C. 1039

U.S. GEOLOGICAL SURVEY CIRCULAR 1039

Magnetic Models for the United States for 1985

AVAILABILITY OF BOOKS AND MAPS OF THE U.S. GEOLOGICAL SURVEY

Instructions on ordering publications of the U.S. Geological Survey, along with prices of the last offerings, are given in the current-year issues of the monthly catalog "New Publications of the U.S. Geological Survey." Prices of available U.S. Geological Survey publications released prior to the current year are listed in the most recent annual "Price and Availability List." Publications that are listed in various U.S. Geological Survey catalogs (**see back inside cover**) but not listed in the most recent annual "Price and Availability List" are no longer available.

Prices of reports released to the open files are given in the listing "U.S. Geological Survey Open-File Reports," updated monthly, which is for sale in microfiche from the U.S. Geological Survey, Books and Open-File Reports Section, Federal Center, Box 25425, Denver, CO 80225. Reports released through the NTIS may be obtained by writing to the National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161; please include NTIS report number with inquiry.

Order U.S. Geological Survey publications **by mail or over the counter** from the offices given below.

BY MAIL

Books

Professional Papers, Bulletins, Water-Supply Papers, Techniques of Water-Resources Investigations, Circulars, publications of general interest (such as leaflets, pamphlets, booklets), single copies of Earthquakes & Volcanoes, Preliminary Determination of Epicenters, and some miscellaneous reports, including some of the foregoing series that have gone out of print at the Superintendent of Documents, are obtainable by mail from

U.S. Geological Survey, Books and Open-File Reports
Federal Center, Box 25425
Denver, CO 80225

Subscriptions to periodicals (Earthquakes & Volcanoes and Preliminary Determination of Epicenters) can be obtained ONLY from the

Superintendent of Documents
Government Printing Office
Washington, D.C. 20402

(Check or money order must be payable to Superintendent of Documents.)

Maps

For maps, address mail orders to

U.S. Geological Survey, Map Distribution
Federal Center, Box 25286
Denver, CO 80225

Residents of Alaska may order maps from

Alaska Distribution Section, U.S. Geological Survey,
New Federal Building - Box 12
101 Twelfth Ave., Fairbanks, AK 99701

OVER THE COUNTER

Books

Books of the U.S. Geological Survey are available over the counter at the following Geological Survey Public Inquiries Offices, all of which are authorized agents of the Superintendent of Documents:

- **WASHINGTON, D.C.**--Main Interior Bldg., 2600 corridor, 18th and C Sts., NW.
- **DENVER, Colorado**--Federal Bldg., Rm. 169, 1961 Stout St.
- **LOS ANGELES, California**--Federal Bldg., Rm. 7638, 300 N. Los Angeles St.
- **MENLO PARK, California**--Bldg. 3 (Stop 533), Rm. 3128, 345 Middlefield Rd.
- **RESTON, Virginia**--503 National Center, Rm. 1C402, 12201 Sunrise Valley Dr.
- **SALT LAKE CITY, Utah**--Federal Bldg., Rm. 8105, 125 South State St.
- **SAN FRANCISCO, California**--Customhouse, Rm. 504, 555 Battery St.
- **SPOKANE, Washington**--U.S. Courthouse, Rm. 678, West 920 Riverside Ave..
- **ANCHORAGE, Alaska**--Rm. 101, 4230 University Dr.
- **ANCHORAGE, Alaska**--Federal Bldg, Rm. E-146, 701 C St.

Maps

Maps may be purchased over the counter at the U.S. Geological Survey offices where books are sold (all addresses in above list) and at the following Geological Survey offices:

- **ROLLA, Missouri**--1400 Independence Rd.
- **DENVER, Colorado**--Map Distribution, Bldg. 810, Federal Center
- **FAIRBANKS, Alaska**--New Federal Bldg., 101 Twelfth Ave.

Magnetic Models for the United States for 1985

By NORMAN W. PEDDIE and AUDRONIS K. ZUNDE

U.S. GEOLOGICAL SURVEY CIRCULAR 1039

DEPARTMENT OF THE INTERIOR

MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, Director

UNITED STATES GOVERNMENT PRINTING OFFICE: 1990

For sale by the
Books and Open-File Reports Section
U.S. Geological Survey
Federal Center
Box 25425
Denver, CO 80225

Library of Congress Cataloging-in-Publication Data

Peddie, Norman W.
Magnetic models for the United States for 1985 / by Norman W. Peddie and Audronis K. Zunde.

p. cm. — (U.S. Geological Survey circular ; 1039)
Includes bibliographical references.
Supt. of Docs. no.: I 19.4/2:1039
1. Geomagnetism—United States—Mathematical models.
2. Geomagnetism—Maps—Methodology. I. Zunde, Audronis K.
II. Title III. Series.
QC825.1.P39 1990
[538'.7873'01'5118—dc] 89-600270
CIP

CONTENTS

FIGURES

TABLES

Magnetic Models for the United States for 1985

By Norman W. Peddie *and* Audronis K. Zunde

Abstract

New models describing the magnetic field in the United States at the beginning of 1985 and the rate of change expected during the next few years have been developed. The models—which will serve as the basis for a new set of magnetic charts—were derived from several tens of thousands of original field measurements from land, marine, and aerial surveys; from values derived from the MAGSAT-based International Geomagnetic Reference Field; and from recent data from magnetic observatories and repeat stations. They are in the form of spherical harmonic series that represent the scalar magnetic potential from which all the field components can be derived. The models for the conterminous States and Alaska are of maximum degree and order 4 (24 coefficients each) and the models for Hawaii are of maximum degree and order 2 (8 coefficients each).

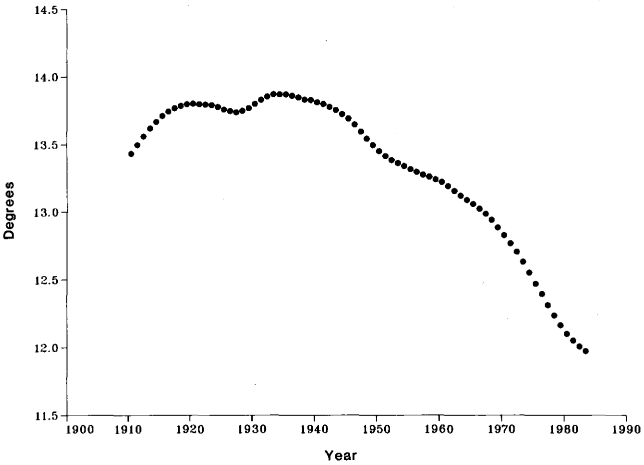


Figure 1. Magnetic declination recorded at the Tucson (Arizona) Magnetic Observatory since 1910.

INTRODUCTION

We developed a set of five new models of the magnetic field in the United States that describe the direction and intensity of the field at 1985.0 (that is, the beginning of 1985) and the annual change expected during the next few years. They form the basis of a new set of magnetic charts (Peddie and Zunde, 1988a, b, c, d, e) that replace those of Fabiano and Jones (1976), Peddie and others (1976), Jones and Fabiano (1976), and Fabiano and Peddie (1980, 1981). Three of the models describe the 1985.0 field in the conterminous (48) States, Alaska, and Hawaii—the three regions shown in separate plates on the charts. The other two models describe annual change—one for the conterminous States and Alaska and the other for Hawaii. This report describes the development of the models and includes the model coefficients and simplified small-scale charts.

Revision of magnetic models and charts is necessary because the geomagnetic field undergoes continual change, called secular variation, that is commonly irregular and not yet predictable. The magnetic declination (*D*) recorded at the Tucson (Arizona) Magnetic Observatory since 1910 is shown in figure 1 and illustrates the irregularity of the secular variation. New magnetic charts for the United States have been issued since the mid-1800's, normally at intervals of 5 or 10 years. Production of associated mathematical models began in 1965. Deel and Howe (1948) and Svendsen (1962) have given brief histories of the U.S. magnetic charts. The development of the 1975 models was described by Fabiano and others (1979), and the 1980 total-intensity (*F*) models by Fabiano and others (1987).

The new models were derived by ordinary spherical harmonic analysis (SHA), a method commonly used for modeling the global field. They represent the scalar magnetic potential as a series of 3-dimensional spherical harmonics, from which the field components are derived by differentiation. The earlier U.S. models were derived by polynomial analysis and represented the field elements themselves as polynomial functions of latitude and longitude.

The new method has some advantages over the older one. For example, now all the field elements are represented by one set of coefficients and the elements

Manuscript approved for publication June 27, 1989.

are mutually consistent. The model field now varies with elevation in a way that is consistent with observation and theory, and, like the real field, it is curl-free. The new models are compatible with widely available programs used for generating field values from global spherical harmonic models, such as those of the International Geomagnetic Reference Field (IGRF).

Before deciding to use SHA we considered two other methods: magnetic dipole analysis and spherical cap harmonic analysis (Haines, 1985). We tested the former method by fitting grids of dipoles, with unconstrained magnetic moment, to the Hawaii data using a nonlinear least-squares technique. We found that the fit did not match that achievable with SHA (using a comparable number of coefficients) and that it improved as the depth of the dipoles was increased (thus making the set of dipoles more like the multipoles of SHA). The latter method, as presently implemented, could not be applied iteratively and thus would not have allowed us to utilize the many *D*- and *F*-only measurements, and, as it requires removal and later addition of a global field, it seemed less efficient than ordinary SHA (L.R. Alldredge, oral commun., 1986).

Acknowledgment

We thank Susan McLean of the National Geophysical Data Center in Boulder, Colorado, for providing the 1980–1983 Project MAGNET data and for helping us to update our repeat station data file.

1985.0 MODELS

The three models of the field at 1985.0 were derived from data selected from the three regions whose boundaries are given in table 1 and indicated by the heavier lines in figure 2 (the lighter lines indicate the regions actually shown on the charts). Data were taken from the following sets (figs. 3–11, which relate to these sets, follow "References Cited"):

Table 1. Boundaries of the regions for which data were selected and 1985.0 models derived

	North latitude (degrees)		East longitude (degrees)	
	South	North	West	East
Conterminous States--	20	54	229	299
Alaska---------------	42	74	160	236
Hawaii---------------	17	24	198	207

Magnetic field survey data (National Geophysical Data Center, 1984, p. 8).—This set comprises several hundred thousand measurements taken on land, sea, and in the air since 1900. We used a subset, created in 1975 for the development of the global model AWC/75 (Peddie and Fabiano, 1976), consisting of all records dated 1939.0 or later that include values of either *D*, or *F*, or the *X* (north), *Y* (east), and *Z* (vertical) field components. These measurements were already adjusted for the secular variation between the measurement date and 1975.0. The measurement locations are in five classes (figs. 3–7): land survey, marine-survey vector, marine-survey total intensity, pre-1975 Project MAGNET-survey vector, and non-Project MAGNET aerial-survey vector.

Field intensity measurements from the 1976–1977 Project MAGNET aerial survey of the conterminous United States (National Geophysical Data Center, 1984, p. 10).—The survey comprised 44 north-south and 7 east-west lines flown at an altitude of 600 meters over flat land and 1220 meters over mountainous areas (see fig. 8).

Field vector measurements from 1980–1983 Project MAGNET aerial surveys (National Geophysical Data Center, 1984, p. 10).—Although these were not intended primarily as surveys of the United States, they did produce some measurements in the chart regions (see fig. 9).

X, Y, and Z aeromagnetic data for Canada (L.R. Newitt, unpub. data).—These data were especially useful for promoting agreement with the charts of Canada (see fig. 10).

Magnetic observatory and repeat station values for 1985.0.—These values were derived by linear extrapolation of recent observatory annual means and repeat station measurements (see fig. 2).

The great number of original Project MAGNET measurements was reduced by retaining only every 50th intensity measurement and every 25th vector measurement. Of these we used only those taken when *Kp* (a geomagnetic disturbance index) was less than 3. To fill gaps in the coverage we included values computed from the International Geomagnetic Reference Field (IGRF) 1985 main-field model (International Association of Geomagnetism and Aeronomy, Division I, Working Group 1, 1986), a global model based mainly on data from the MAGSAT satellite survey of 1979–1980 (Langel and others, 1982). These were computed for a grid of points at 500-kilometer altitude and spaced one degree in latitude and longitude (see fig. 11).

The data were analyzed using the method of iterative SHA (for example, Cain and others, 1965). The resulting overall root-mean-square residuals, for maximum degree and order (n^*) ranging from 1 to 5 for the conterminous States and Alaska and from 1 to 3 for

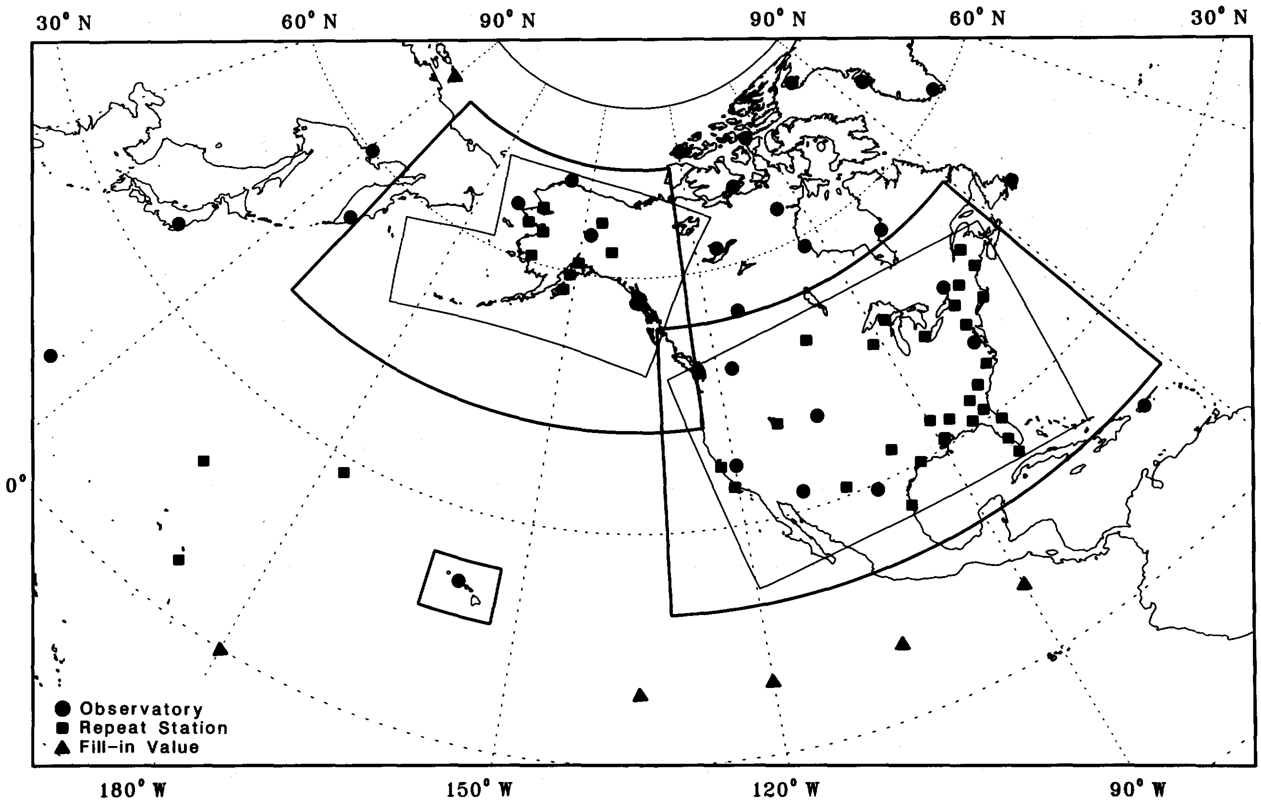


Figure 2. Map showing the three regions for which 1985.0 models were derived (heavy boundary lines), and the regions actually shown on the 1985 U.S. magnetic charts (light boundary lines). Also shown are the locations of the magnetic observatories (solid circles) and repeat stations (solid squares) whose data, along with fill-in values (solid triangles), were used to derive the secular-variation models.

Hawaii, are shown in table 2. For the chart compilation we chose the models for the conterminous States and Alaska of $n^* = 4$ (24 coefficients each) and for Hawaii of $n^* = 2$ (8 coefficients) because they are the simplest of the models that adequately represent the data.

Table 2. Overall root-mean-square residual

[Units, nanotesla; n^*, maximum degree and order; cont., conterminous. Leaders (---) indicate that value was not computed]

n^*	Cont. States	Alaska	Hawaii
1	1582	1554	277
2	403	547	197
3	211	281	193
4	176	154	---
5	174	153	---

SECULAR-VARIATION MODELS

The two secular-variation models were derived by the same method. The model for the conterminous States and Alaska was derived from estimates of the rates of change of the X, Y, and Z components at 30 magnetic observatories and 50 repeat stations and, for six locations far from the observatories and repeat stations, fill-in values computed from global secular-variation model USGS85S (Peddie and Zunde, 1987) (see fig. 2). The estimates were taken as the slopes of straight lines fitted by least-squares to recent data. We used the latest four or five observatory annual means, mostly for years from 1981 to 1985, and the latest two or three sets of repeat-station measurements. Because observatory-based rates are more accurate, we gave them triple weight. The model for Hawaii was derived from grid values computed from this model along with rates estimates for the Honolulu observatory. The data used to derive the secular-variation models are given in the appendix.

COEFFICIENTS

The coefficients of the five models, in the Schmidt quasi-normalized form (Chapman and Bartels, 1940) and referring to a sphere of radius 6371.2 km, are listed in table 3. The models are not considered valid for points outside the regions specified in table 1. They can be used with programs that synthesize field values from global spherical harmonic models, such as those of the IGRF. A suitable program can be obtained from the National Geophysical Data Center, NOAA, Code E/GC4/FLI, 325 Broadway, Boulder, CO 80303.

CHARTS AND "GEOMAG"

The five new charts based on these models depict the declination, inclination (*I*), horizontal intensity (*H*), vertical intensity, and total intensity and their expected rates of change (Peddie and Zunde, 1988a, b, c, d, e). The

Table 3. Spherical harmonic coefficients (*g*'s and *h*'s) of the 1985 models

[Cont., conterminous; *n*, degree; *m*, order; nT, nanotesla; nT/yr, nanotesla per year. Leaders (---) indicate coefficients that were not determined]

			1985.0 field (nT)			Annual change (nT/yr)	
	n	m	Cont. States	Alaska	Hawaii	Cont. States; Alaska	Hawaii
g	1	0	-28004	-27446	-36259	78.0	33.6
g	1	1	1186	-1853	-5785	34.5	0.7
h	1	1	6036	1749	5497	-0.9	7.6
g	2	0	-6761	-5178	3784	-101.8	-17.3
g	2	1	118	6617	-2557	12.0	7.2
h	2	1	-2379	5820	108	4.3	1.8
g	2	2	3459	6134	-2086	3.4	-12.4
h	2	2	4617	-859	97	29.0	20.6
g	3	0	6566	1011	---	48.6	---
g	3	1	-3156	-8553	---	-38.4	---
h	3	1	-1502	-6076	---	-30.8	---
g	3	2	-587	-6470	---	-4.3	---
h	3	2	-4175	2073	---	-16.0	---
g	3	3	-1335	-1667	---	-12.9	---
h	3	3	1321	-1673	---	4.0	---
g	4	0	-691	2080	---	-3.8	---
g	4	1	2267	4087	---	13.3	---
h	4	1	2034	1317	---	20.5	---
g	4	2	771	4124	---	-8.7	---
h	4	2	625	-1002	---	0.3	---
g	4	3	405	-374	---	-7.0	---
h	4	3	-1417	505	---	-1.8	---
g	4	4	-79	-723	---	-14.3	---
h	4	4	-1028	-1082	---	-2.1	---

charts, which are 31 inches high and 45 inches wide, show the 48 conterminous States on one side at a scale of 1 to 5 million and Alaska and Hawaii on the other at 1 to 3.5 million. They are priced at $6.20 each, and are available from Distribution Branch, U.S. Geological Survey, Box 25286, Federal Center, Building 810, Denver, Colorado 80225. To order, please use Order Form P, if available. Otherwise, print your order plainly, specifying the reference code, title, and quantity of each chart required. Include your mailing address with zip code. Prepayment is required and must be made in U.S. funds by check or money order payable to Department of the Interior—USGS. For transmittal of maps outside the United States (except Canada and Mexico) a surcharge of 25 percent of the net amount should be included to cover surface transportation. A $1.00 postage and handling charge is applicable on orders of less than $10.00. Please note that prices are subject to change.

Simplified small-scale versions of the charts, along with charts for the X and Y components, are given in figures 12–18 (after "References Cited"). A dial-in service called "GEOMAG", by means of which field values from these models as well as those of the IGRF may be obtained directly via terminal and modem, has been described by Peddie (1987). For additional information write to Norman Peddie, U.S. Geological Survey, Box 25046, Mail Stop 968, Denver Federal Center, Denver, CO 80225.

REFERENCES CITED

Cain, J.C., Daniels, W.E., Hendricks, S.J., and Jensen, D.C., 1965, An evaluation of the main geomagnetic field, 1940–1962: Journal of Geophysical Research, v. 70, no. 15, p. 3647–3674.

Chapman, S., and Bartels, J., 1940, Geomagnetism, v. 2: New York, Oxford University Press, p. 611–612.

Deel, S.A., and Howe, H.H., 1948, United States magnetic tables and magnetic charts for 1945, U.S. Coast and Geodetic Survey Serial 667: Washington, D.C., U.S. Government Printing Office, p. 10–12.

Fabiano, E.B., and Jones, W.J., 1976, Magnetic horizontal intensity in the United States—Epoch 1975.0: U.S. Geological Survey Miscellaneous Investigations Series Map I–913.

Fabiano, E.B., Jones, W.J., and Peddie, N.W., 1979, The magnetic charts of the United States for epoch 1975: U.S. Geological Survey Circular 810, 15 p.

Fabiano, E.B., and Peddie, N.W., 1980, Magnetic declination in the United States—Epoch 1980: U.S. Geological Survey Miscellaneous Investigations Series Map I–1283.

_____ 1981, Magnetic total intensity in the United States—Epoch 1980: U.S. Geological Survey Miscellaneous Investigations Series Map I–1370.

Fabiano, E.B., Peddie, N.W., and Zunde, A.K., 1987, Models of total magnetic intensity in the United States for 1980: U.S. Geological Survey Open-File Report 87–619.

Haines, G.V., 1985, Spherical cap harmonic analysis: Journal of Geophysical Research, v. 90, no. B3, p. 2583–2591.

International Association of Geomagnetism and Aeronomy, Division I, Working Group 1, 1986, International Geomagnetic Reference Field revision 1985: EOS, v. 67, p. 523–524.

Jones, W.J., and Fabiano, E.B., 1976, Magnetic vertical intensity in the United States—Epoch 1975.0: U.S. Geological Survey Miscellaneous Investigations Series Map I–914.

Langel, R., Ousley, G., Berbert, J., Murphy, J., and Settle, M., 1982, The MAGSAT mission: Geophysical Research Letters, v. 9, p. 243–245.

National Geophysical Data Center, 1984, Terrestrial geophysics data services—Key to geophysical records documentation no. 17 (revised edition): Boulder, Colo., 27 p.

Peddie, N.W., 1987, GEOMAG—A geomagnetic field program: EOS, v. 68, no. 20, p. 530.

Peddie, N.W., and Fabiano, E.B., 1976, A model of the geomagnetic field for 1975: Journal of Geophysical Research, v. 81, no. 14, p. 2539–2542.

Peddie, N.W., Jones, W.J., and Fabiano, E.B., 1976, Magnetic inclination in the United States—Epoch 1975.0: U.S. Geological Survey Miscellaneous Investigations Series Map I–912.

Peddie, N.W., and Zunde, A.K., 1987, A model of geomagnetic secular variation for 1980–1983: Physics of the Earth and Planetary Interiors, v. 48, p. 324–329.

_____ 1988a, The magnetic field in the United States, 1985, declination chart: U.S. Geological Survey Geophysical Investigations Map GP–986–D.

_____ 1988b, The magnetic field in the United States, 1985, inclination chart: U.S. Geological Survey Geophysical Investigations Map GP–986–I

_____ 1988c, The magnetic field in the United States, 1985, horizontal intensity chart: U.S. Geological Survey Geophysical Investigations Map GP–986–H.

_____ 1988d, The magnetic field in the United States, 1985, vertical intensity chart: U.S. Geological Survey Geophysical Investigations Map GP–986–Z.

_____ 1988e, The magnetic field in the United States, 1985, total intensity chart: U.S. Geological Survey Geophysical Investigations Map GP–986–F.

Svendsen, K.L., 1962, United States magnetic tables for 1960: U.S. Coast and Geodetic Survey Publication 40–2, 91 p.

Figures 3–18

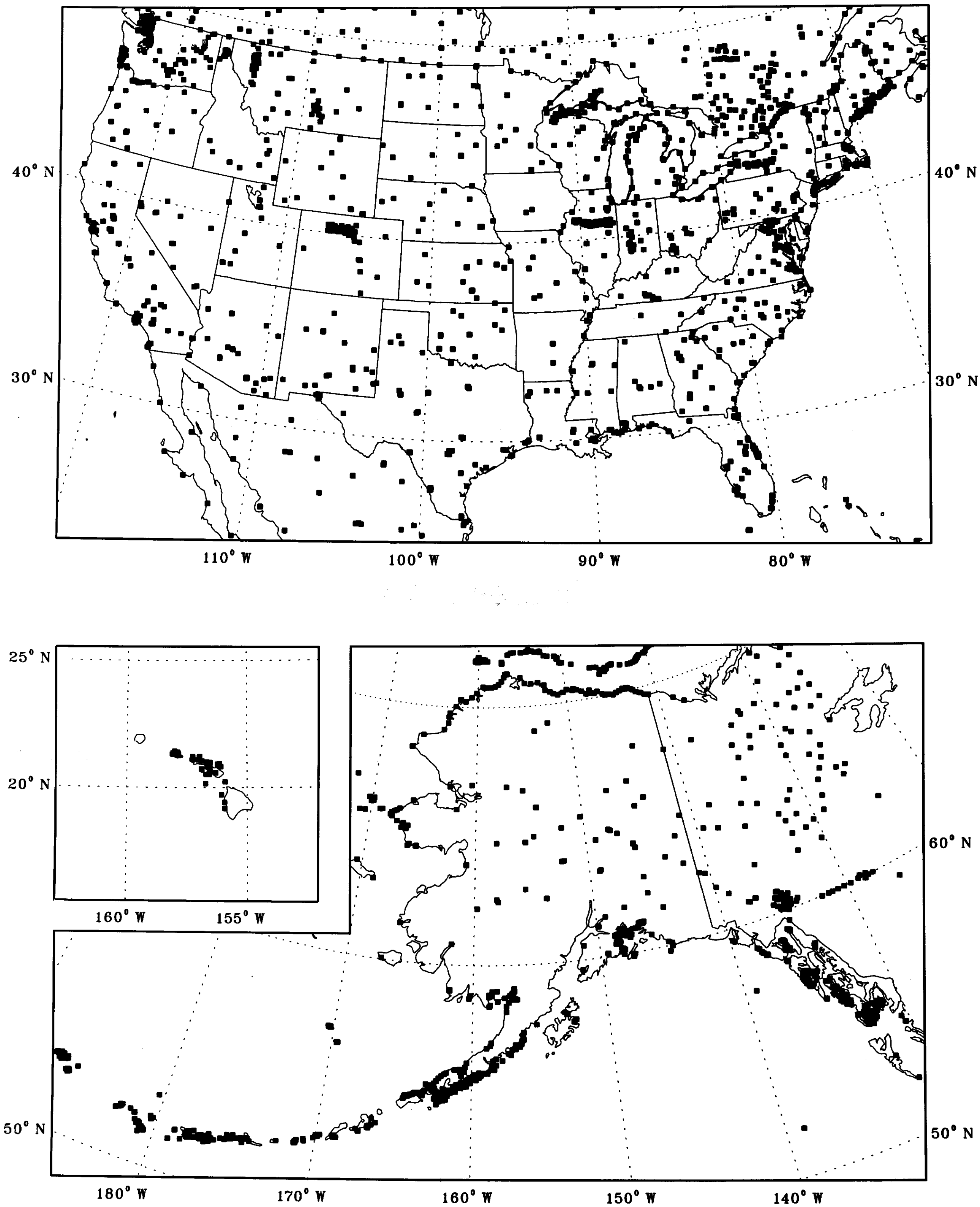


Figure 3. Locations (solid squares) of land-survey measurements used to derive the 1985.0 models.

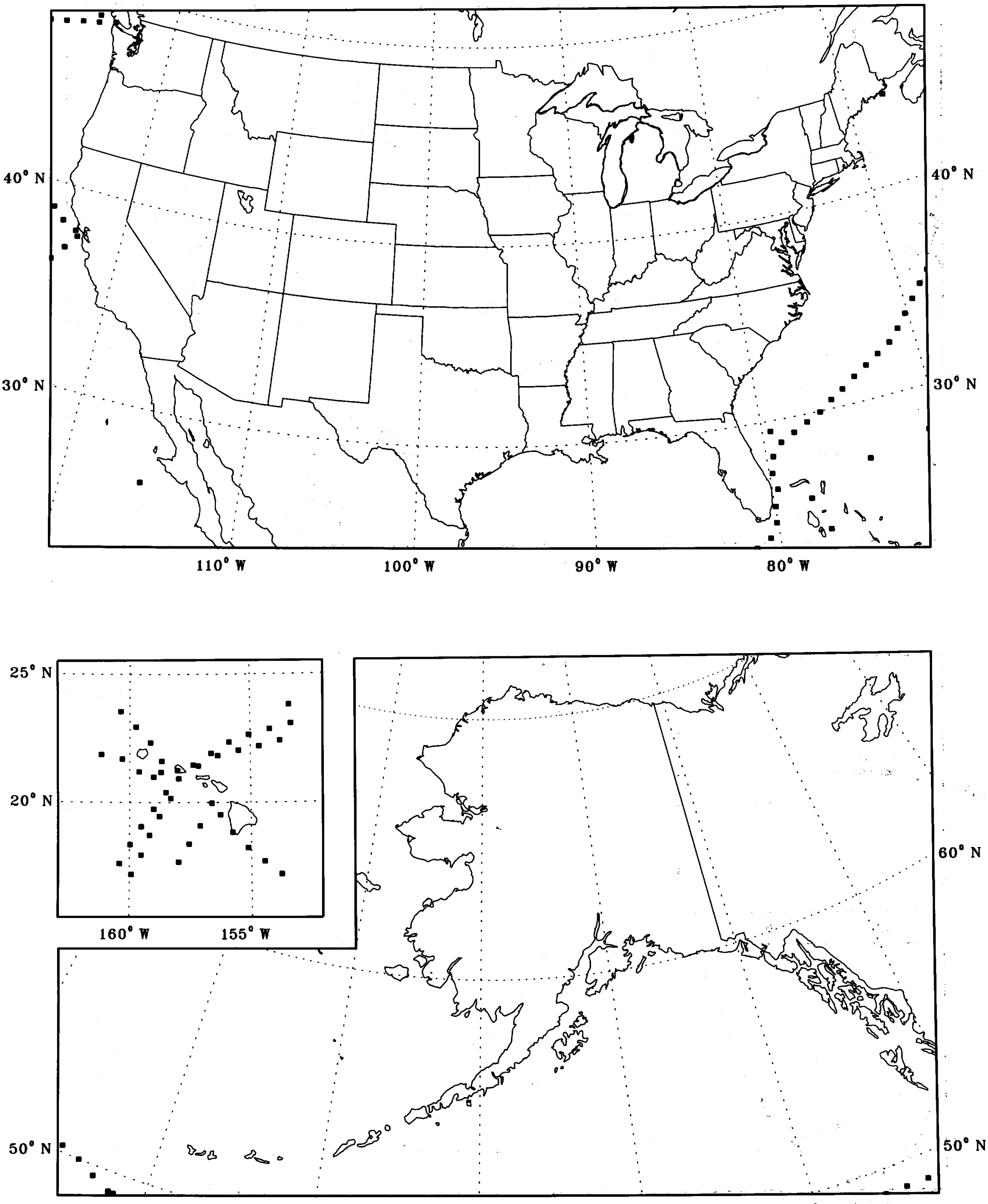


Figure 4. Locations (solid squares) of marine-survey vector measurements used to derive the 1985.0 models.

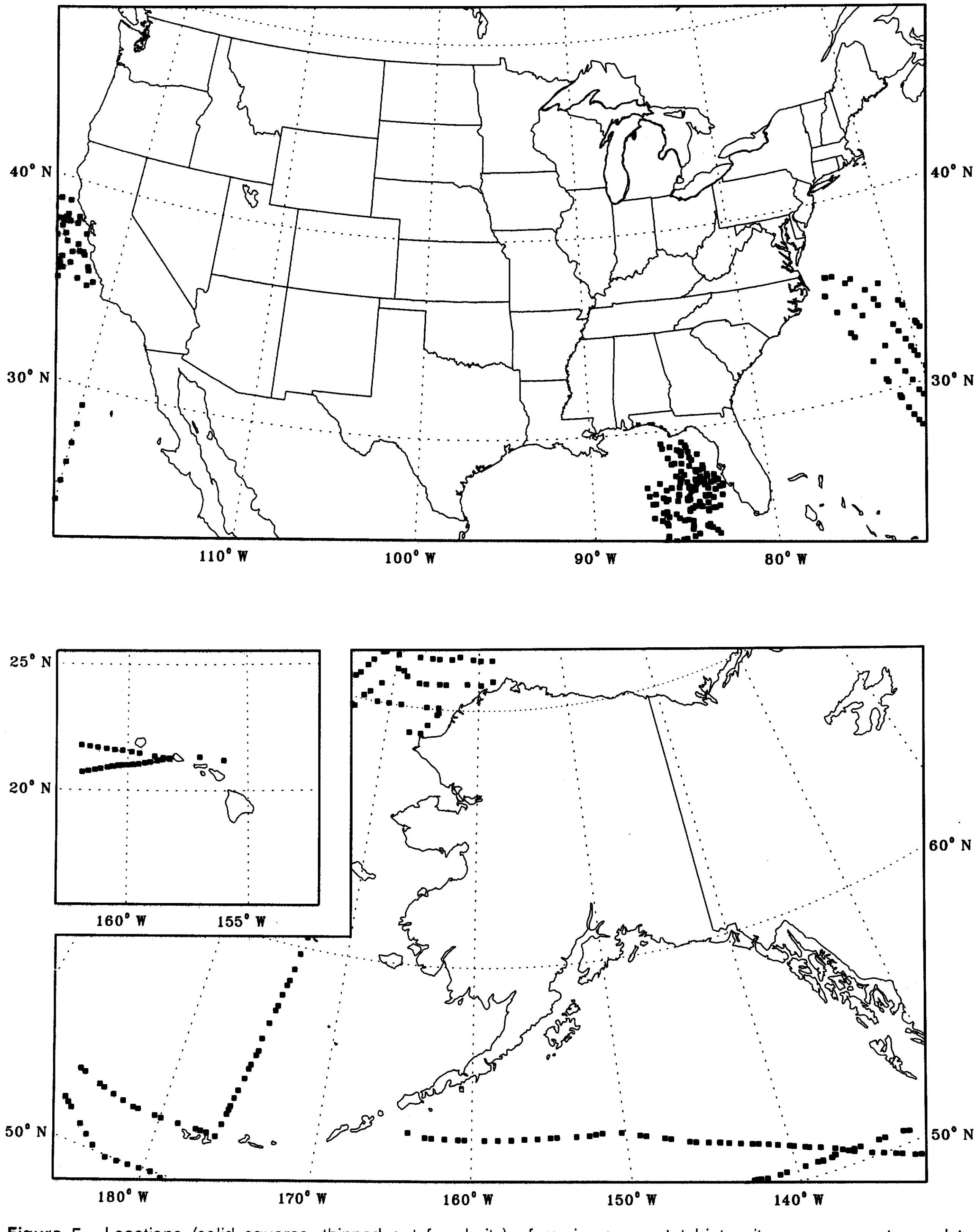
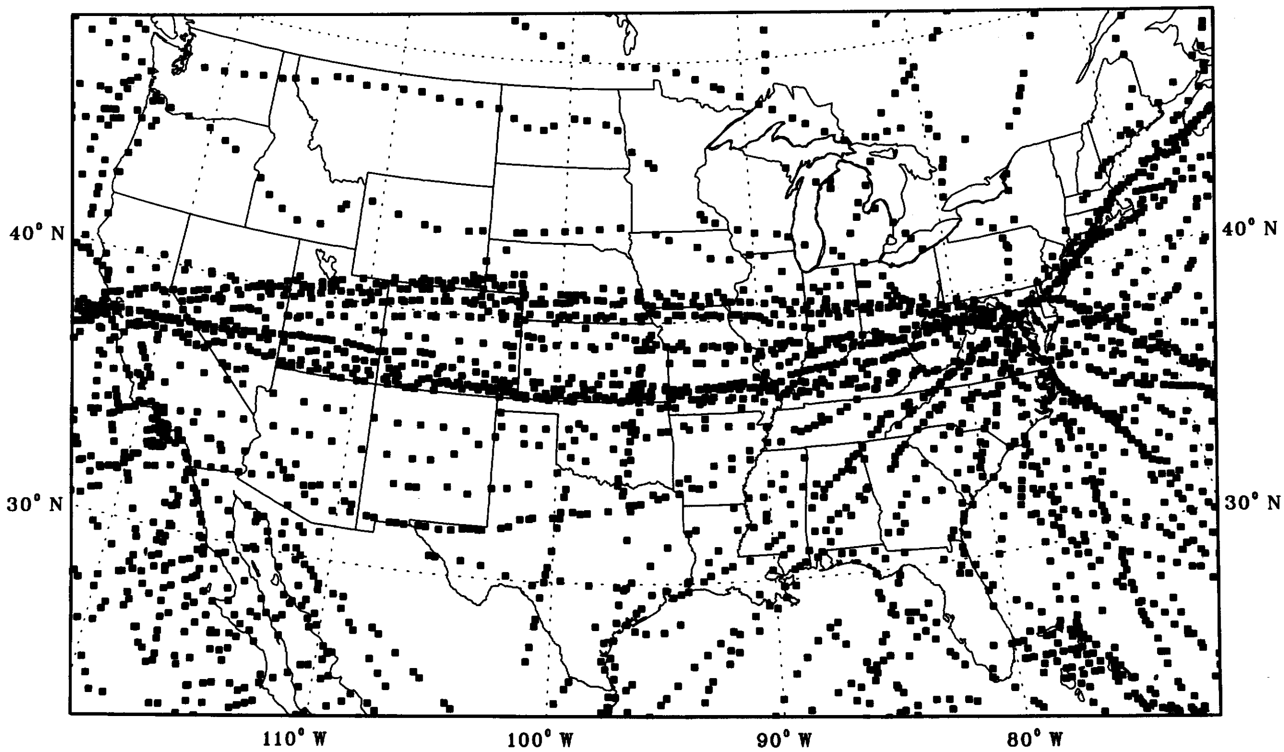


Figure 5. Locations (solid squares, thinned out for clarity) of marine-survey total-intensity measurements used to derive the 1985.0 models.



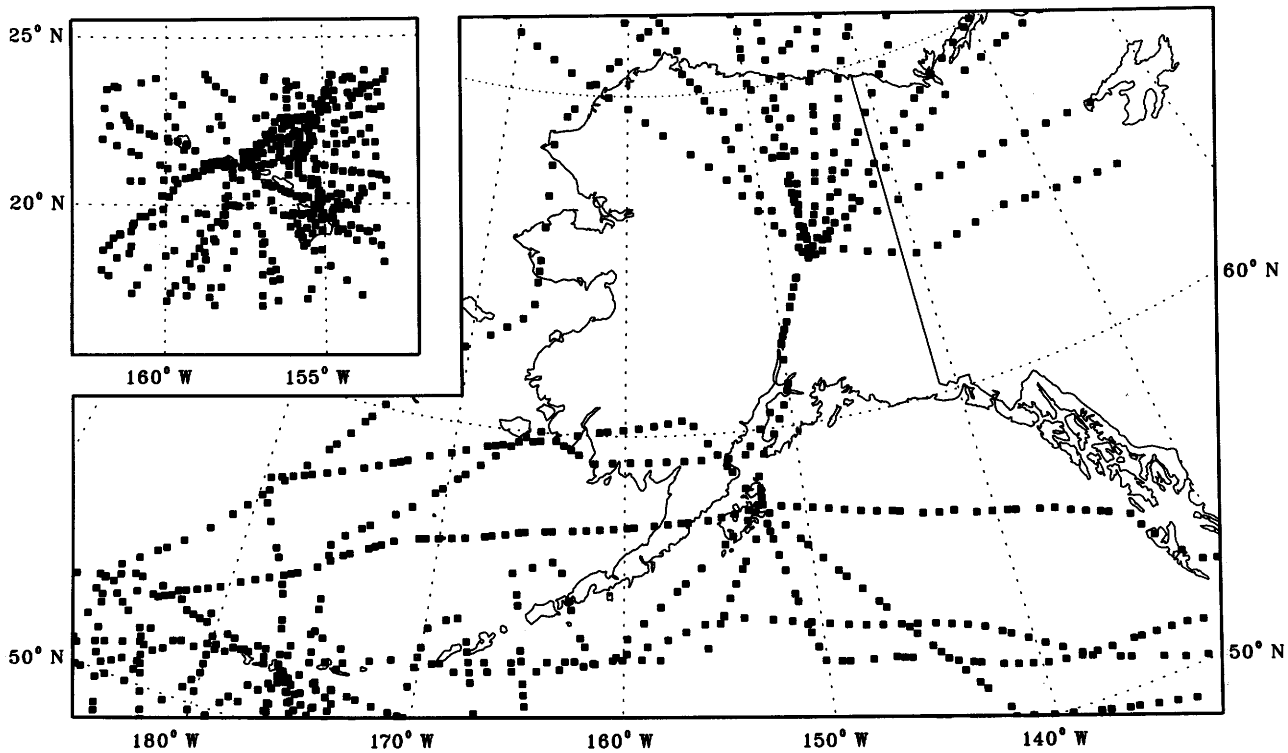


Figure 6. Locations (solid squares, thinned out for clarity) of pre-1975 Project MAGNET aerial-survey vector measurements used to derive the 1985.0 models.

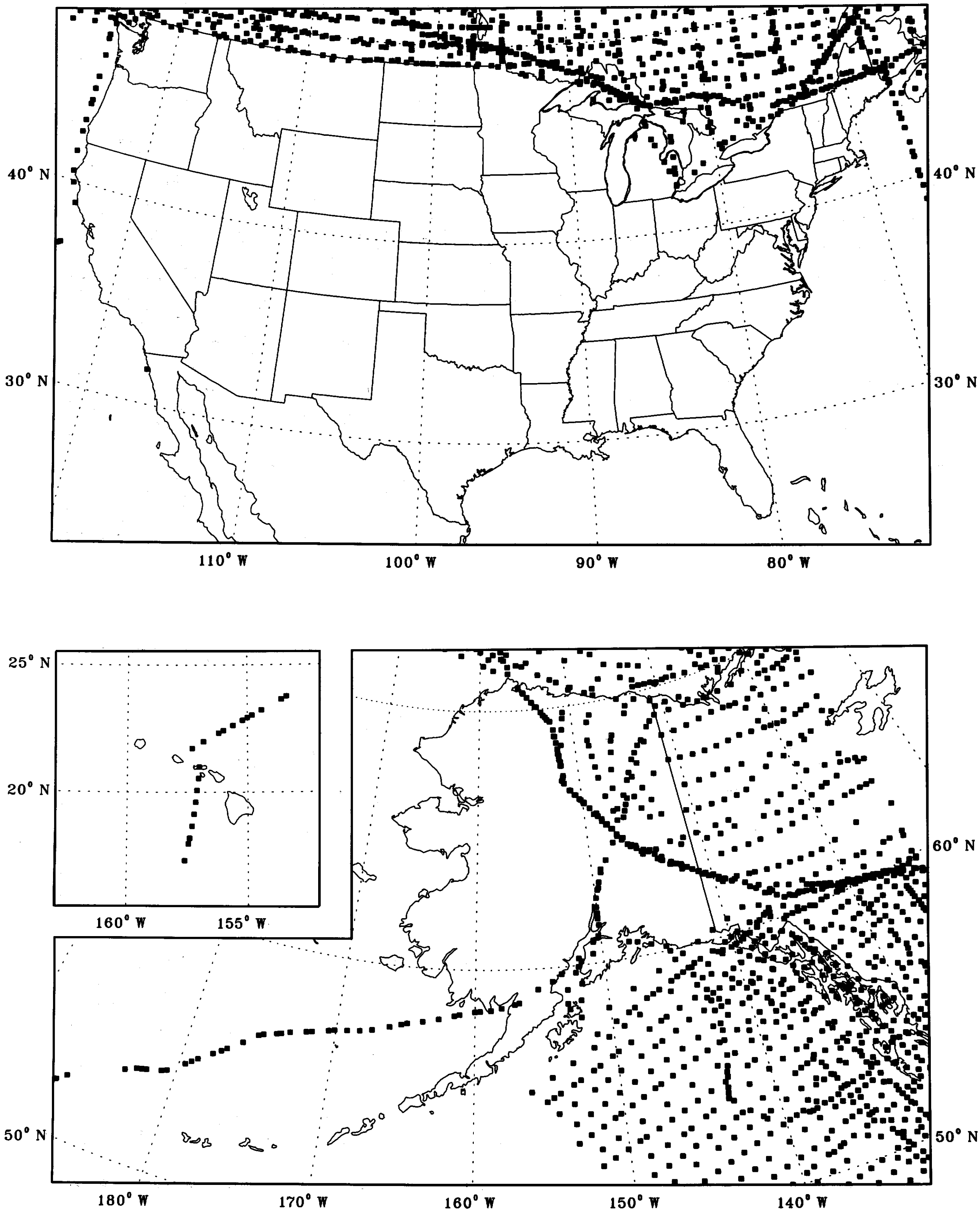


Figure 7. Locations (solid squares, thinned out for clarity) of non-Project MAGNET aerial-survey vector measurements used to derive the 1985.0 models.

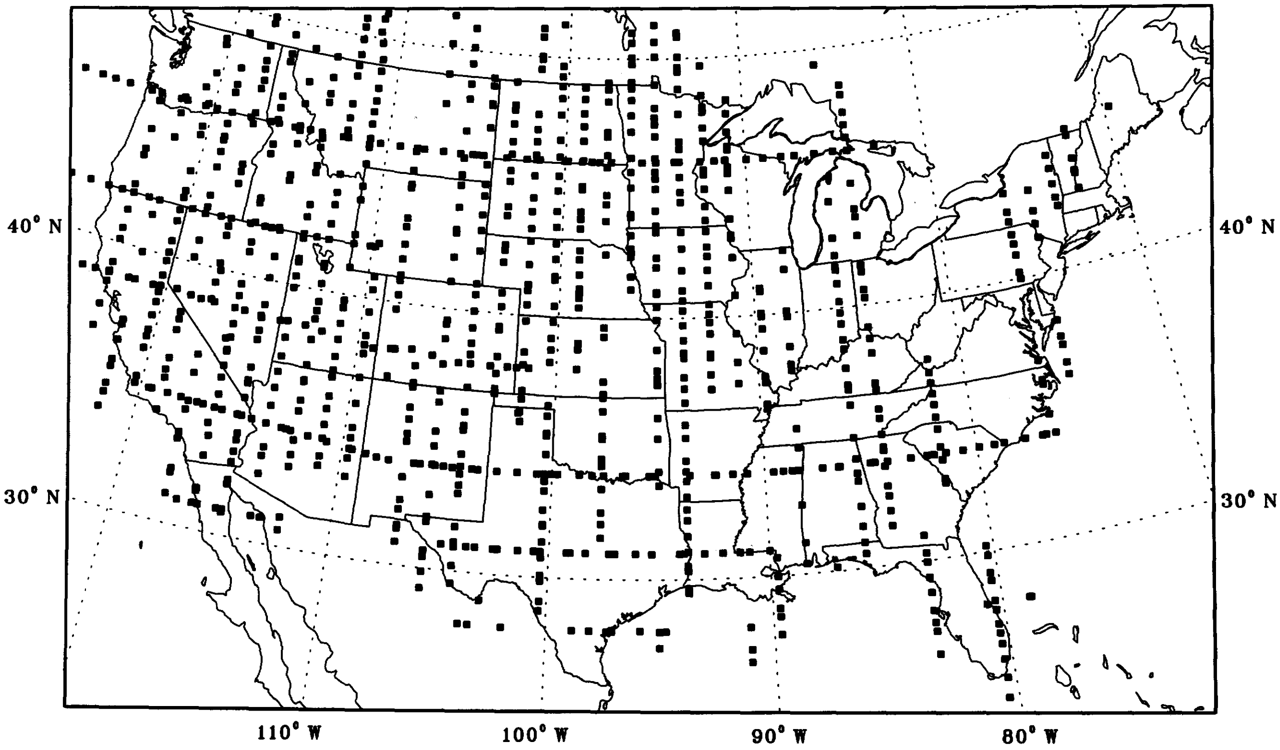


Figure 8. Locations (solid squares, thinned out for clarity) of Project MAGNET aerial survey total-intensity measurements taken during 1976–1977 used to derive the 1985.0 models.

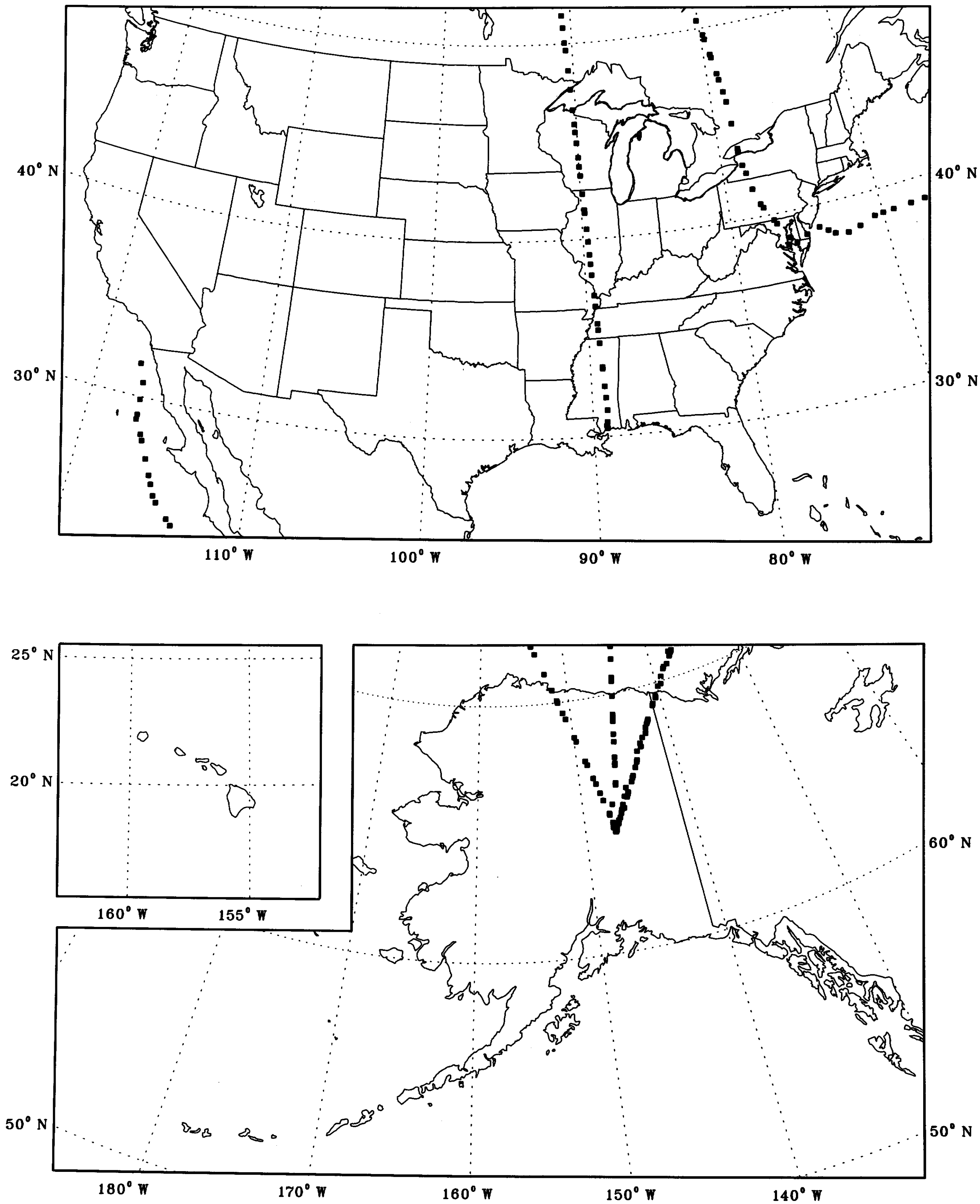


Figure 9. Locations (solid squares, thinned out for clarity) of Project MAGNET aerial-survey vector measurements taken during 1980–1983 used to derive the 1985.0 models.

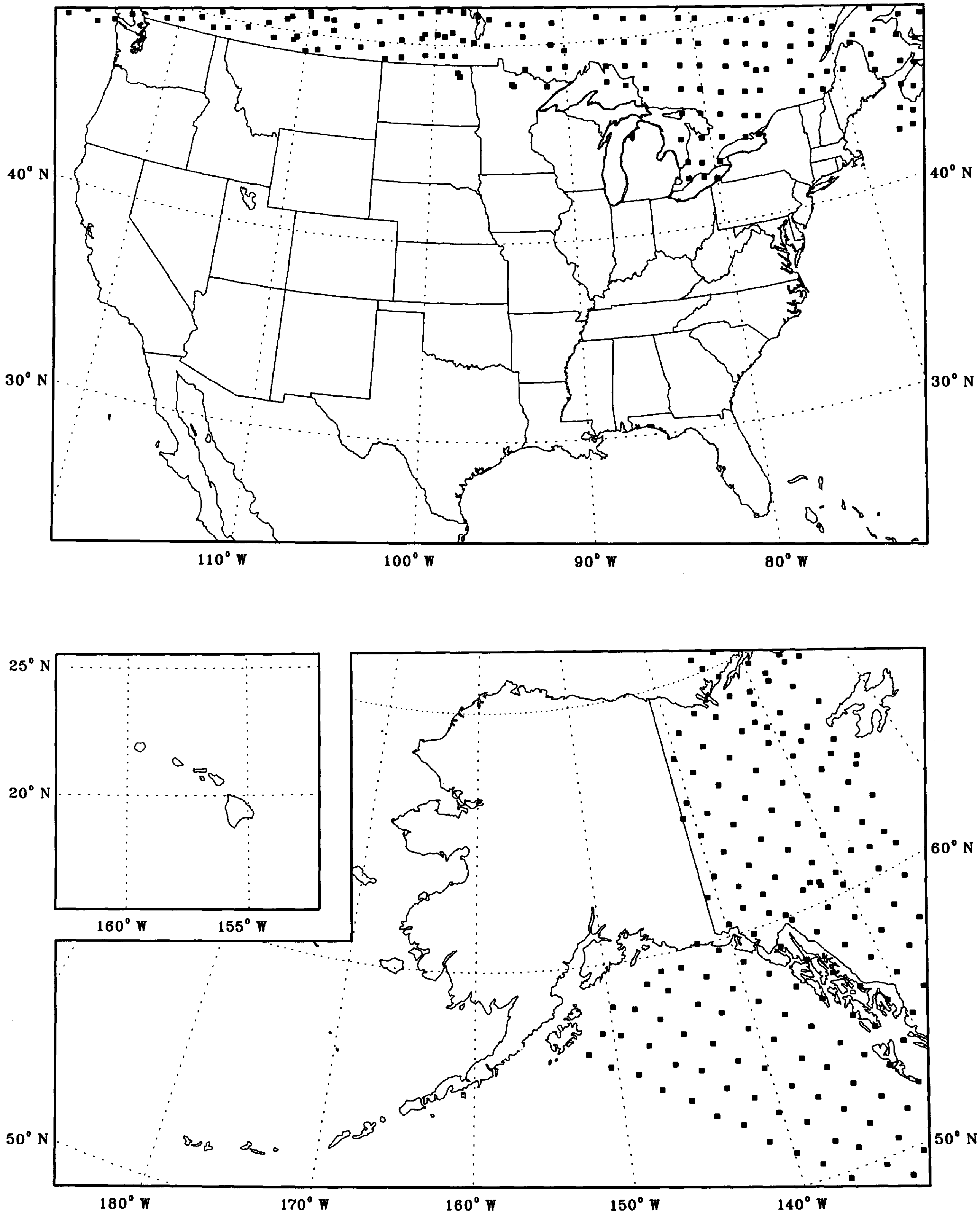


Figure 10. Locations (solid squares) of Canadian aerial-survey vector measurements used to derive the 1985.0 models.

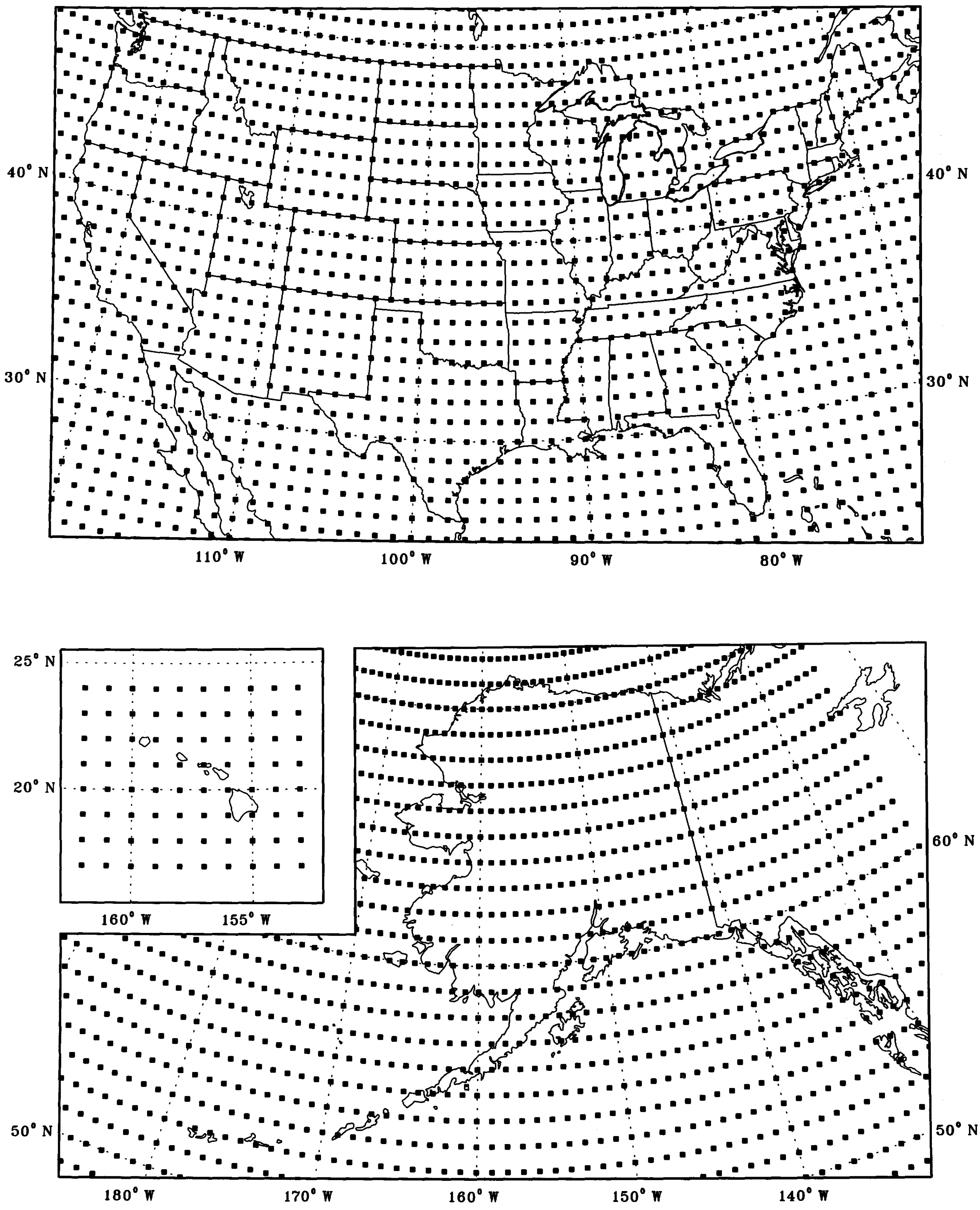
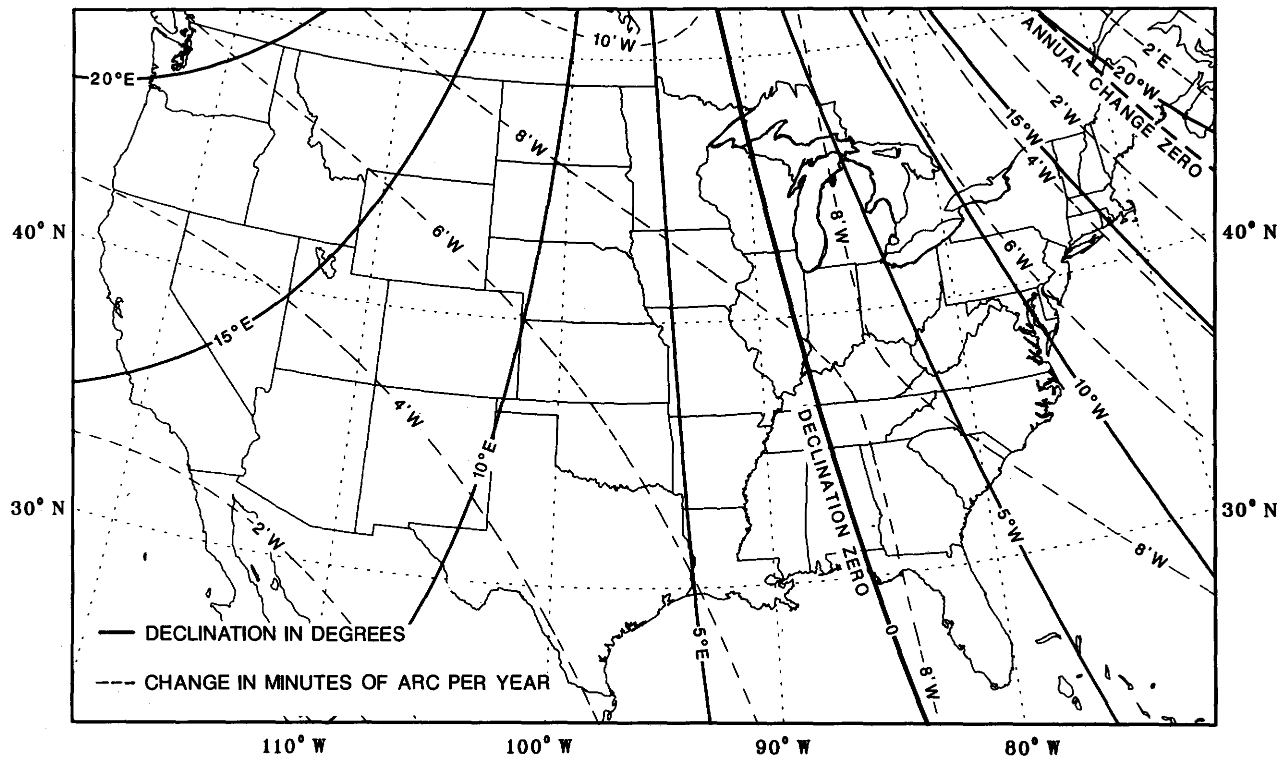


Figure 11. Locations (solid squares) for which International Geomagnetic Reference Field 1985 vector values were produced for use in deriving the 1985.0 models.



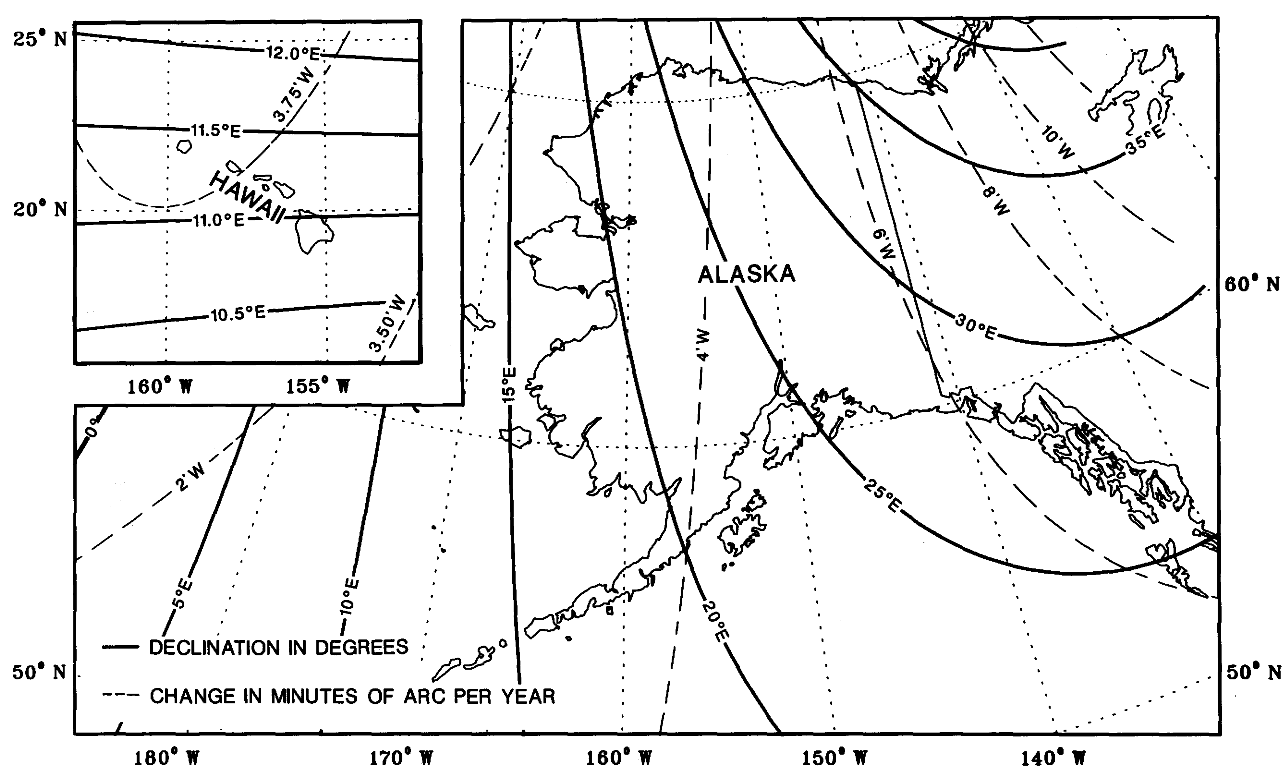


Figure 12. Magnetic declination in the United States, 1985.

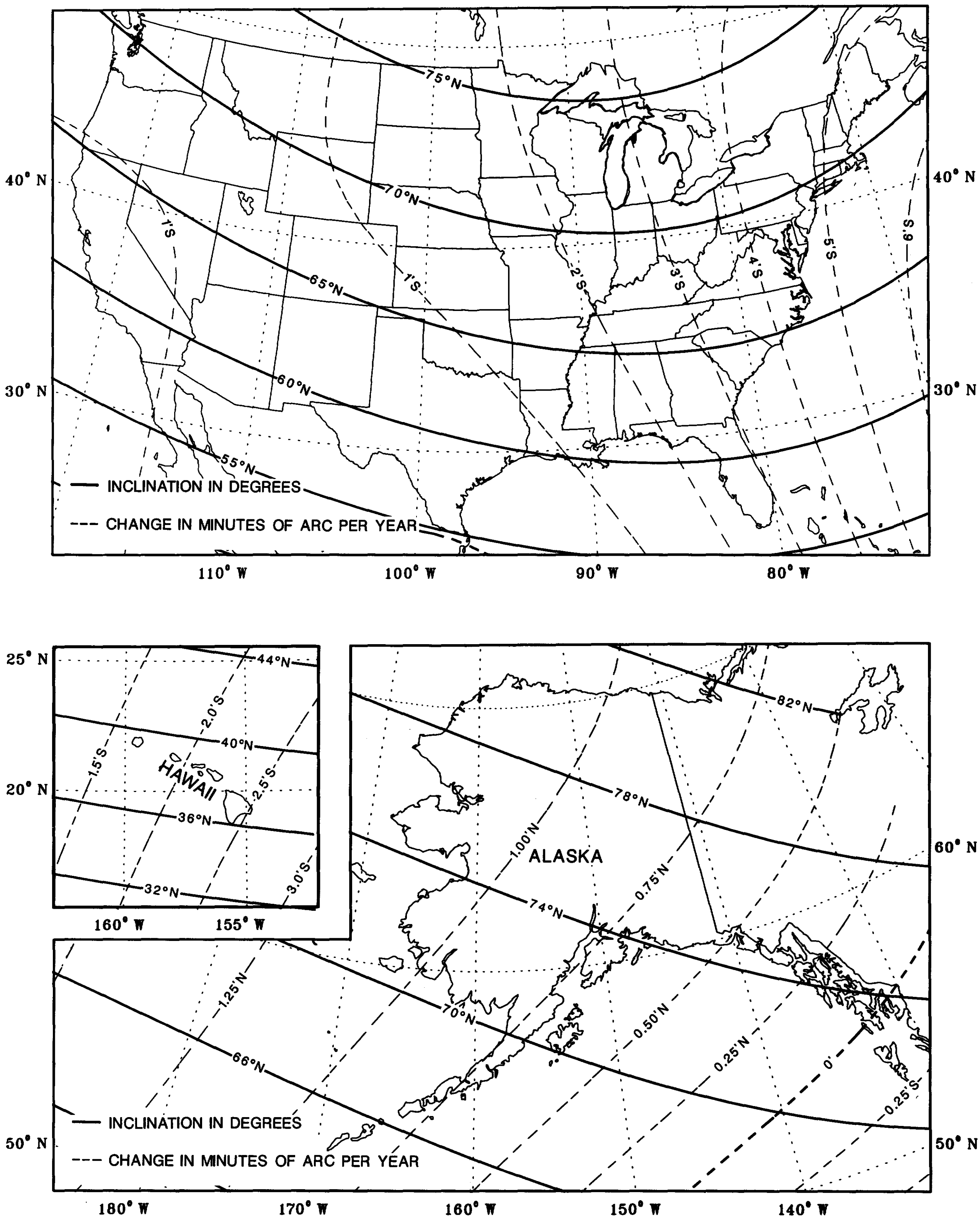


Figure 13. Magnetic inclination in the United States, 1985.

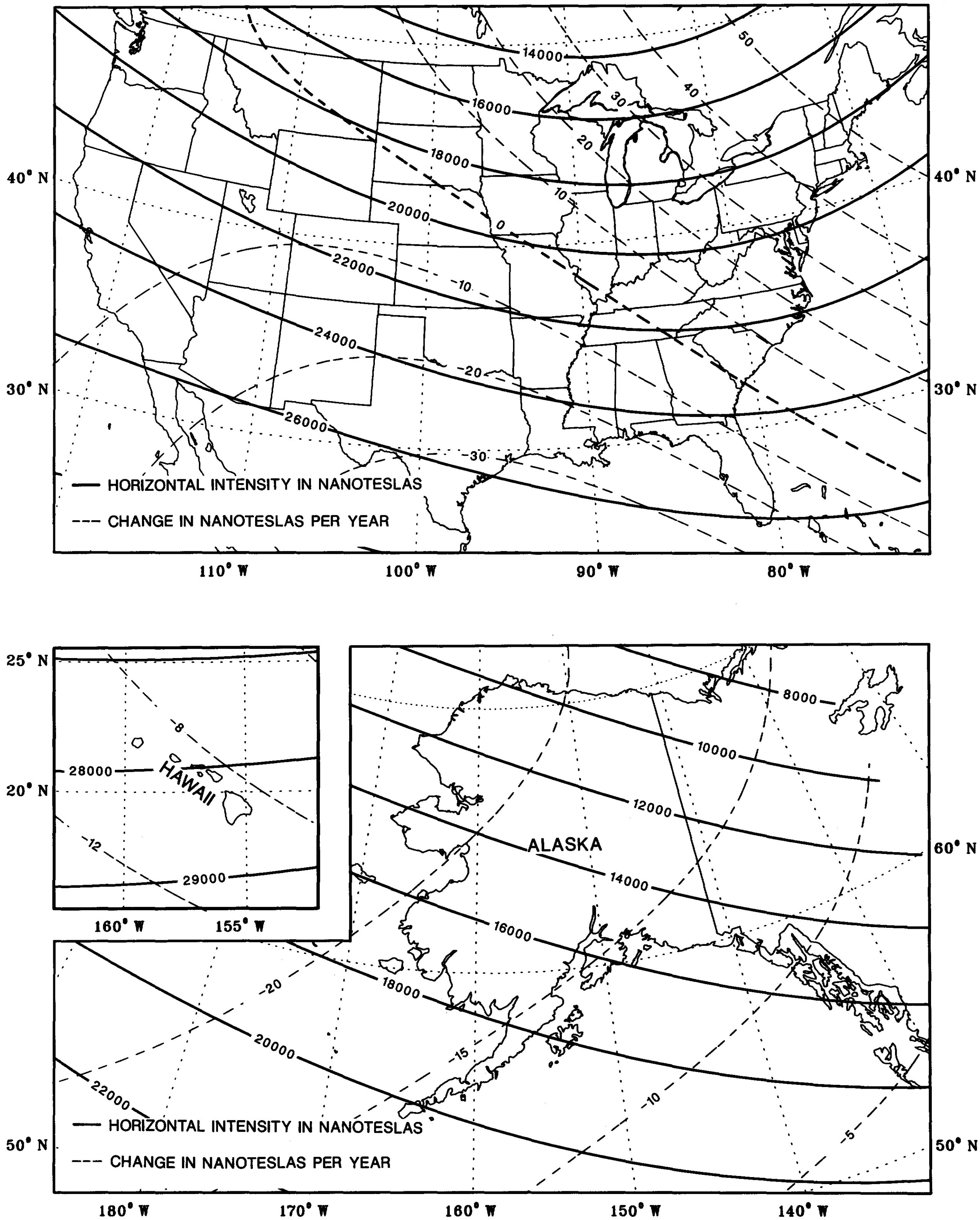


Figure 14. Magnetic horizontal intensity in the United States, 1985.

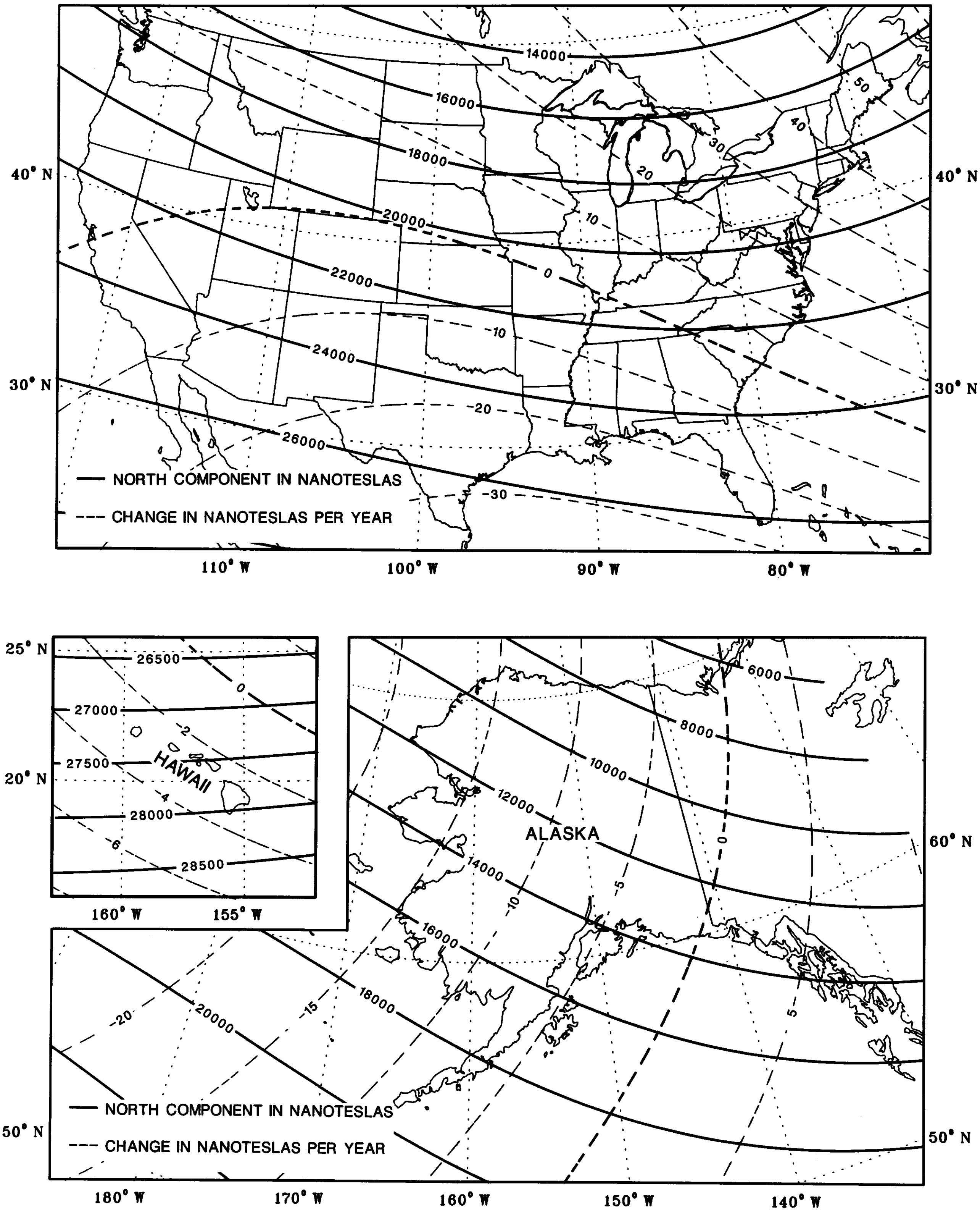


Figure 15. Magnetic north component in the United States, 1985.

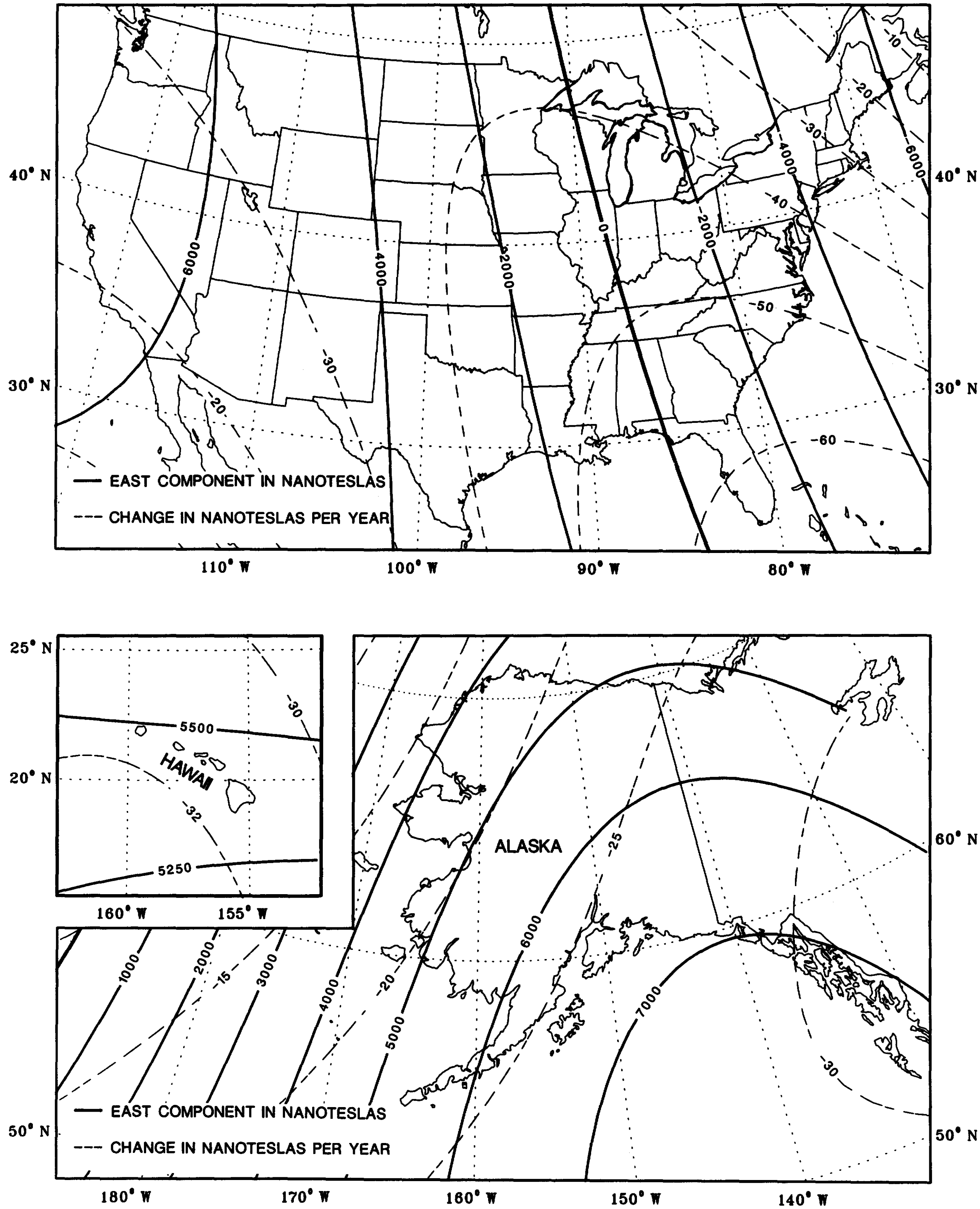
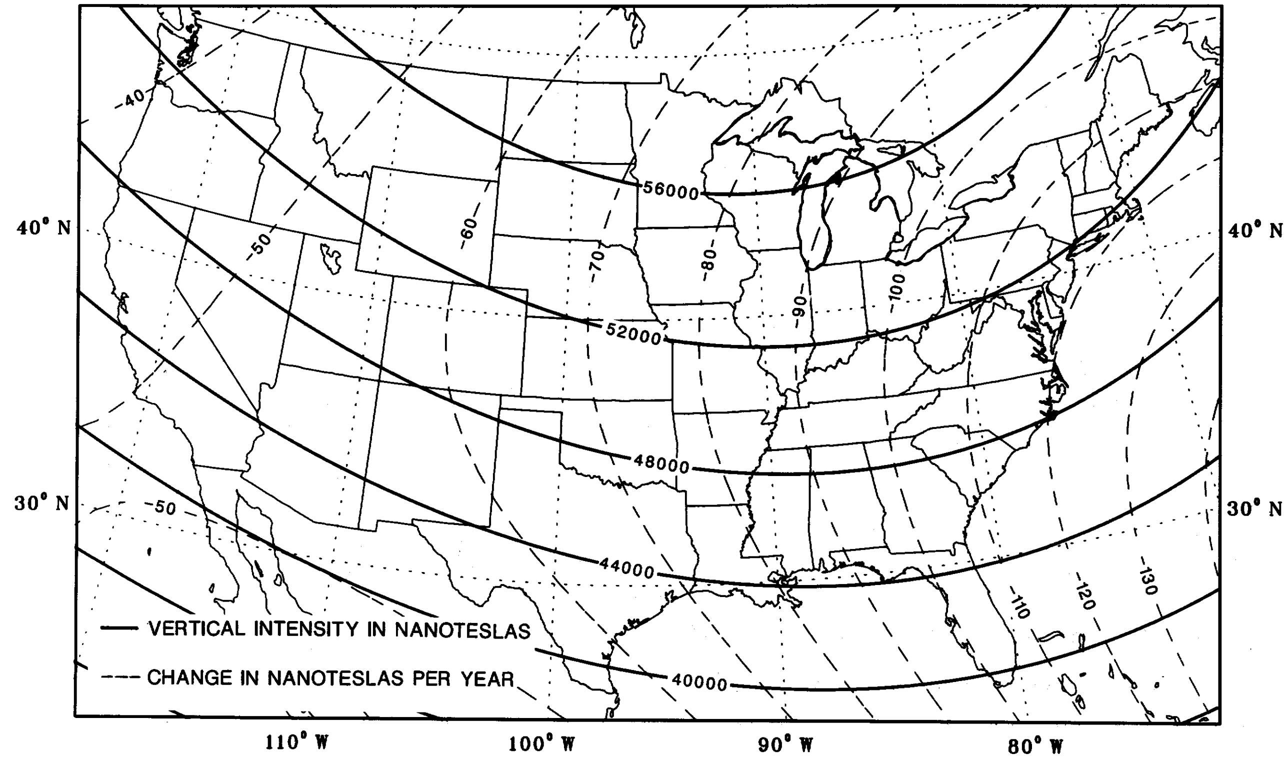


Figure 16. Magnetic east component in the United States, 1985.



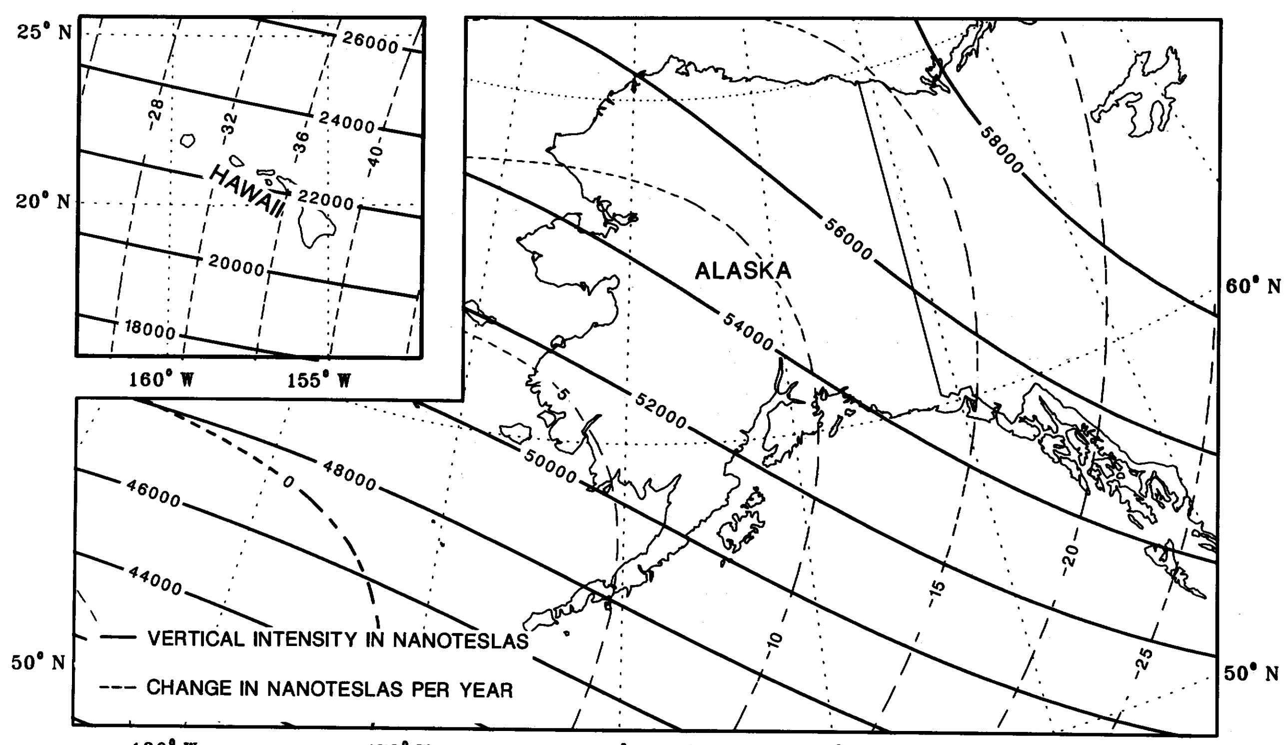


Figure 17. Magnetic vertical intensity in the United States, 1985.

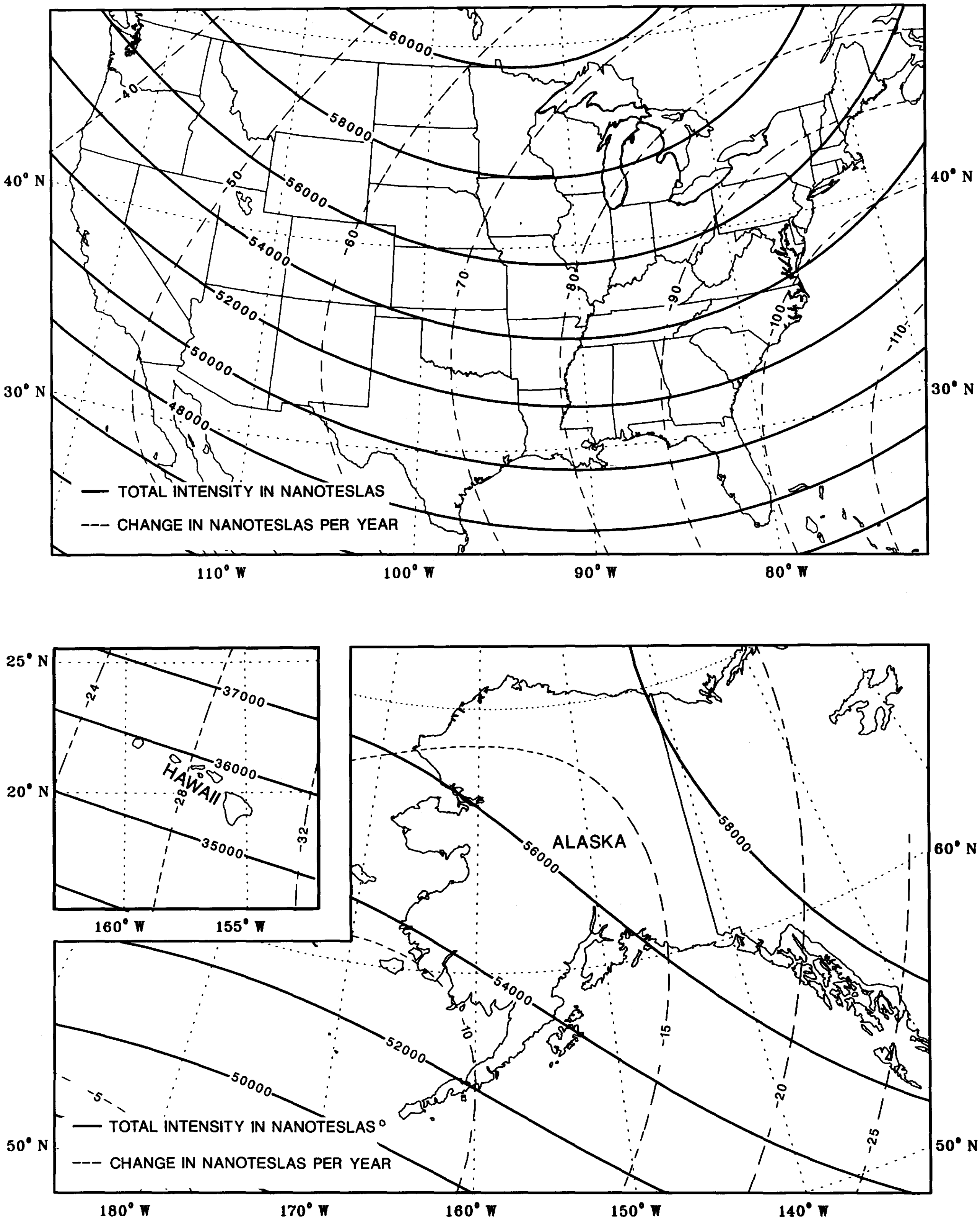


Figure 18. Magnetic total intensity in the United States, 1985.

APPENDIX: Secular-variation data

[Lat, latitude; Lon, Longitude (east if positive, west if negative); Elev, elevation above mean sea level; $\dot{X}$, $\dot{Y}$, and $\dot{Z}$ estimated rates of change of the X, Y, and Z field components; m, meters; St, State postal zip code abbreviation. Parenthetical part of repeat-station name serves to distinguish that station from others nearby]

Name	St	Lat	Lon	Elev	$\dot{X}$	$\dot{Y}$	$\dot{Z}$
		(degrees)		(m)	(nanotesla per year)		
Magnetic observatories							
Baker Lake, Canada		64.333	-96.033	45	23.6	-14.5	-39.4
Barrow	AK	71.323	-156.620	0	-22.1	-21.7	-25.5
Boulder	CO	40.138	-105.238	1650	-1.1	-30.8	-63.4
Cambridge Bay, Canada		69.200	-105.000	20	17.5	-25.5	-25.0
Cape Wellen, USSR		66.163	-169.835	10	-16.1	-13.5	-0.2
College	AK	64.860	-147.837	90	-3.8	-29.7	-18.0
Del Rio	TX	29.300	-100.800	357	-16.7	-31.0	-52.0
Fort Churchill, Canada		58.767	-94.100	40	26.5	-26.3	-51.2
Fredericksburg	VA	38.205	-77.373	69	22.4	-42.1	-115.6
Fresno	CA	37.092	-119.718	336	3.4	-22.8	-59.4
Godhavn, Greenland		69.252	-53.533	24	30.5	25.0	-21.0
Great Whale River, Canada		55.267	-77.783	23	50.6	-18.5	-58.9
Guam, U.S.		13.583	144.870	150	11.9	-4.3	1.3
Honolulu	HI	21.320	-158.002	3	1.4	-27.2	-32.7
Kakioka, Japan		36.230	140.190	26	-5.2	-12.2	25.9
Magadan, USSR		60.117	151.017	0	-35.7	-5.3	-5.6
Meanook, Canada		54.617	-113.333	678	8.9	-39.4	-46.1
Mould Bay, Canada		76.200	-119.400	150	-0.3	-19.5	-19.1
Narssarssuaq, Greenland		61.100	-45.200	4	46.3	33.5	-24.4
Newport	WA	48.263	-117.120	780	8.2	-34.0	-37.5
Ottawa, Canada		45.400	-75.550	760	45.3	-27.6	-103.6
Petropavlovsk, USSR		52.900	158.433	110	-25.7	-9.9	10.8
Resolute Bay, Canada		74.700	-94.900	30	14.2	-8.7	-29.0
San Juan, Puerto Rico		18.113	-66.150	400	-17.9	-63.9	-144.9
Sitka	AK	57.058	-135.325	22	13.7	-34.0	-29.5
Saint John's, Canada		47.600	-52.683	0	57.6	19.0	-83.6
Thule (II), Greenland		77.483	-69.167	60	21.2	8.4	-22.2
Tucson	AZ	32.247	-110.833	770	-16.1	-18.3	-53.8
Victoria, Canada		48.517	-123.417	197	13.2	-30.7	-41.6
Yellowknife, Canada		62.400	-114.500	183	11.0	-32.3	-35.8

Name	St	Lat (degrees)	Lon (degrees)	Elev (m)	$\dot{X}$ (nanotesla per year)	$\dot{Y}$ (nanotesla per year)	$\dot{Z}$ (nanotesla per year)
Repeat stations							
Majuro (new airport) ---------		7.067	171.280	0	-16.9	-7.7	-40.3
Midway (1980) ---------------		28.210	-177.380	0	-12.3	-27.8	5.1
Wake ------------------------		19.312	166.623	0	-21.3	-6.5	19.9
Anchorage (NBS) ---------	AK	61.235	-149.868	40	-2.7	-30.9	-14.5
Bethel (airport 2) ------	AK	60.783	-161.833	30	-9.1	-23.4	5.7
Fort Yukon (IGY) --------	AK	66.563	-145.260	130	5.9	-15.8	4.2
Homer (1) ---------------	AK	59.640	-151.493	10	1.0	-16.7	4.6
Kodiak (1975) -----------	AK	57.800	-152.365	0	-0.6	-22.9	4.9
Kotzebue (1975) ---------	AK	66.877	-162.637	0	-8.9	-9.2	0.4
Nome (airport 3) --------	AK	64.515	-165.383	20	-23.7	-8.0	-5.1
Northway (IGY) ----------	AK	63.018	-141.797	580	1.3	-24.5	0.6
Unalakleet (1975) -------	AK	63.890	-160.797	0	-8.5	-10.4	1.2
Marion (forest) ---------	AL	32.657	-87.278	0	-9.9	-52.7	-88.6
Castle Rock -------------	CA	37.240	-122.130	490	-16.7	-28.4	-39.5
Lompoc ------------------	CA	34.637	-120.532	80	-4.2	-18.8	-44.5
Fort Myers --------------	FL	26.610	-81.883	0	-41.2	-66.0	-102.7
Key West (golf aux 2) ---	FL	24.573	-81.743	0	-35.0	-85.8	-95.3
Spruce Creek (1958) -----	FL	29.077	-81.032	10	-14.6	-72.7	-105.2
Bainbridge (1958) -------	GA	30.907	-84.600	30	-16.2	-58.5	-96.8
Milledgeville (golf) ----	GA	33.095	-83.283	0	-6.4	-50.8	-98.4
Waycross (airport) ------	GA	31.255	-82.400	40	-9.3	-56.0	-105.0
Bangor (Broadway) -------	ME	44.828	-68.788	60	57.4	-19.1	-111.3
Bangor (Griffin) --------	ME	44.825	-68.808	40	50.2	-17.7	-115.0
Fort Kent (hosp. B) -----	ME	47.268	-68.595	190	58.2	-15.3	-105.9
Fort Kent (pasture) -----	ME	47.247	-68.587	190	69.9	-8.1	-104.6
Detroit (River Rouge) ---	MI	42.343	-83.253	190	23.9	-50.6	-106.3
Detroit (park) ----------	MI	42.355	-83.262	190	23.9	-50.2	-106.0
Marquette (golf 1947) ---	MI	46.538	-87.423	270	19.1	-45.6	-79.7
Marquette (golf 2) ------	MI	46.538	-87.422	240	23.4	-43.9	-79.7
Brooklyn ----------------	MS	31.030	-89.170	120	-14.9	-52.3	-82.8
Grenada (1971) ----------	MS	33.750	-89.797	60	-14.3	-44.7	-81.1
Lamar (B 1981) ----------	MS	30.925	-89.387	0	-17.3	-51.4	-81.9
Goldsboro (airport) -----	NC	35.385	-77.983	40	-6.5	-54.7	-123.5
Bowbells ----------------	ND	48.800	-102.242	590	40.3	-48.4	-55.4
Syracuse (Drumlins B) ---	NY	43.017	-76.105	210	31.5	-36.0	-114.9
Syracuse (Drumlins) -----	NY	43.017	-76.103	220	33.6	-35.7	-114.8
Indiantown Gap (airf) ---	PA	40.453	-76.545	160	35.1	-44.0	-122.1
Indiantown Gap (lake) ---	PA	40.417	-76.597	130	35.1	-46.5	-121.8
Kingston (campus) -------	RI	41.480	-71.518	70	42.7	-30.6	-126.6
Kingston (turf) ---------	RI	41.488	-71.545	30	37.5	-29.5	-128.7

Name	St	Lat (degrees)	Lon (degrees)	Elev (m)	$\dot{X}$ (nanotesla per year)	$\dot{Y}$ (nanotesla per year)	$\dot{Z}$ (nanotesla per year)
Repeat stations--Continued							
Fort Jackson ------------	SC	34.017	-80.915	150	9.1	-53.6	-107.4
Fort Jackson (2) --------	SC	34.018	-80.910	150	11.2	-53.8	-108.8
Brownsville (golf 2) ----	TX	25.883	-97.497	10	-48.3	-39.5	-48.5
Dallas (observatory) ----	TX	32.982	-96.750	210	-29.1	-51.9	-77.2
Orange (C) --------------	TX	30.063	-93.802	0	-27.6	-47.7	-68.3
Van Horn (airport) ------	TX	31.062	-104.787	1200	-31.4	-33.0	-54.0
Salt Lake City (hill) ---	UT	40.782	-111.855	0	-32.9	-31.3	-36.4
Burlington (LP) ---------	VT	44.457	-73.155	120	45.1	-28.9	-110.6
Burlington (RS) ---------	VT	44.470	-73.197	120	40.1	-34.8	-124.2
Eau Claire --------------	WI	44.833	-91.532	300	11.0	-55.3	-84.9
Model fill-in values							
		10.000	-90.000	0	-49.9	-41.4	-16.1
		10.000	-105.000	0	-34.9	1.9	-25.9
		10.000	-120.000	0	-20.6	0.6	-58.5
		10.000	-135.000	0	-14.1	-19.3	-53.1
		75.000	150.000	0	-22.5	-6.6	-34.2
		0.000	180.000	0	-8.8	-9.3	7.6

*U.S. GOVERNMENT PRINTING OFFICE: 1989-0-773-047/06018

SELECTED SERIES OF U.S. GEOLOGICAL SURVEY PUBLICATIONS

Periodicals

Earthquakes & Volcanoes (issued bimonthly).
Preliminary Determination of Epicenters (issued monthly).

Technical Books and Reports

Professional Papers are mainly comprehensive scientific reports of wide and lasting interest and importance to professional scientists and engineers. Included are reports on the results of resource studies and of topographic, hydrologic, and geologic investigations. They also include collections of related papers addressing different aspects of a single scientific topic.

Bulletins contain significant data and interpretations that are of lasting scientific interest but are generally more limited in scope or geographic coverage than Professional Papers. They include the results of resource studies and of geologic and topographic investigations; as well as collections of short papers related to a specific topic.

Water-Supply Papers are comprehensive reports that present significant interpretive results of hydrologic investigations of wide interest to professional geologists, hydrologists, and engineers. The series covers investigations in all phases of hydrology, including hydrogeology, availability of water, quality of water, and use of water.

Circulars present administrative information or important scientific information of wide popular interest in a format designed for distribution at no cost to the public. Information is usually of short-term interest.

Water-Resources Investigations Reports are papers of an interpretive nature made available to the public outside the formal USGS publications series. Copies are reproduced on request unlike formal USGS publications, and they are also available for public inspection at depositories indicated in USGS catalogs.

Open-File Reports include unpublished manuscript reports, maps, and other material that are made available for public consultation at depositories. They are a nonpermanent form of publication that may be cited in other publications as sources of information.

Maps

Geologic Quadrangle Maps are multicolor geologic maps on topographic bases in 7 1/2- or 15-minute quadrangle formats (scales mainly 1:24,000 or 1:62,500) showing bedrock, surficial, or engineering geology. Maps generally include brief texts; some maps include structure and columnar sections only.

Geophysical Investigations Maps are on topographic or planimetric bases at various scales; they show results of surveys using geophysical techniques, such as gravity, magnetic, seismic, or radioactivity, which reflect subsurface structures that are of economic or geologic significance. Many maps include correlations with the geology.

Miscellaneous Investigations Series Maps are on planimetric or topographic bases of regular and irregular areas at various scales; they present a wide variety of format and subject matter. The series also includes 7 1/2-minute quadrangle photogeologic maps on planimetric bases which show geology as interpreted from aerial photographs. Series also includes maps of Mars and the Moon.

Coal Investigations Maps are geologic maps on topographic or planimetric bases at various scales showing bedrock or surficial geology, stratigraphy, and structural relations in certain coal-resource areas.

Oil and Gas Investigations Charts show stratigraphic information for certain oil and gas fields and other areas having petroleum potential.

Miscellaneous Field Studies Maps are multicolor or black-and-white maps on topographic or planimetric bases on quadrangle or irregular areas at various scales. Pre-1971 maps show bedrock geology in relation to specific mining or mineral-deposit problems; post-1971 maps are primarily black-and-white maps on various subjects such as environmental studies or wilderness mineral investigations.

Hydrologic Investigations Atlases are multicolored or black-and-white maps on topographic or planimetric bases presenting a wide range of geohydrologic data of both regular and irregular areas; principal scale is 1:24,000 and regional studies are at 1:250,000 scale or smaller.

Catalogs

Permanent catalogs, as well as some others, giving comprehensive listings of U.S. Geological Survey publications are available under the conditions indicated below from the U.S. Geological Survey, Books and Open-File Reports Section, Federal Center, Box 25425, Denver, CO 80225. (See latest Price and Availability List.)

"Publications of the Geological Survey, 1879- 1961" may be purchased by mail and over the counter in paperback book form and as a set of microfiche.

"Publications of the Geological Survey, 1962- 1970" may be purchased by mail and over the counter in paperback book form and as a set of microfiche.

"Publications of the U.S. Geological Survey, 1971- 1981" may be purchased by mail and over the counter in paperback book form (two volumes, publications listing and index) and as a set of microfiche.

Supplements for 1982, 1983, 1984, 1985, 1986, and for subsequent years since the last permanent catalog may be purchased by mail and over the counter in paperback book form.

State catalogs, "List of U.S. Geological Survey Geologic and Water-Supply Reports and Maps For (State)," may be purchased by mail and over the counter in paperback booklet form only

"Price and Availability List of U.S. Geological Survey Publications," issued annually, is available free of charge in paperback booklet form only.

Selected copies of a monthly catalog "New Publications of the U.S. Geological Survey" available free of charge by mail or may be obtained over the counter in paperback booklet form only. Those wishing a free subscription to the monthly catalog "New Publications of the U.S. Geological Survey" should write to the U.S. Geological Survey, 582 National Center, Reston, VA 22092.

Note.--Prices of Government publications listed in older catalogs, announcements, and publications may be incorrect. Therefore, the prices charged may differ from the prices in catalogs, announcements, and publications.