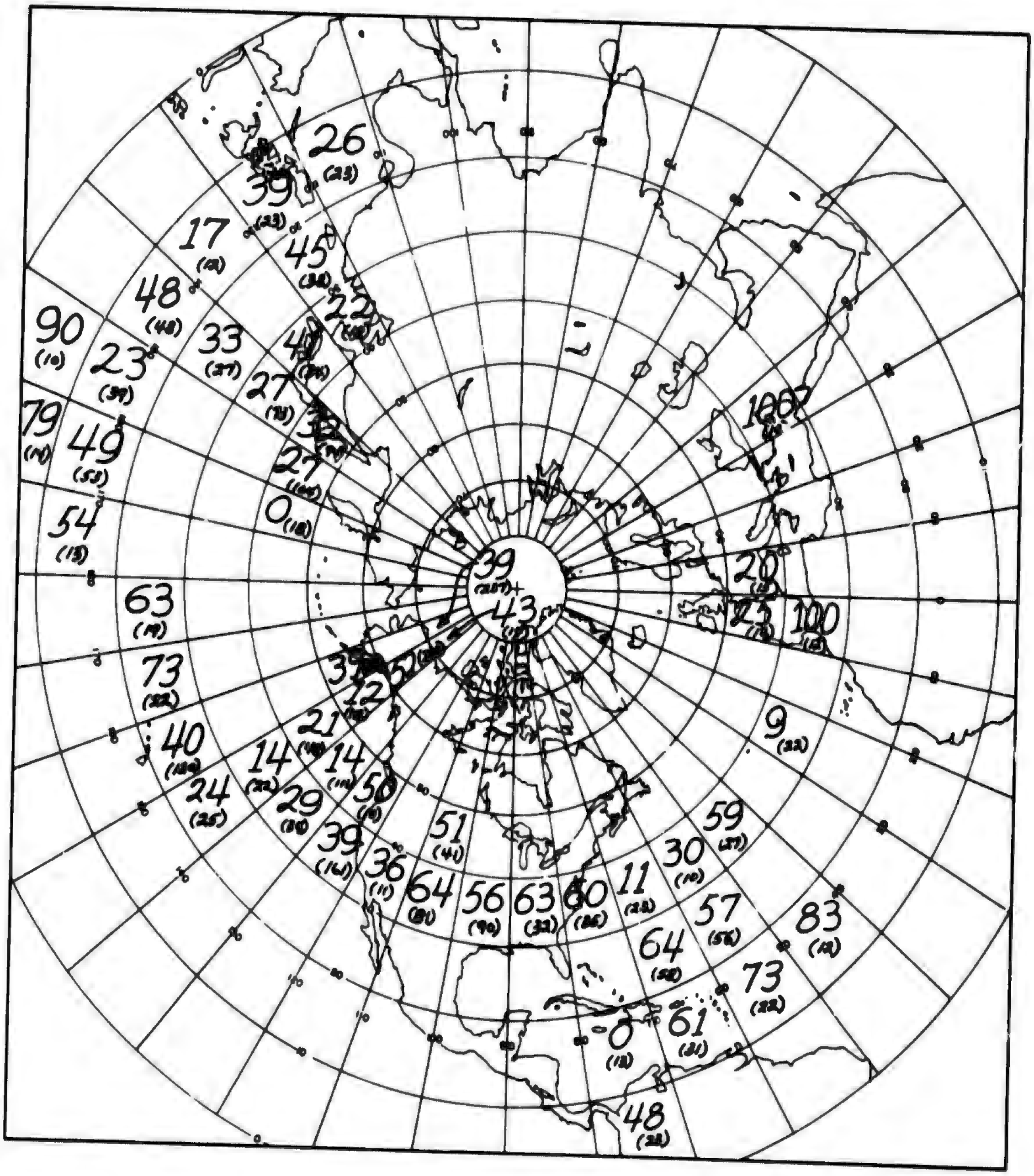

Figure D22. Estimates of the Probability of Seeing the Ground at 30° Below the Horizon (-30°) from Altitudes of 15,000 to 24,999 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

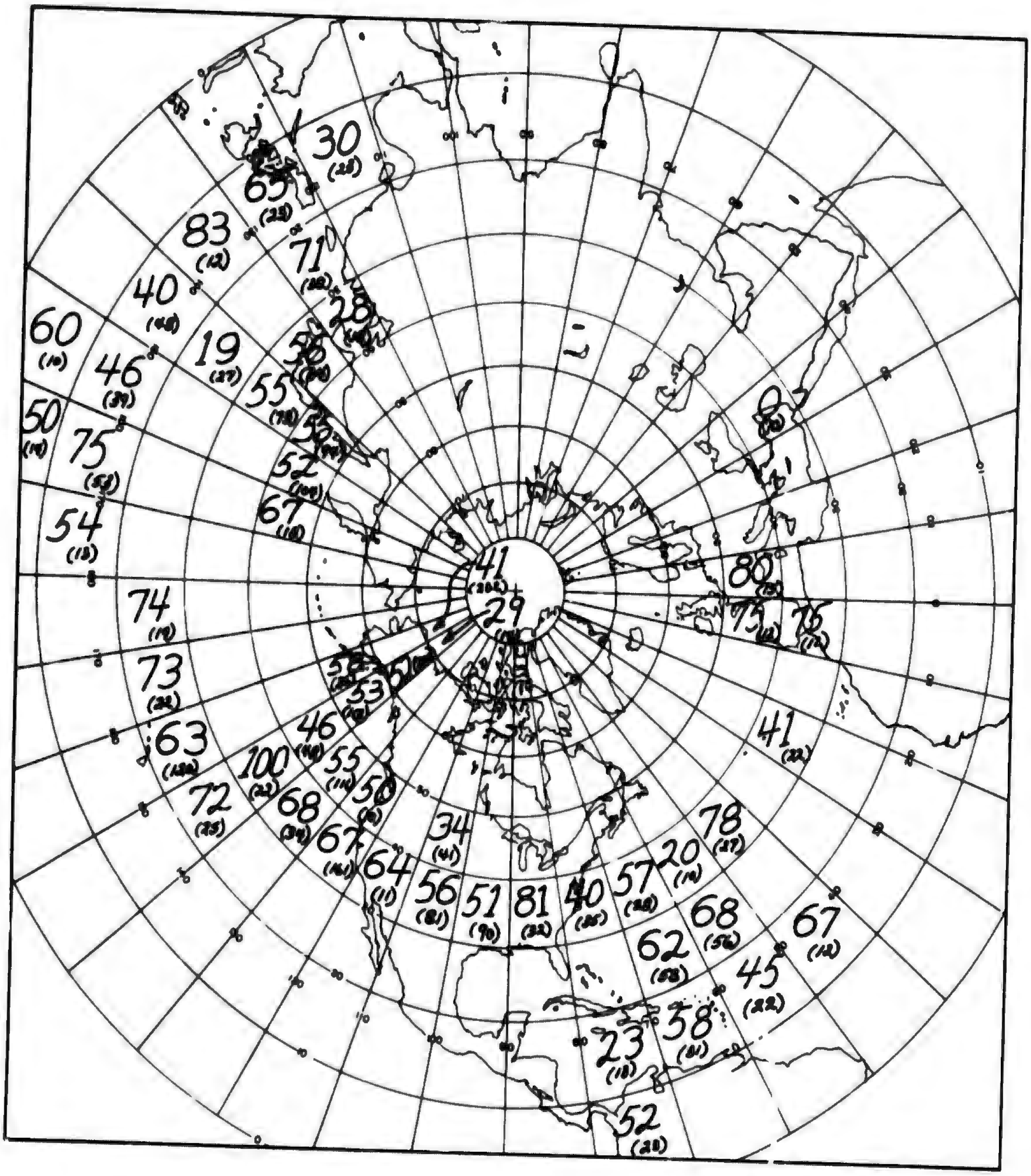

Figure D23. Estimates of the Probability of Seeing the Horizon from Altitudes of 15,000 to 24,999 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

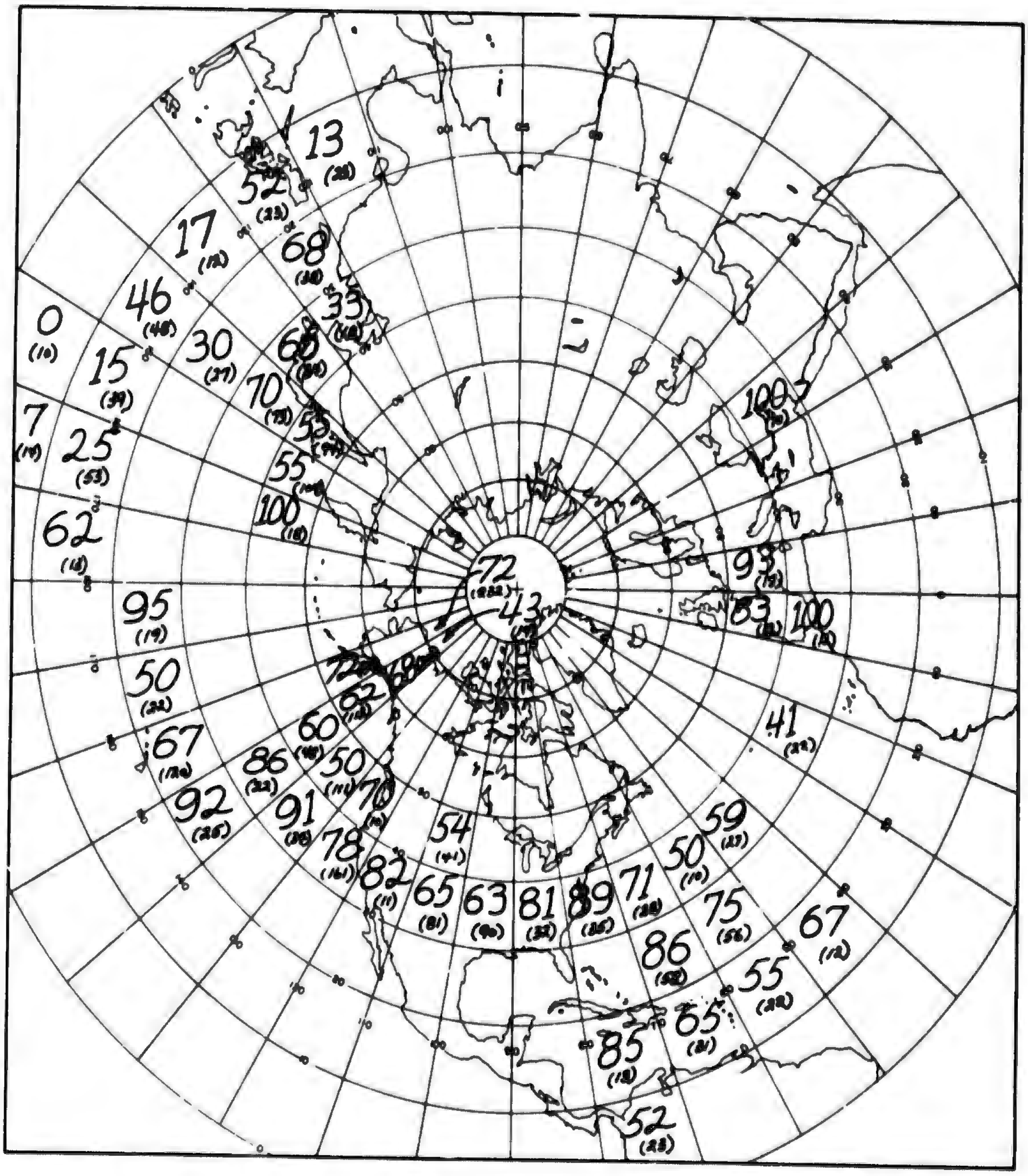

Figure D24. Estimates of the Probability of Seeing Blue Sky at 30° Above the Horizon (+ 30°) from Altitudes of 15,000 to 24,999 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

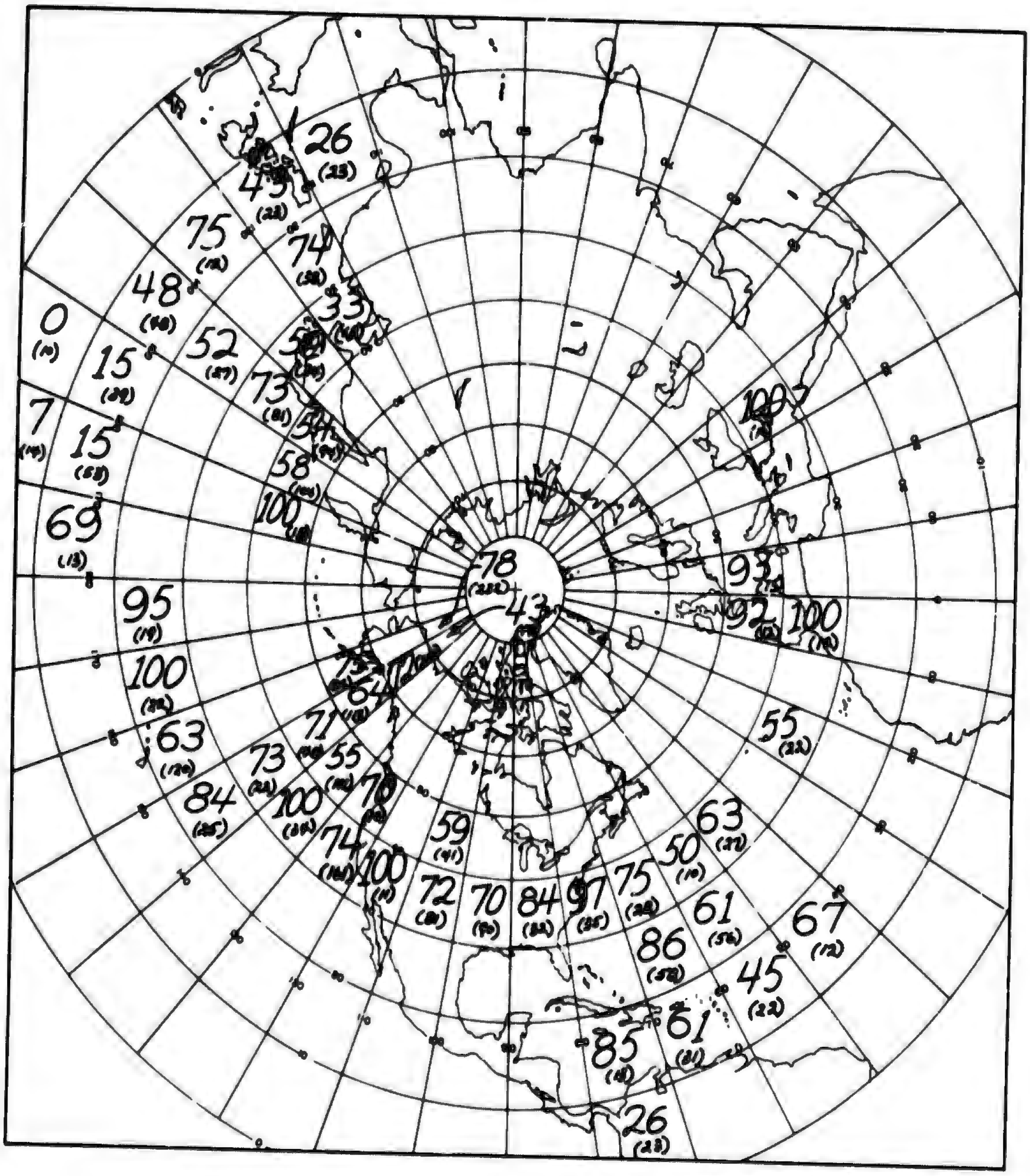

Figure D25. Estimates of the Probability of Seeing Blue Sky at 90° Above the Horizon (+90°) from Altitudes of 15,000 to 24,999 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

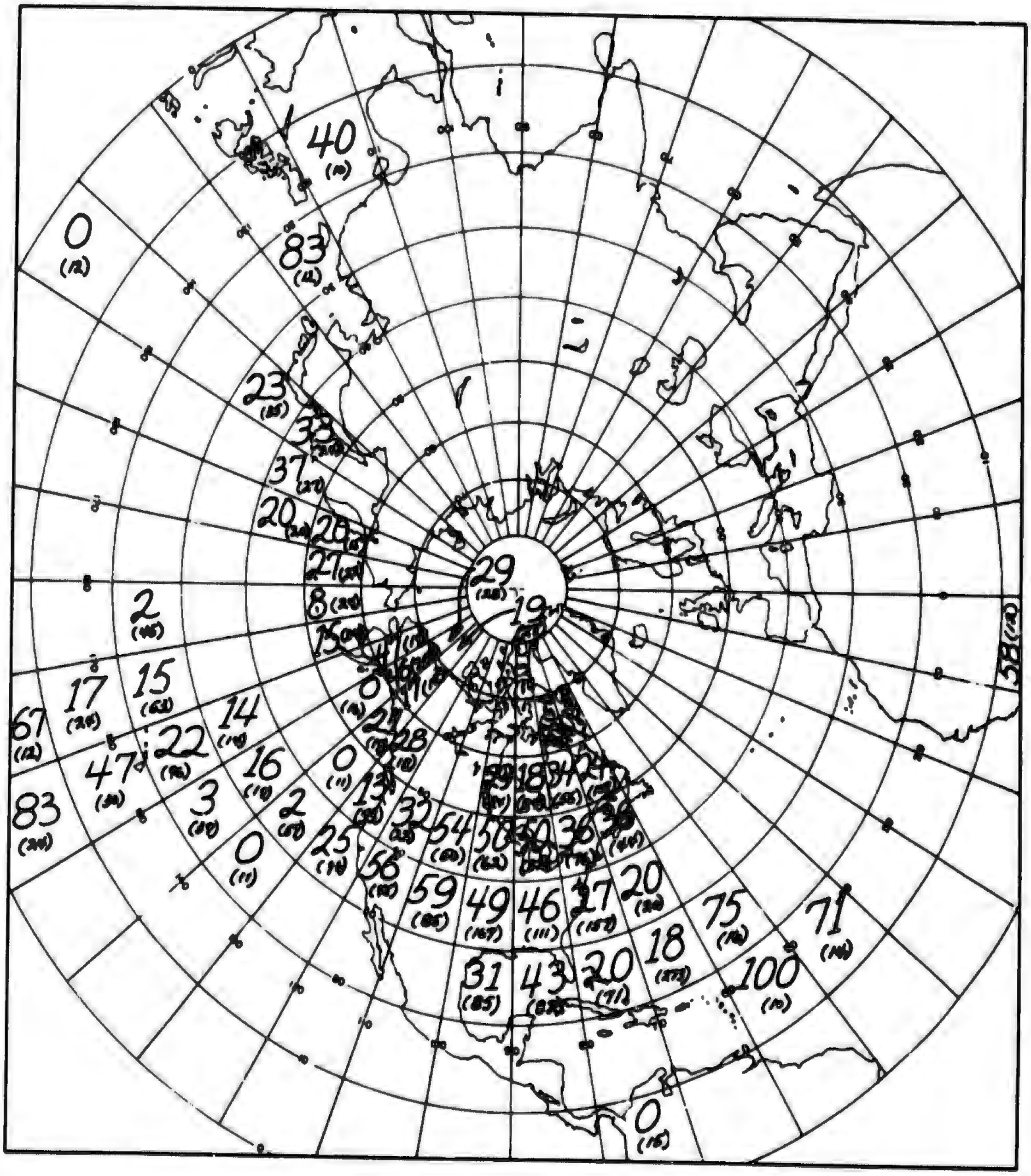

Figure D26. Estimates of the Probability of Seeing the Ground Directly Below the Aircraft (-90°) from Altitudes of 25,000 to 34,999 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

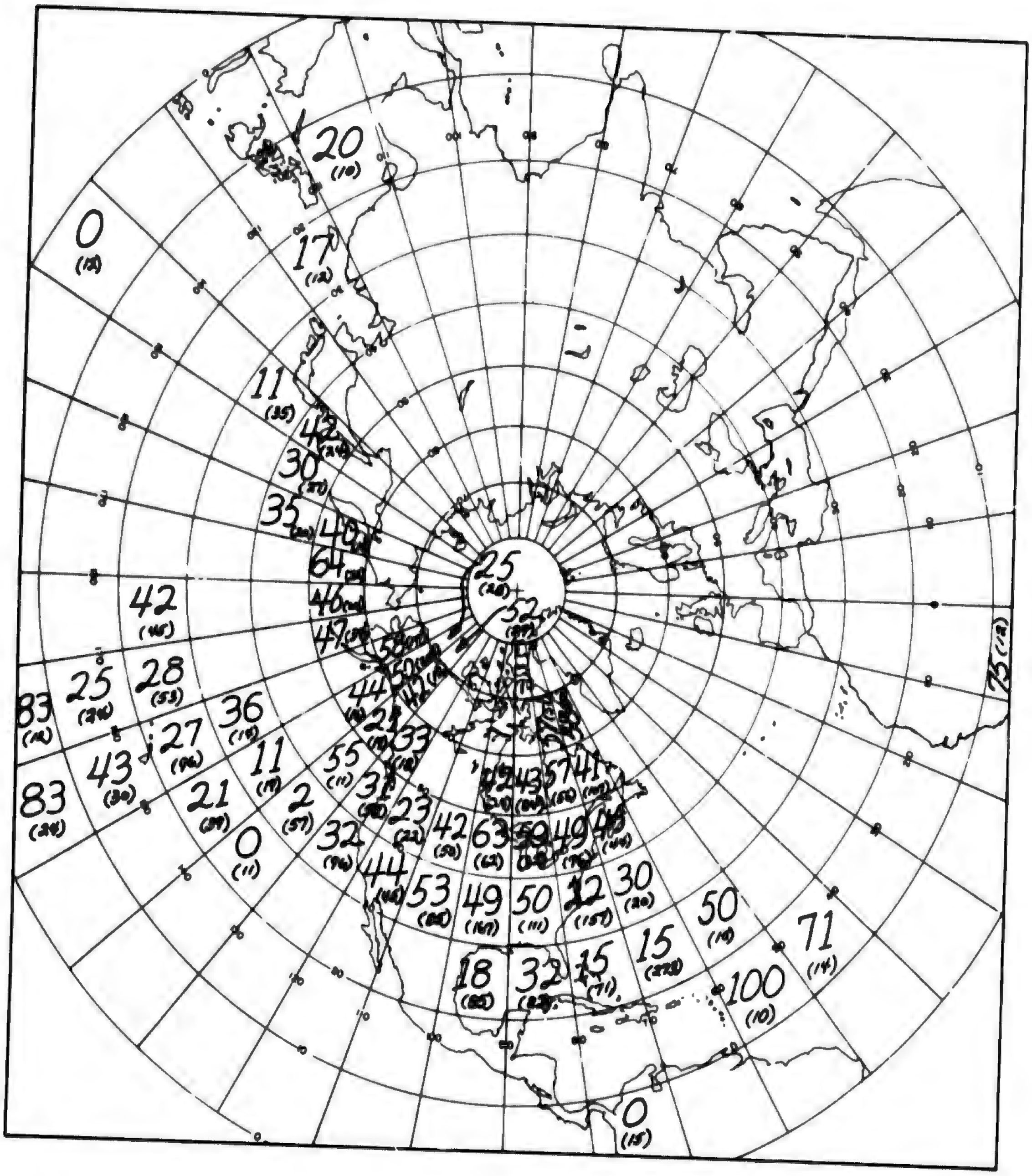

Figure D27. Estimates of the Probability of Seeing the Ground at 30° Below the Horizon (-30°) from Altitudes of 25,000 to 34,999 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

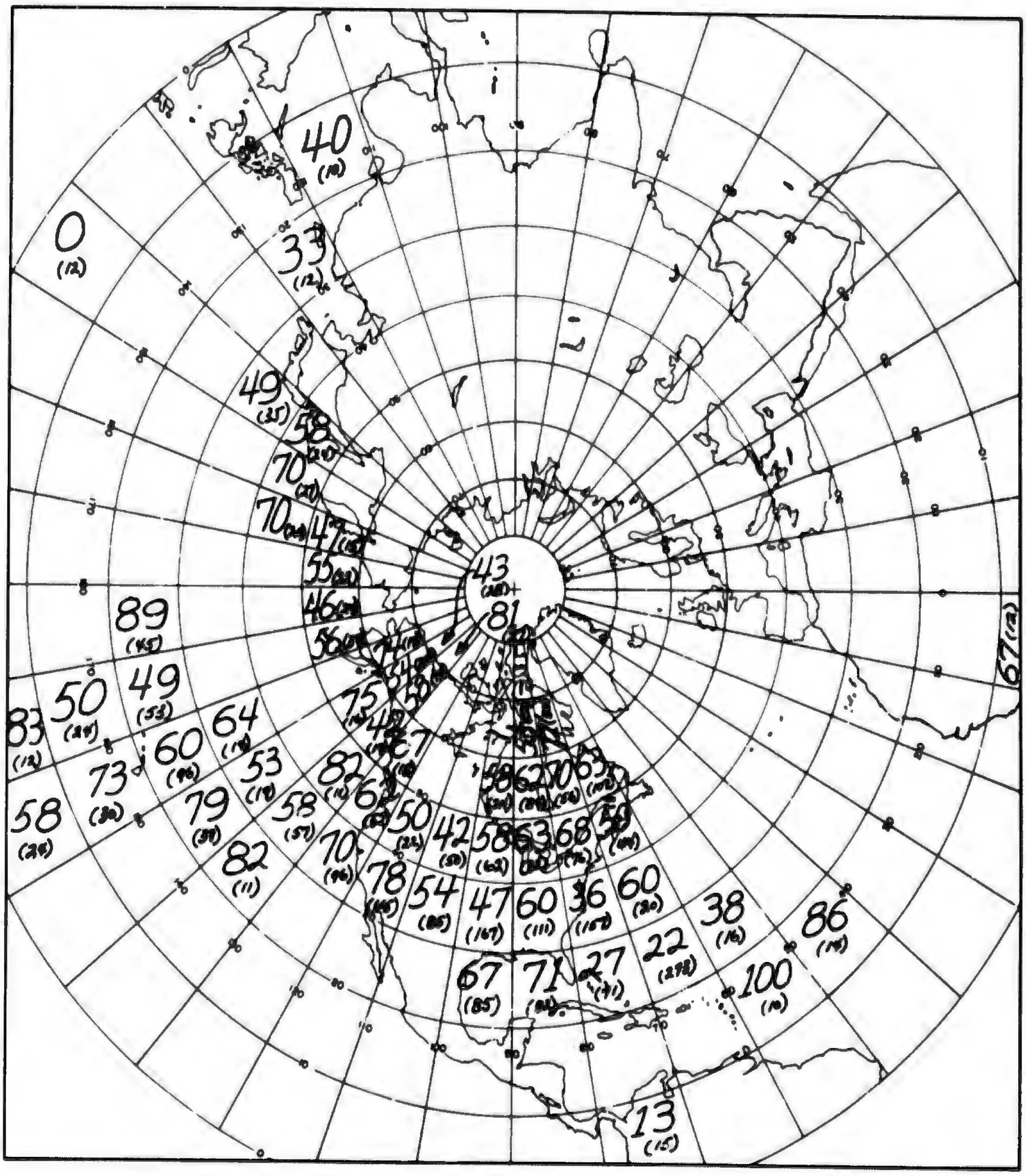

Figure D28. Estimates of the Probability of Seeing the Horizon from Altitudes of 25,000 to 34,999 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

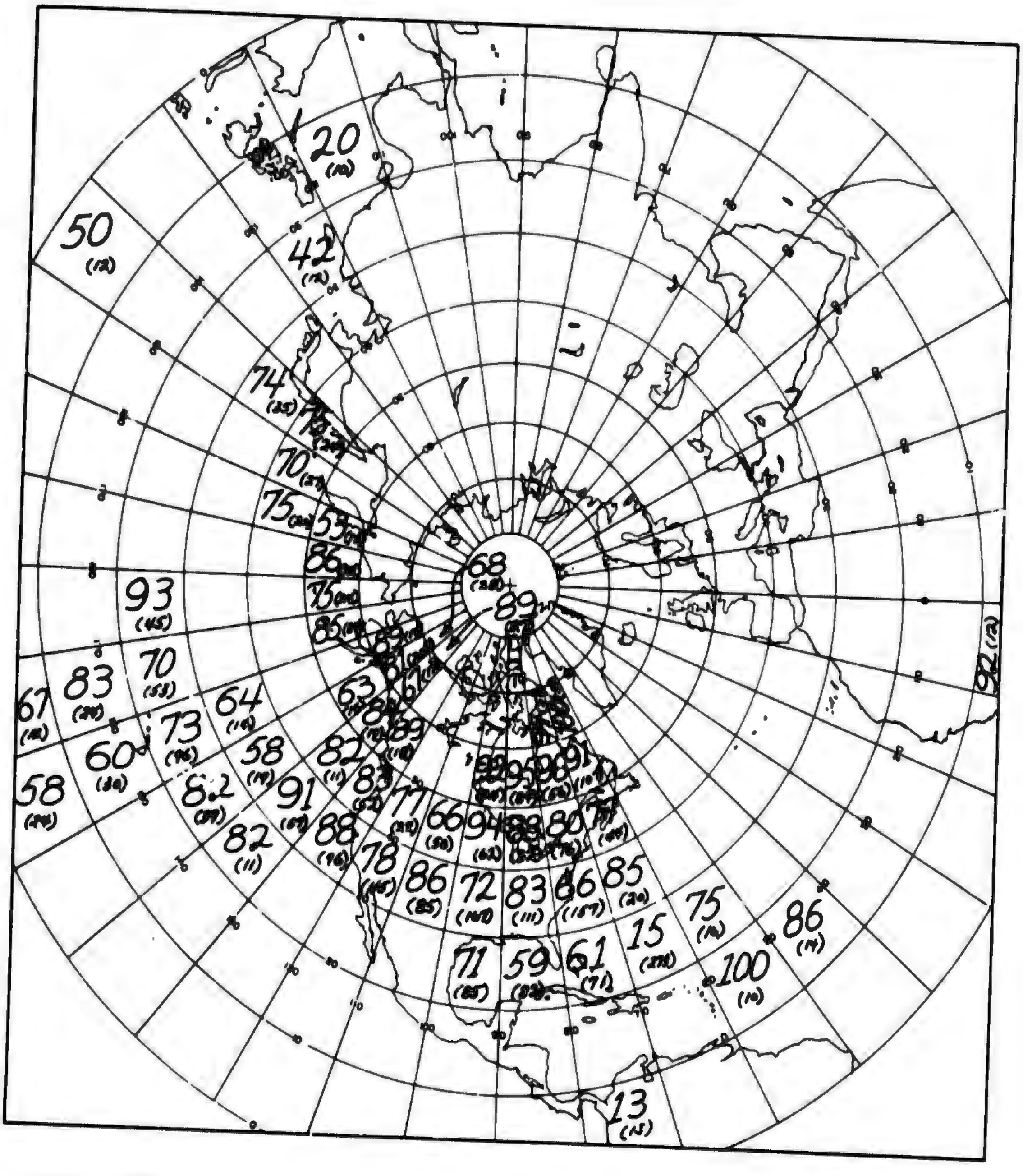

Figure D29. Estimates of the Probability of Seeing Blue Sky at 30° Above the Horizon (+ 30°) from Altitudes of 25,000 to 34,999 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

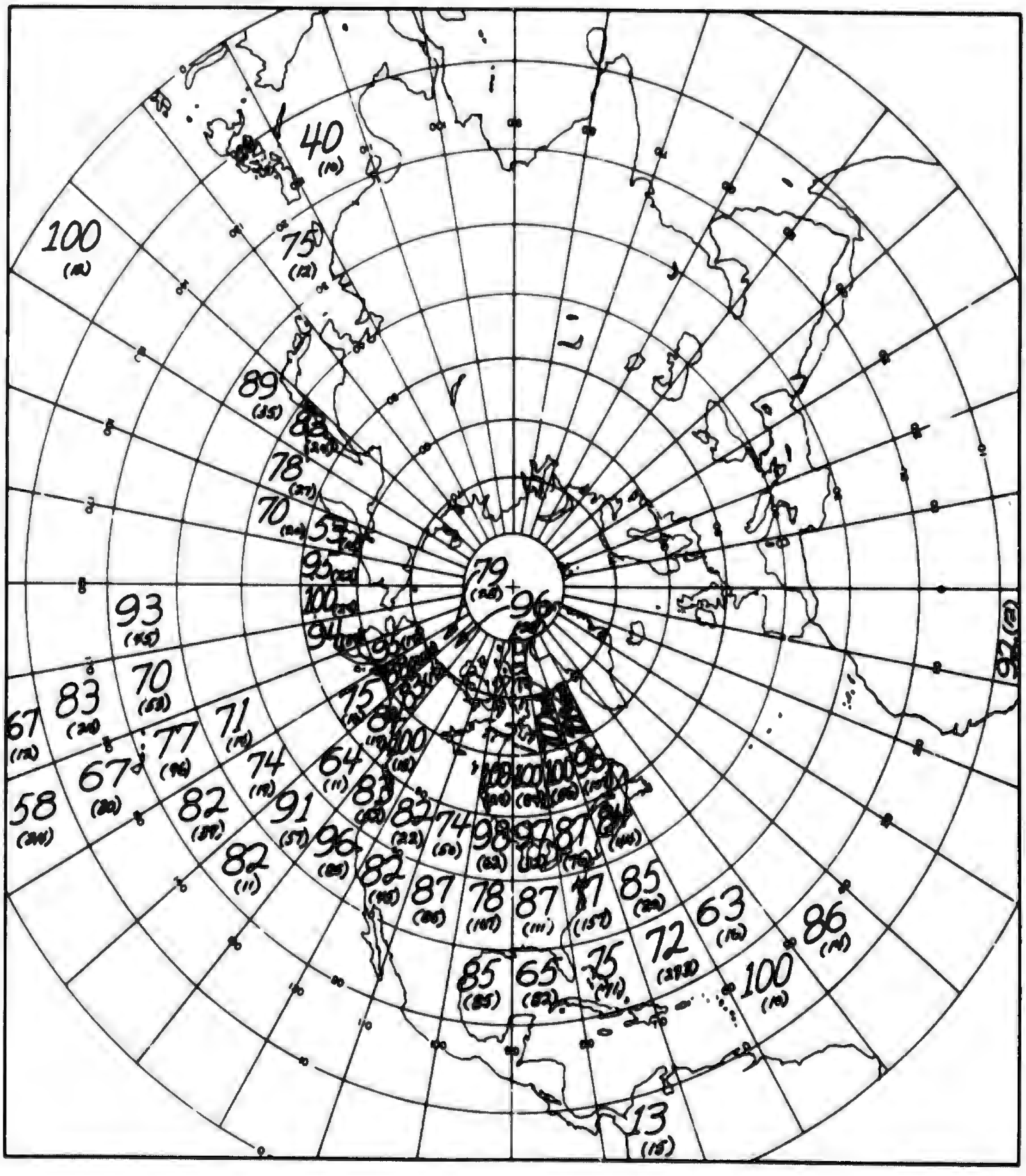

Figure D30. Estimates of the Probability of Seeing Blue Sky at 90° Above the Horizon (+ 90°) from Altitudes of 25,000 to 34,999 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

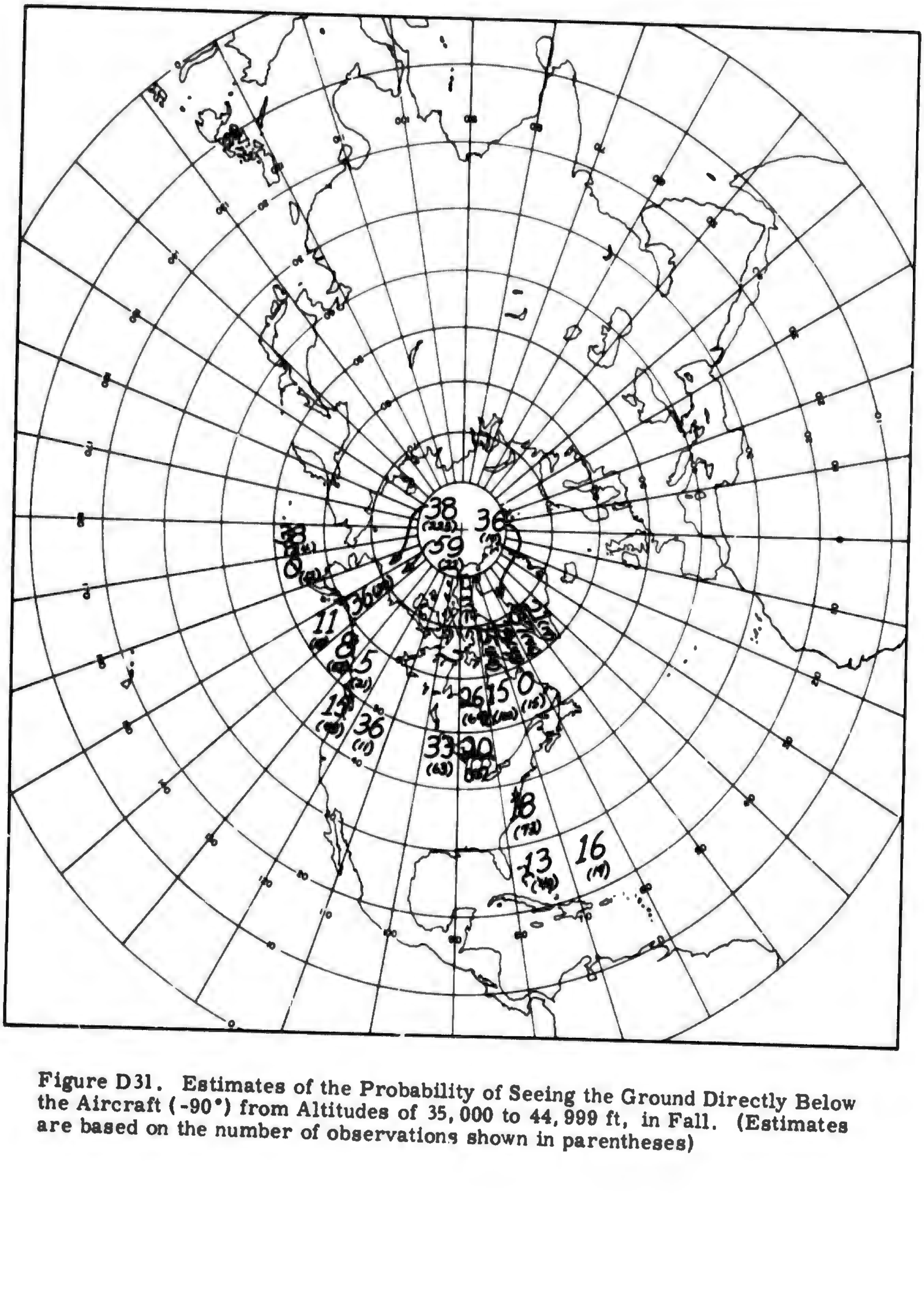

Figure D31. Estimates of the Probability of Seeing the Ground Directly Below the Aircraft (-90°) from Altitudes of 35,000 to 44,999 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

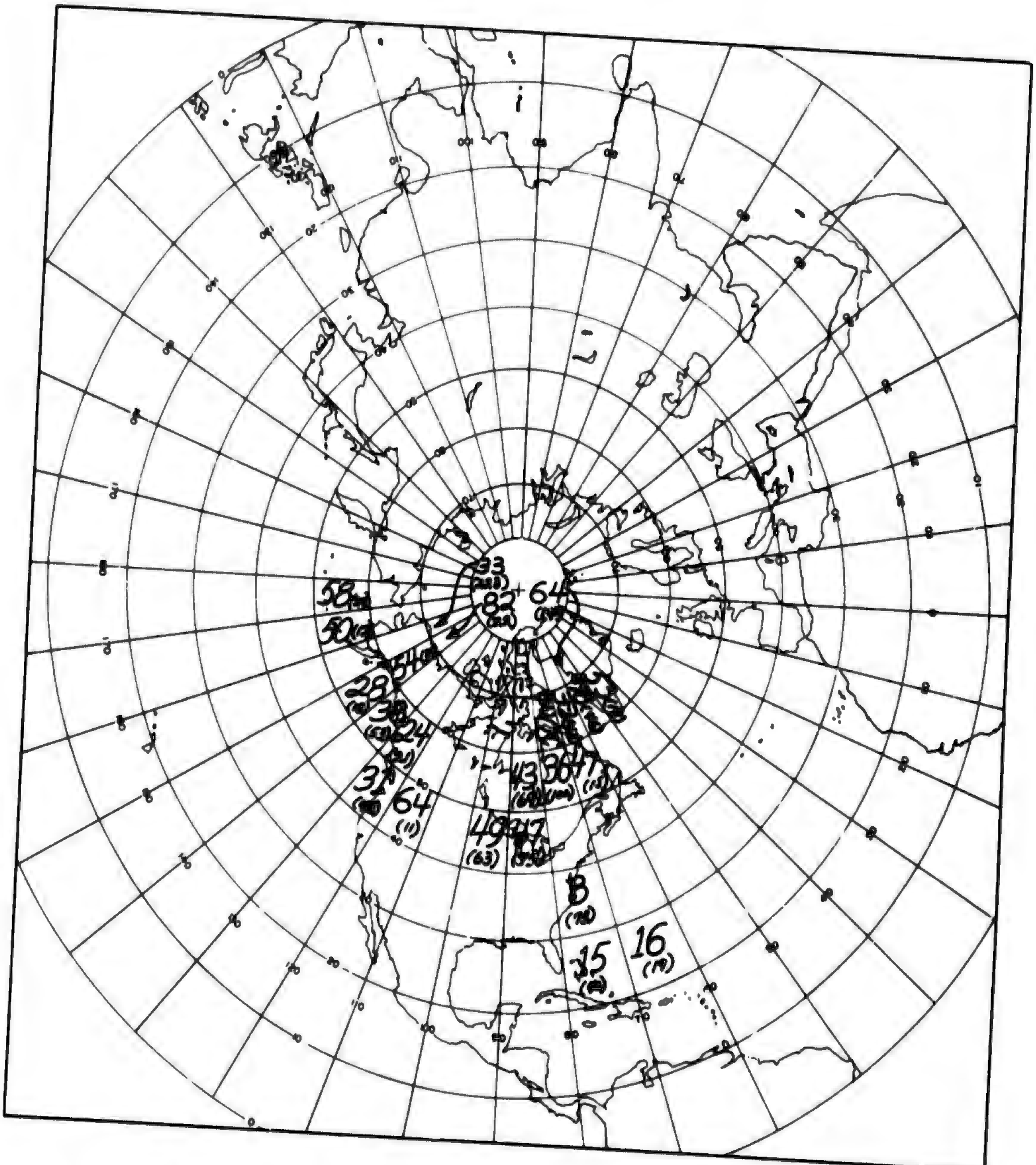

Figure D32. Estimates of the Probability of Seeing the Ground at 30° Below the Horizon (-30°) from Altitudes of 35,000 to 44,999 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

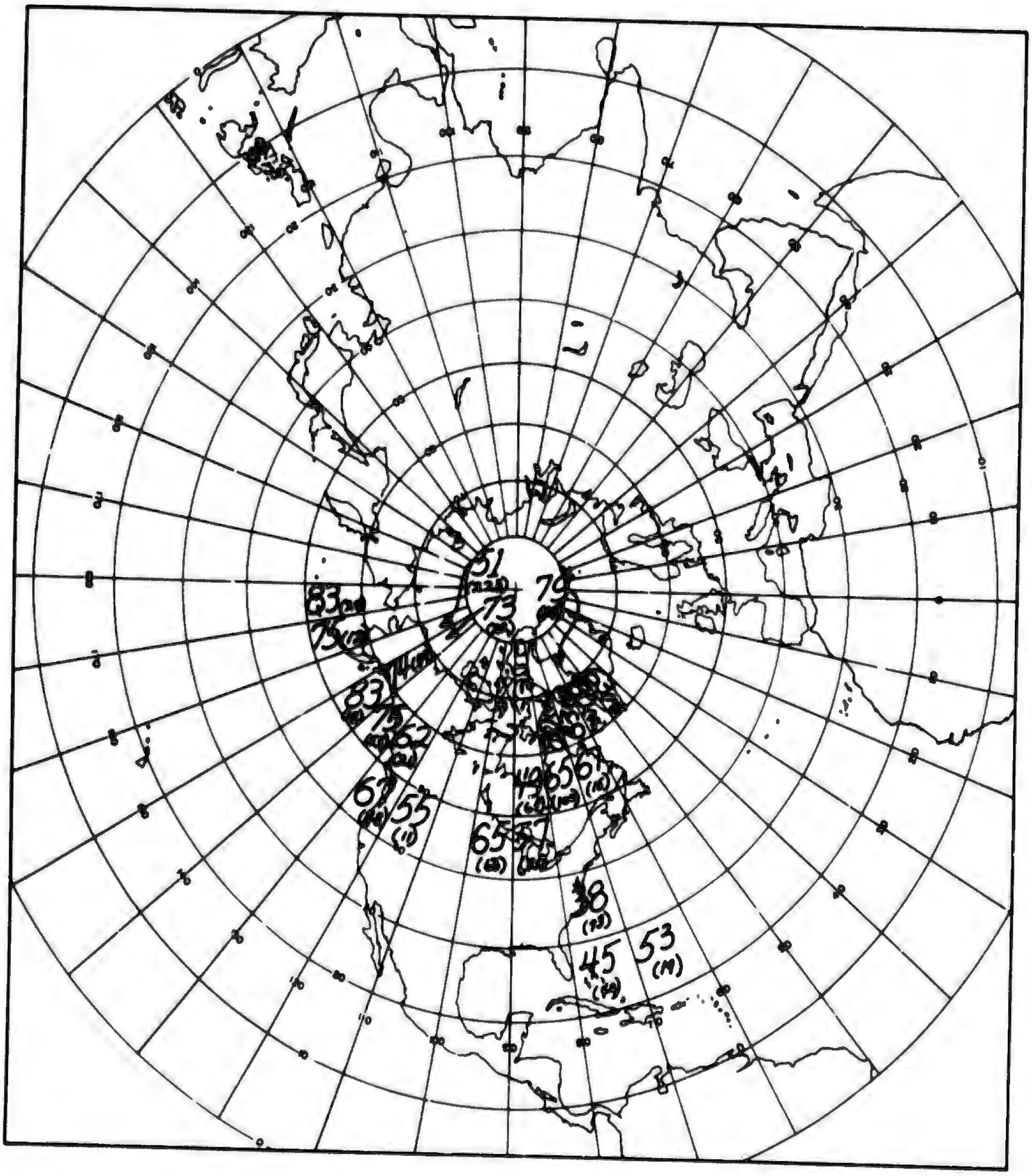

Figure D33. Estimates of the Probability of Seeing the Horizon from Altitudes of 35,000 to 44,999 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

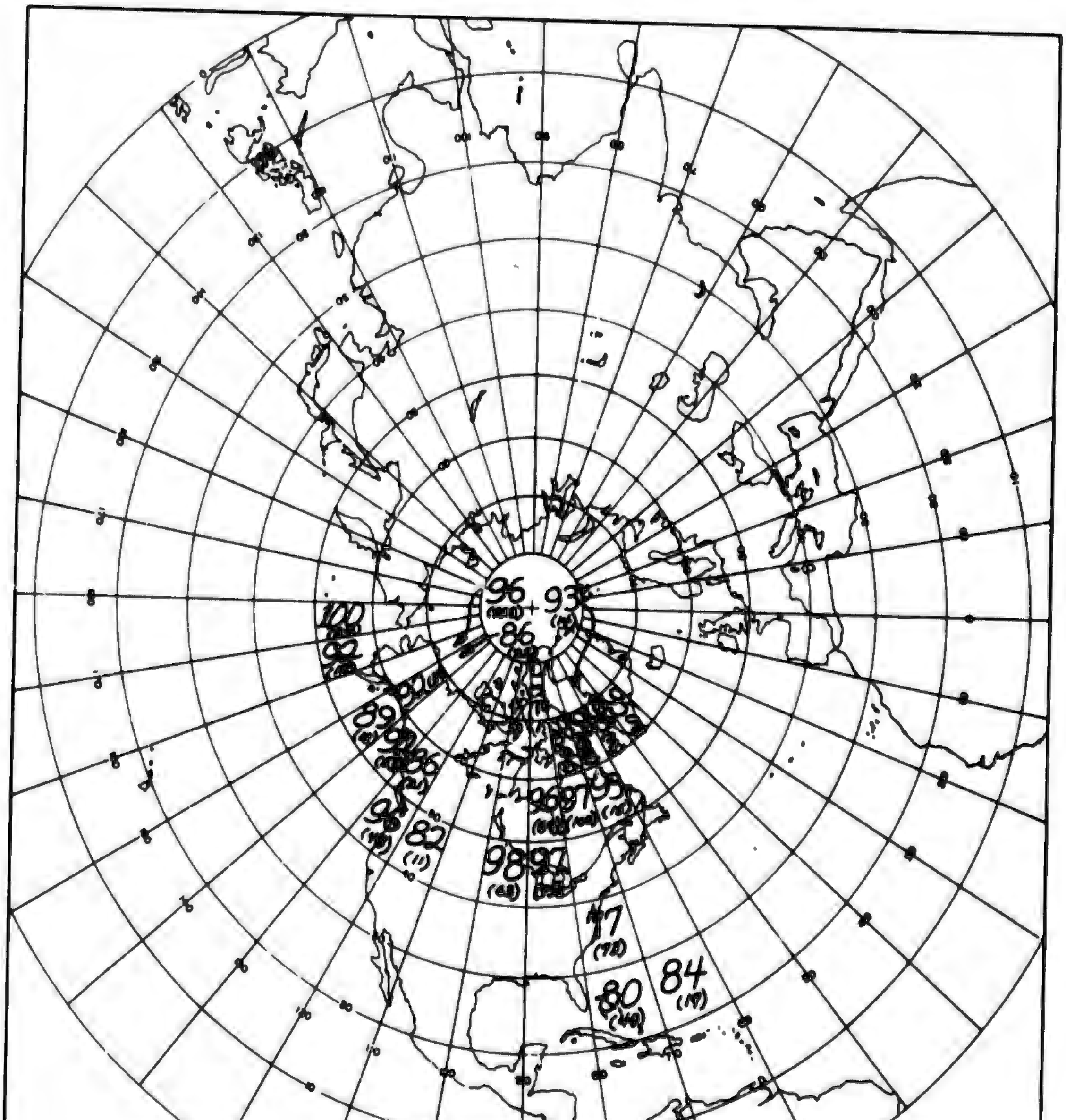

Figure D34. Estimates of the Probability of Seeing Blue Sky at 30° Above the Horizon (+ 30°) from Altitudes of 35,000 to 44,999 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

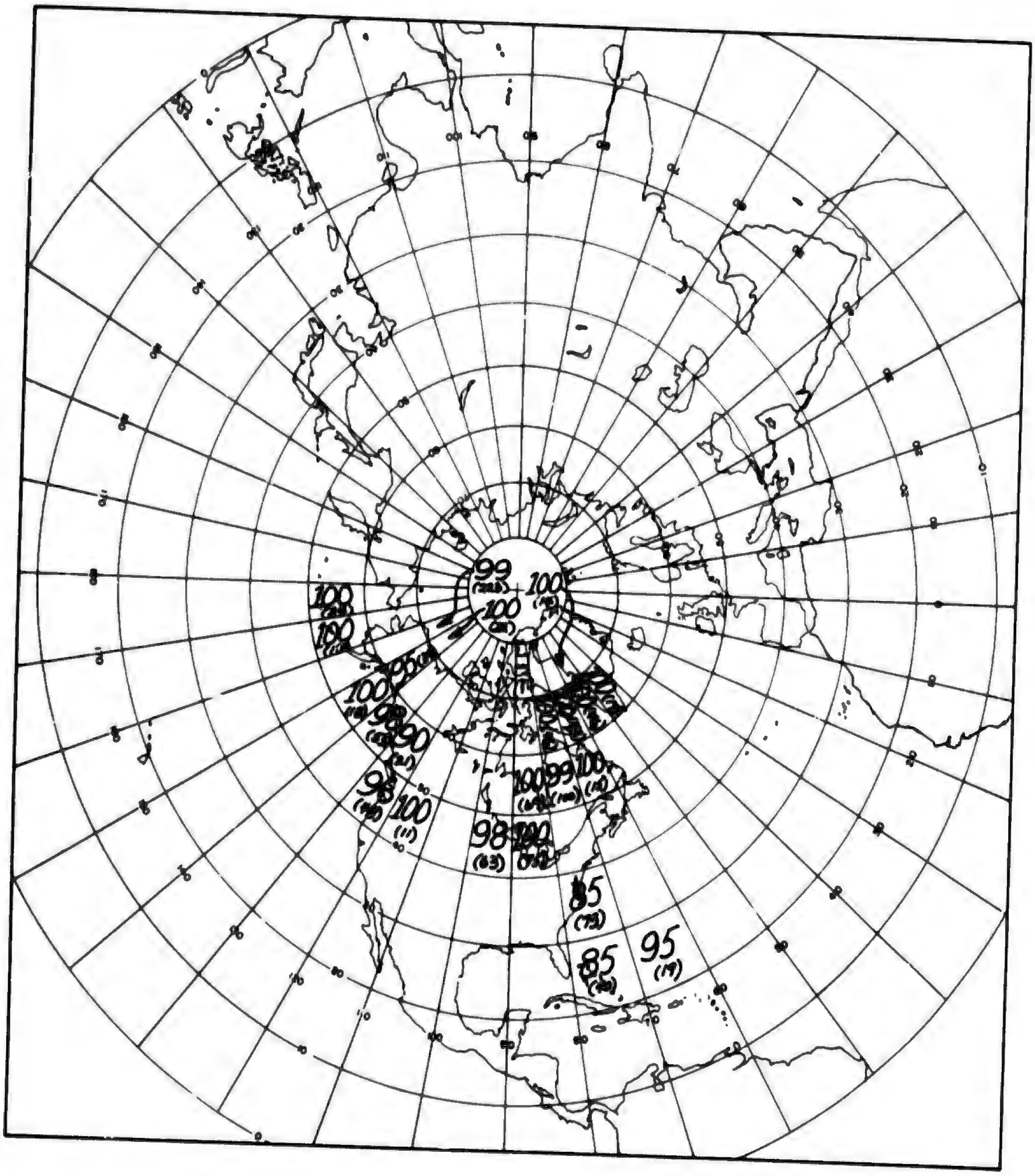

Figure D35. Estimates of the Probability of Seeing Blue Sky at 90° Above the Horizon (+ 90°) from Altitudes of 35,000 to 44,999 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

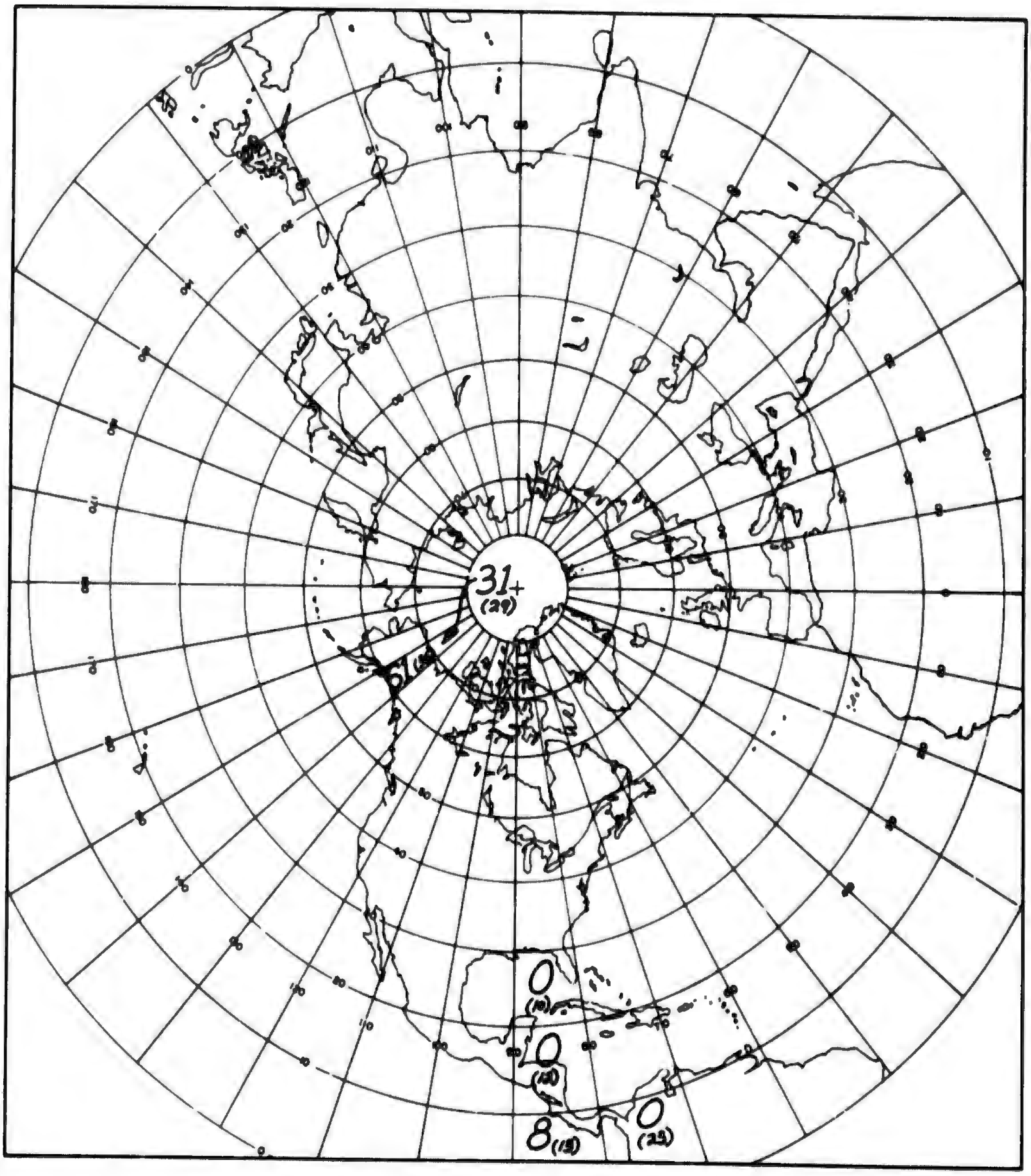

Figure D36. Estimates of the Probability of Seeing the Ground Directly Below the Aircraft (-90°) from Altitudes Above 45,000 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

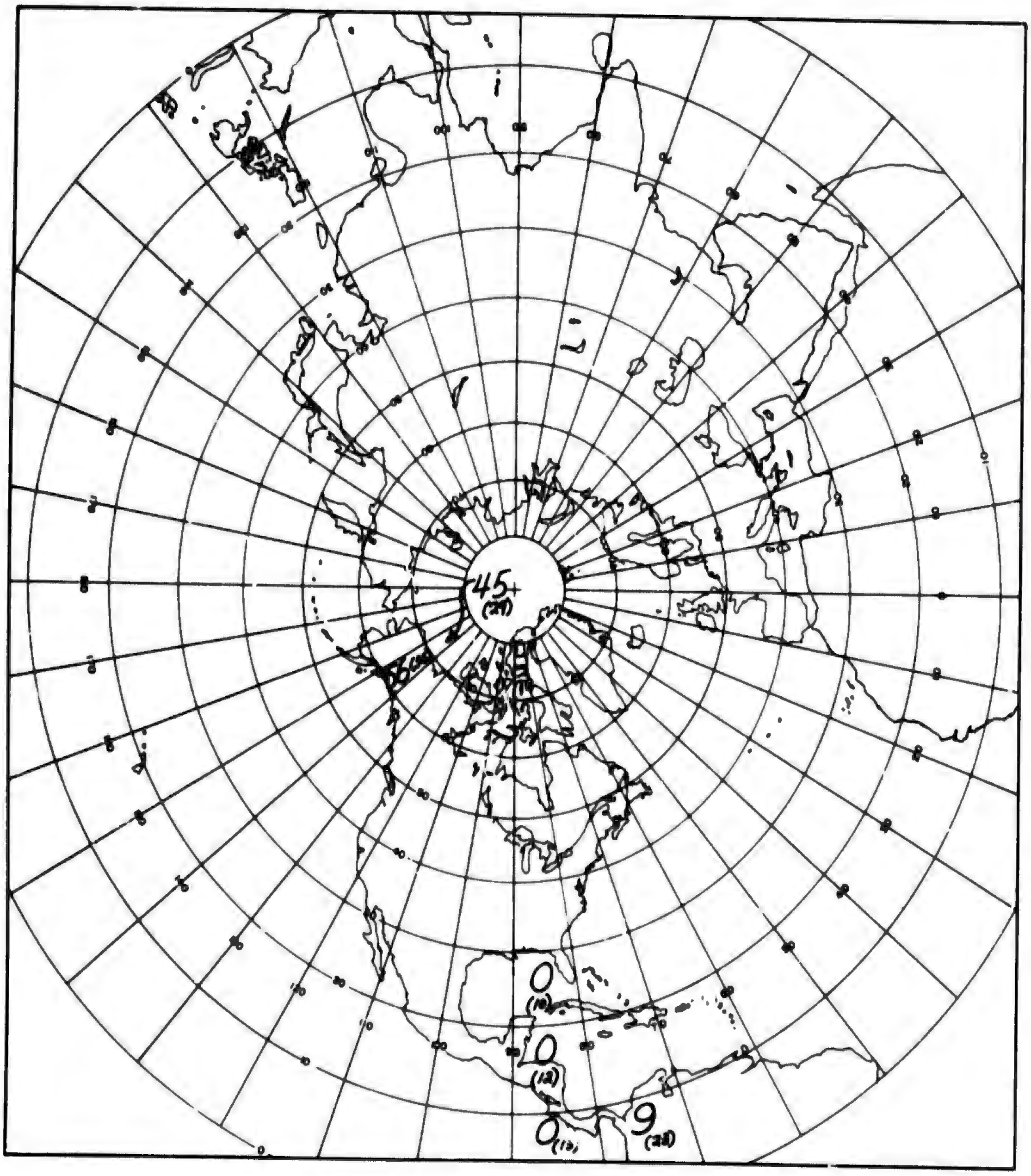

Figure D37. Estimates of the Probability of Seeing the Ground at 30° Below the Horizon (-30°) from Altitudes Above 45,000 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

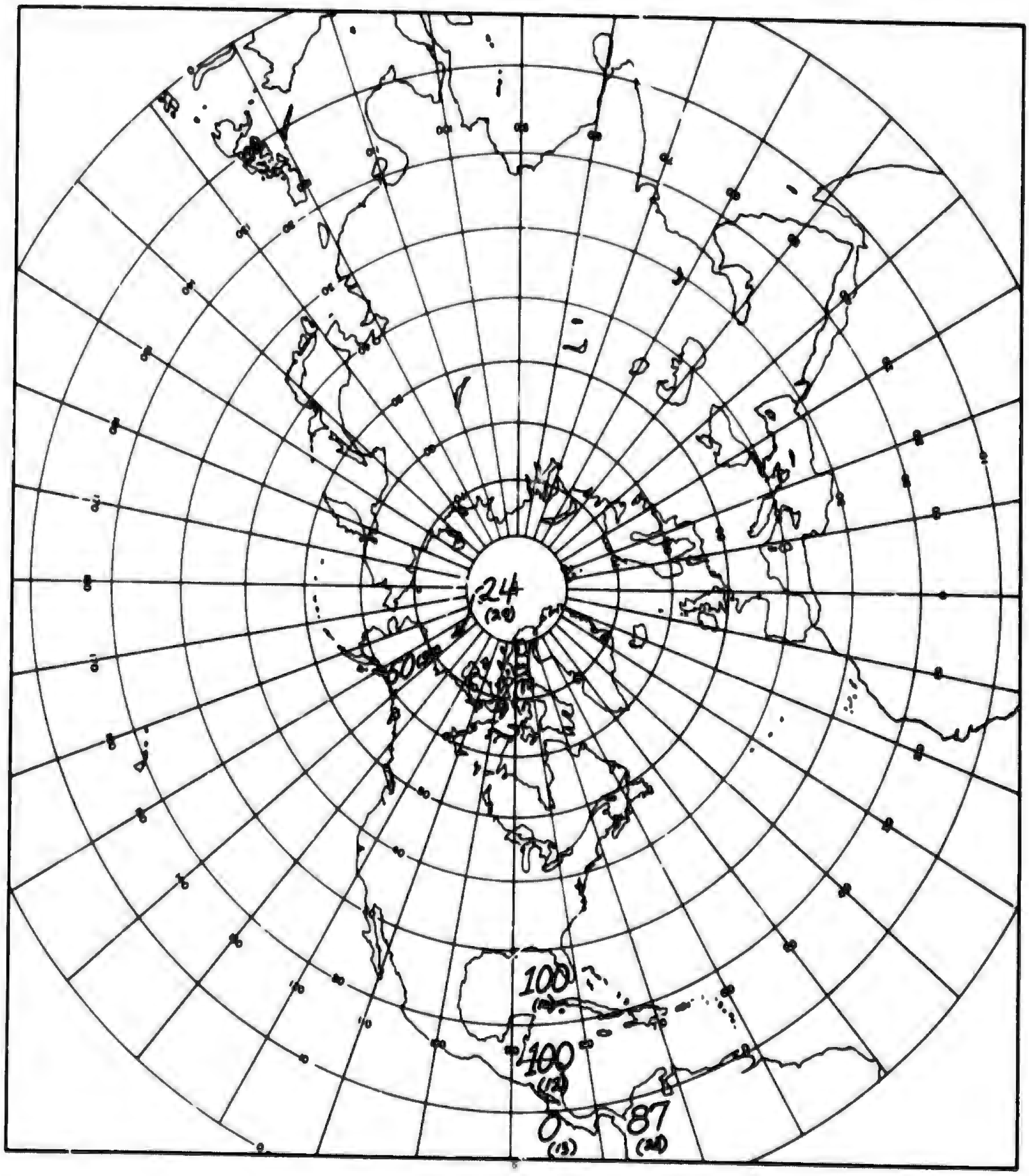

Figure D38. Estimates of the Probability of Seeing the Horizon from Altitudes Above 45,000 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

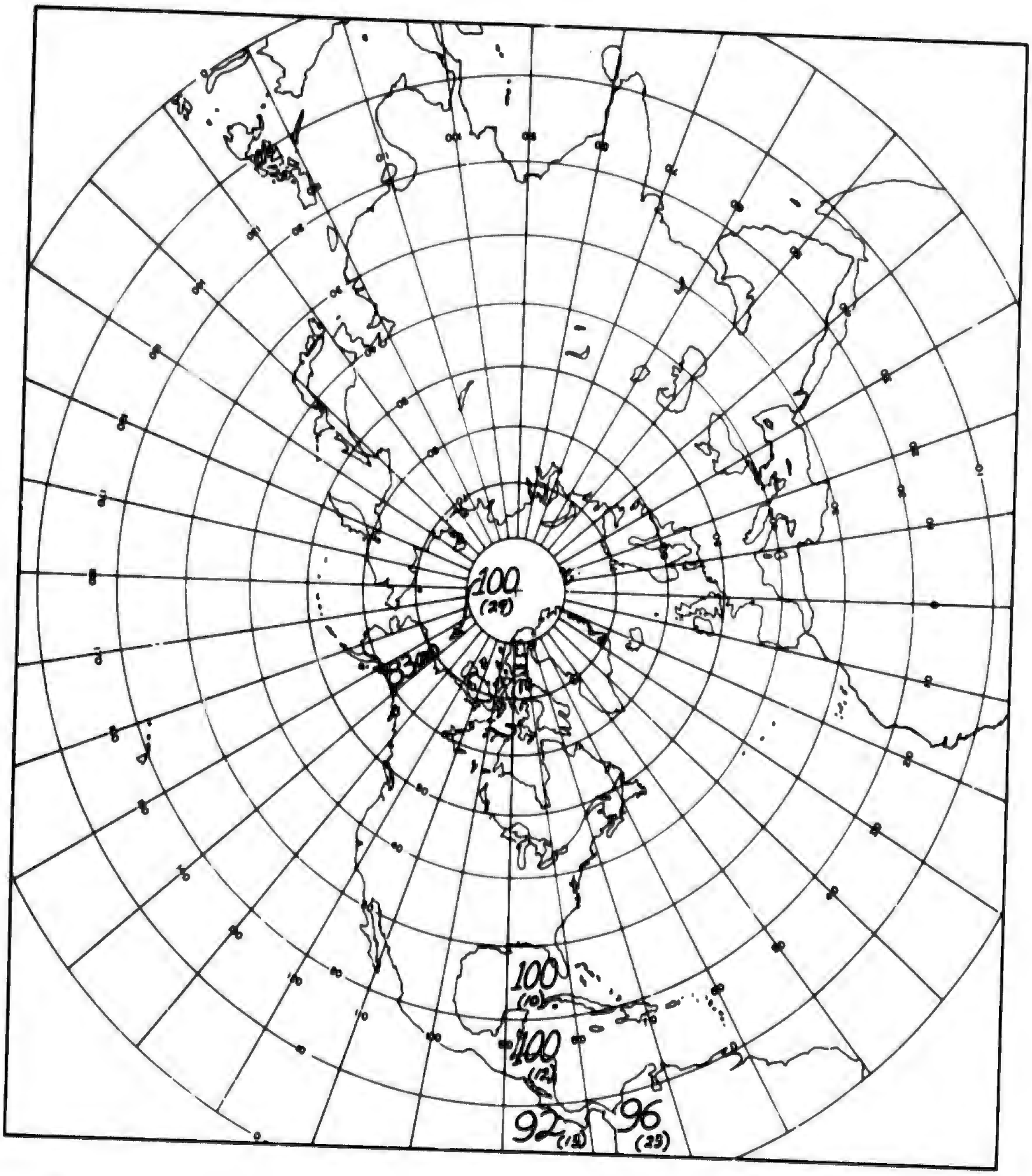

Figure D39. Estimates of the Probability of Seeing Blue Sky at 30° Above the Horizon (+ 30°) from Altitudes Above 45,000 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

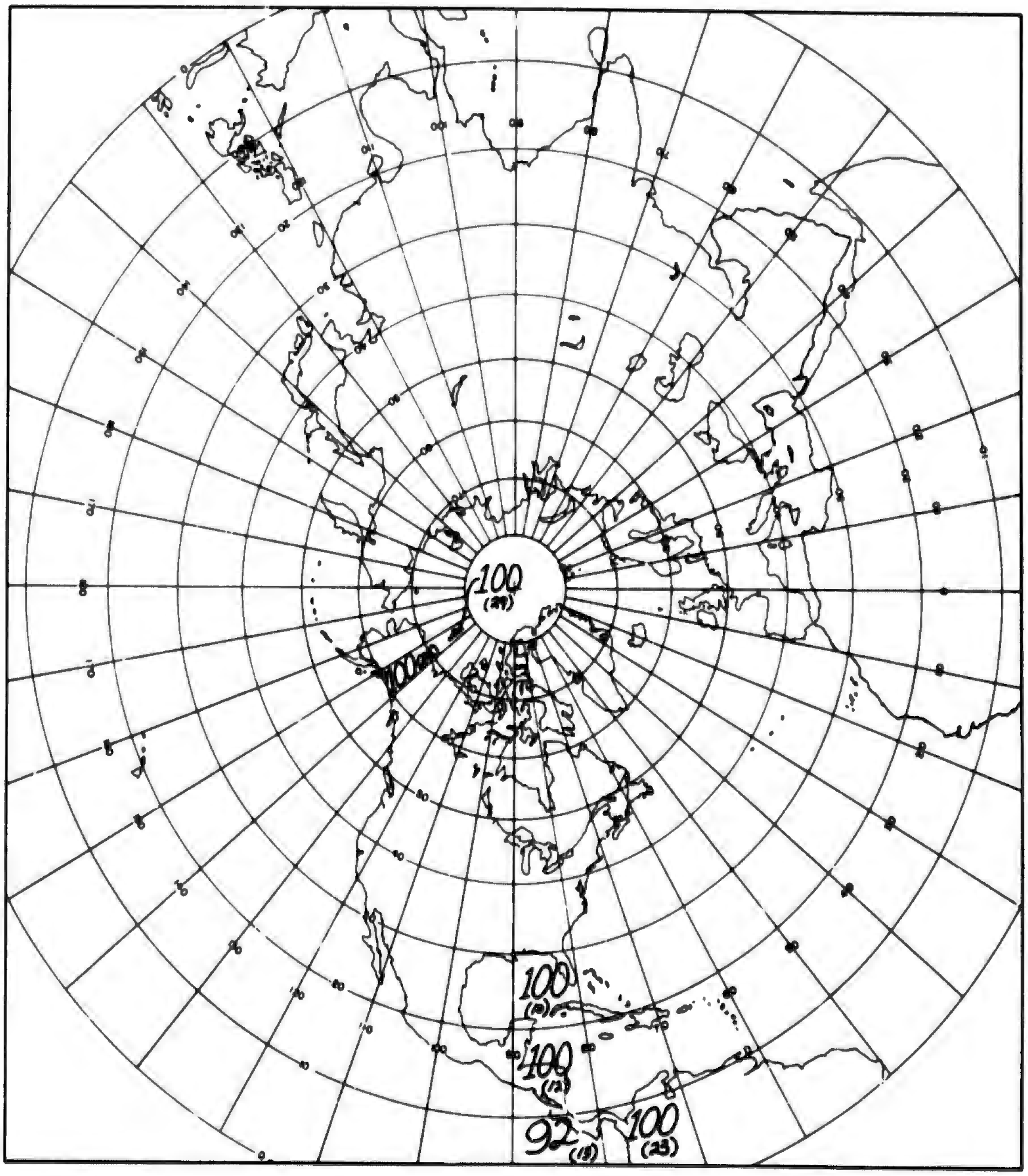

Figure D40. Estimates of the Probability of Seeing Blue Sky at 90° Above the Horizon (+90°) from Altitudes Above 45,000 ft, in Fall. (Estimates are based on the number of observations shown in parentheses)

Unclassified
Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Air Force Cambridge Research Laboratories (CRE) L.G. Hanscom Field Bedford, Massachusetts 01730	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP -

3. REPORT TITLE

Clear Lines-of-Sight from Aircraft

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Scientific. Interim.

5. AUTHOR(S) (First name, middle initial, last name)

Eugene A. Bertoni

6. REPORT DATE August 1967	7a. TOTAL NO. OF PAGES 186	7b. NO. OF REFS 5
8a. CONTRACT OR GRANT NO. b. PROJECT, TASK, WORK UNIT NOS. 8624-01-01 c. DOD ELEMENT 62405394 d. DOD SUBELEMENT 681000	9a. ORIGINATOR'S REPORT NUMBER(S) AFCRL-67-0435 AFSG, No. 196 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) AFCRL-67-0435	

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11. SUPPLEMENTARY NOTES -	12. SPONSORING MILITARY ACTIVITY Air Force Cambridge Research Laboratories (CRE) L.G. Hanscom Field Bedford, Massachusetts 01730

13. ABSTRACT

An in-flight observation program to collect observations of the presence, or absence, of clear lines-of-sight at several angles in the vertical plane has been completed. Approximately 72,000 observations were collected over a period of about 15 months. Observations were taken by flight crews of the Air Force, Navy, and Pan American Airways. Data were obtained over most of the Northern Hemisphere, except the area from 30°E to 110°E.

All observations taken within a 10° latitude-longitude sector were grouped together by altitude and season. The relative frequency of a clear line-of-sight is plotted in the appropriate area on maps for various lines-of-sight. The number of observations on which the relative frequency is based is shown in parentheses.

The relative frequencies are intended to serve as estimates of the probabilities of clear lines-of-sight. These estimates should be considered as a first approximation since, (a) the observations were taken in a very subjective manner, (b) the estimates are based only on about one season of data, and (c) cloud variability may be quite large within some 10° sectors.

DD FORM 1 NOV 65 1473

Unclassified
Security Classification

Unclassified

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Meteorology Climatology Clouds Cloud Amount Cloud Cover Reconnaissance Aerial Photography Infrared Detection Surveillance						

Unclassified

Security Classification