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THE UTILITY OF SURFACE MAGNETIC FIELD MEASUREMENTS IN THE MAGSAT PROGRAM

by

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INTRODUCTION

Magsat is a satellite designed for making measurements of the geomagnetic vector field. When launched in September of 1979 it will occupy a low (less than 450 km) polar orbit, with a lifetime of about 6 months. The fully stabilized, earth-oriented spacecraft will measure the earth's field to an expected root-sum-square (rss) accuracy of 6 nanotesla (nT) in each component and 3 nT in total intensity. The rss is taken over all expected error contributions, including orbital position and attitude accuracy. Attitude error is unique to the vector measurement and accounts for the difference in error magnitude between the component measurements and the total intensity measurements.

The Magsat data will have important applications, including the creation of updated models of the internal magnetic field of the earth, investigations of the internal characteristics of the earth via study of fields induced within the earth, and the study of fields due to currents in the ionosphere and magnetosphere. All of the uses mentioned can be enhanced by the acquisition of data from magnetic observatories and repeat stations at the surface of the earth. This report is our assessment of the need and value of such surface measurements and our recommendations concerning how the present measurement plans could be profitably expanded. The views expressed are those of the authors and do not constitute official positions of the two agencies.

GEOMAGNETIC FIELD MODELS - SECULAR CHANGE

Accurate, up-to-date field models are required for a number of applications, including the production of declination charts for navigation, removal of background fields from aeromagnetic and ship-borne magnetic surveys, satellite attitude control and determination, and calculations of field lines and conjugate points for ionospheric and magnetospheric studies. Magsat will perform the first truly global, vector, survey of the geomagnetic field. Field models incorporating the Magsat data should be the most accurate, for their epoch, of any in existence. However, unless an accurate model of the secular variation (See Figure 1) is available, these models will become unreliable in some regions within a few years and would be out of date in about five years. A more accurate model of secular change would greatly extend the period of usefulness of field models based on Magsat data. Knowledge of the secular variation is crucial in tying together regional surveys taken at different epochs and it is one of the few sources of information regarding the earth's core, where the internal field originates, and the core-mantle boundary.

Secular change models depend for their accuracy on the availability of an adequate global distribution of data at token intervals of a few years. Between 1964 and 1971 measurements of the scalar field were obtained from the POGO (Polar Orbiting Geophysical Observatory) satellites. In late 1979 and early 1980 global vector measurements will be obtained from Magsat. But in periods when no spacecraft is measuring the field, truly global coverage is not available. This can and has resulted in field models with large errors in some locations, such as the ocean areas, because of inadequate determination of the secular variation. Properly placed magnetic observatories and repeat stations, with measurements repeated every 3-5 years, can alleviate this problem.

A basic data set for use in model development will be obtained from the active standard observatories and variation stations. Those known to us as of this date are shown in Figure 2. These will be supplemented by regular repeat measurements. Based on past experience and known commitments, regular repeat measurements will be acquired for the U.S., Canada, Western Europe, Australia, Japan, South Africa and other countries. We strongly encourage the continuation of such measurements and recommend additional measurements to obtain more uniform coverage in late 1979 and in 1980, during the lifetime of Magsat. These measurements should be repeated in 1982 and in 1984.

It is clear from Figure 2 that the expected distribution of surface data omits many large areas, particularly in the oceans. This has resulted in a major shortcoming in previous secular variation models. In order to improve the useful lifetime of Magsat-based models, magnetic measurements are desirable at key locations throughout the world. Figure 3 is a map showing the standard observatories, variation stations, and recommended new observatories and special repeat stations. Table 1 is a list of the recommended new and special station locations. All of these stations are important, but in the event that limited resources or other considerations require making a choice among the additional recommended stations, we suggest that the higher priority stations be selected for occupation. The list of locations is based on the work of D. Voppel in Circular No. III. of IAGA Working Group V-10.

All measurements should be absolute with the following accuracies as a goal:

ELEMENT	OBSERVATORY	REPEAT STATIONS
D	0.5′	1.′0
H	2-5 nT	5 nT
Z	< 5 nT	5 nT
F	1 nT	2 nT

The figures under the observatory column represent the probable accuracy of values scaled from magnetograms or obtained from digitized data. The figures for the repeat sations show the probable accuracy of the absolute measurements.

Repeat measurements should be made for a sufficient period (from several days to two weeks) to insure that the measurements are representative of quiet day periods.

UPPER MANTLE CONDUCTIVITY

Knowledge of the conductivity of the upper mantle is valuable in inferring temperature, structural, and compositional variations. Some investigations are underway utilizing Pogo data, but the vector data from Magsat will be more suitable, and we believe that, when augmented by suitably spaced surface measurements, it will extend the existing analysis capability.

Investigations of upper mantle conductivity utilizing satellite data are conducted with data acquired during magnetic storms. The relevant disturbing fields are due to currents in the distant magnetosphere, in particular the equatorial current sheet or ring current. During geomagnetic storms these disturbing fields are large compared with fields from other sources and the resulting signal to noise ratio facilitates separation of internal from external currents. In addition to the need for more accuracy in separating external from internal fields, there is a need to extend existing research in two directions: the frequency range measured needs to be extended and the inversion to conductivity needs to be accomplished as a function of latitude and longitude, i.e. not assuming spherical symmetry. Analysis of Pogo data indicates the potential feasibility of accomplishing the first. The second is, as yet, an unsolved theoretical problem, but is under investigation. If analytic solutions are not obtained, computerized numerical methods will be utilized.

Upper mantle conductivity studies would be greatly enhanced by the acquisition of relatively evenly spaced global surface data. The desired data distribution is the same as that for secular variation described in the previous section, so we propose that these measurements also be made at the locations indicated in Figure 3 and Table 1.

For these studies simultaneous global measurements are required. We propose a special observing period of two months duration, during the Magsat lifetime, at which time observatory measurements would be augmented with suitably located temporary sites to provide the needed global data on a continuous basis. The appropriate time period is soon after Magsat has been launched and its operational status verified. Allowing some time for unforseen difficulties, we suggest that an appropriate time period is November and December of 1979. Absolute measurements may not be required for these investigations, providing that the instrument is stable in sensitivity and the base level does not change by more than 10nT during the two month period.

IONOSPHERIC/MAGNETOSPHERIC STUDIES

Magsat is not intended to study the ionosphere or magnetosphere. In fact the twilight orbit was chosen deliberately to avoid some of the regions of intense ionospheric currents. Nevertheless, because the Magsat data will be the most accurate near-earth, satellite, vector data ever obtained, it will make a significant contribution to ionospheric/magnetospheric studies. It will provide the first accurate in situ measurement of field aligned currents near the earth and will help resolve as yet unexplained characteristics of disturbance fields at high latitudes, including some features of the Pogo data.

It is clear from the analyses of the Pogo data and from theoretical studies that a combination of satellite and ground measurements yield more information than either alone. When combined with suitable ground measurements, it should be possible to use Magsat data to distinguish fields from various sources: field aligned currents, ionospheric currents and distant magnetospheric currents.

All of the measurements mentioned in previous sections will be of value in ionospheric/magnetospheric studies. In addition, concentrated measurements at high latitudes are used in delineating current systems. Several networks of high latitude stations will be in operation during the International Magnetospheric Study (IMS). The planned time period for operation is 1976-1979. These networks include the Canada-U.S. North American magnetometer network, the CCOG (Committee for Coordination of Observations associated with Geos) networks in Scandinavia and Greenland, and the three chains and two areas of intensive observations in the U.S.S.R. We therefore recommend a continuation of operation of these networks during the lifetime of Magsat, i.e., through the Fall of 1980.

Crustal conductivities will influence measurements at high latitude IMS network stations. Therefore, crustal conductivity studies from Magsat would be possible in the regions of high latitude ionospheric currents. However, these regions are spatially limited and are generally difficult to access, and so we do not propose an augmented measurement program specifically for crustal conductivity studies.

SUMMARY

To take full advantage of the global, vector, survey by the Magsat satellite we have proposed an international program of augmented surface measurements. For secular variation and upper mantle conductivity studies the proposed measurements are global. The repeat station measurements for secular variation should be occupied at 2-3 year intervals. A special observing period in November and December of 1979 is proposed during which simultaneous, continuous, global measurements for upper mantle conductivity studies are to be gathered. Finally, it is recommended that the networks in operation during the IMS extend their operation through the Fall of 1980 to provide correlative data useful for high latitude disturbance studies and for crustal conductivity studies.

TABLE 1 -- RECOMMENDATIONS FOR GROUND MEASUREMENTS

A. NEW OBSERVATORIES

STATION	PRIORITY	LATITUDE	LONGITUDE
Easter	1	29.0 S	109.3 W
Nouvelle Amsterdam	1	37.5 S	77.3 E
Tristan da Cunha	1	35.3 S	12.2 W
or Gough	1	39.2 S	11.1 W
Bermuda	2	32.2 N	64.5 W
Koror	2	7.3 N	134.5 E
Chagos	2	7.0 S	73.0 E
USA (West)	2	38 N	122 W
USA (South)	3	26 N	97 W
South Pole	3	90.0 S	

B. REPEAT STATIONS -- PACIFIC OCEAN

STATION	PRIORITY	LATITUDE	LONGITUDE
Gambier	1	23.8 S	134.6 W
Wake	1	19.1 N	166.3 E
Adak	1	51.4 N	176.4 W
Kermadec	2	30.0 S	178.0 W
Jarvis (or Fanning)	2	0.2 S	160.0 W
Clipperton	3	11.0 N	109.2 W
Marquesas	3	9.0 S	140.0 W
Baker	3	0.1 N	176.5 W

C. REPEAT STATIONS -- ATLANTIC OCEAN

STATION	PRIORITY	LATITUDE	LONGITUDE
St. Helena	1	15.6 S	5.4 W
Cape Verde	1	16.0 N	24.0 W
Jan Mayen	2	71.0 N	8.0 N
Ascension	1	7.6 N	14.2 N
Trinidad	2	20.2 S	29.4 N

D. REPEAT STATIONS -- INDIAN OCEAN

STATION	PRIORITY	LATITUDE	LONGITUDE
Heard	1	52.1 S	74.4 E
Marion	1	46.4 S	37.6 E
Seychelles	2	5.2 S	55.1 E
Maldive	2	5.0 N	73.0 E
Cocos	3	12.0 S	96.0 E

E. CONTINENTAL REPEAT STATIONS (Approximate Locations, all priority 1)

LATITUDE	LONGITUDE
5 S	75 W
10 S	42 W
10 S	60 W
37 S	71 W
20 N	10 W
15 N	25 E
17 N	46 E
38 N	87 W
47 N	93 W
62 N	130 W
55 N	60 W
75 N	43 W
70 N	150 E
22 S	122 E
22 S	143 E

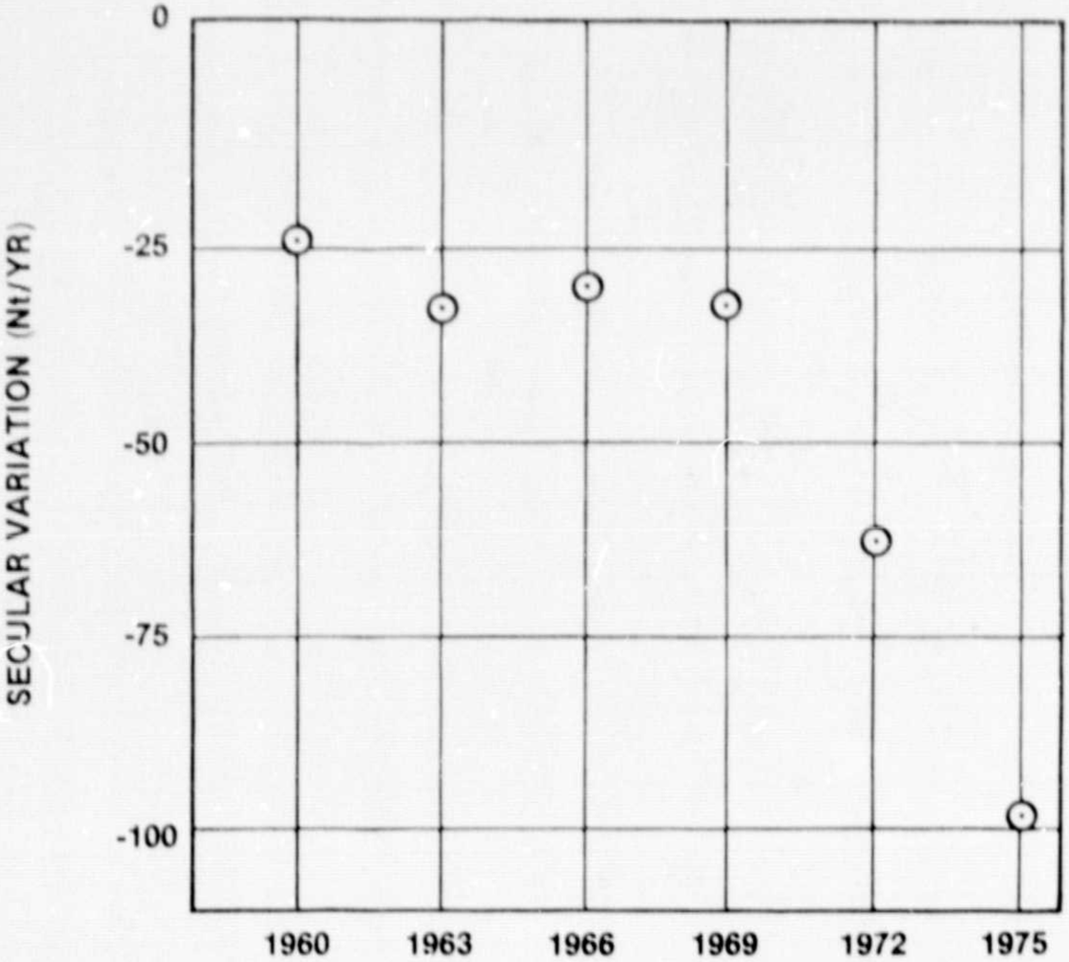

Figure 1: Secular variation in Total Intensity at the Fredericksburg, Virginia (U.S.) Observatory (3 year linear averages) showing that the field not only varies with time but also that its rate of variation is undergoing rapid change.

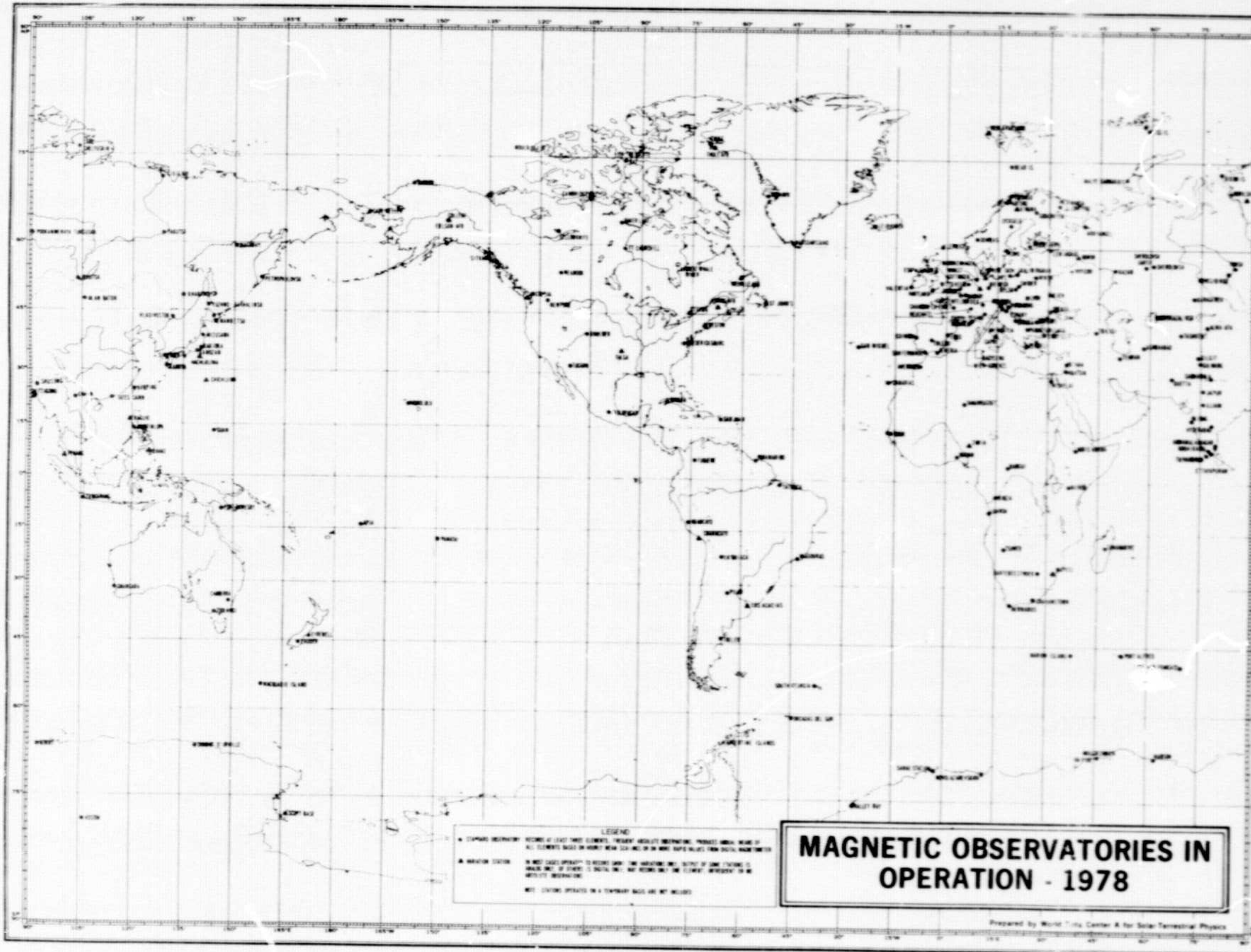
MAGNETIC OBSERVATORIES IN OPERATION - 1978
LEGEND
Prepared by World Data Center A for Solar-Terrestrial Physics

Figure 2

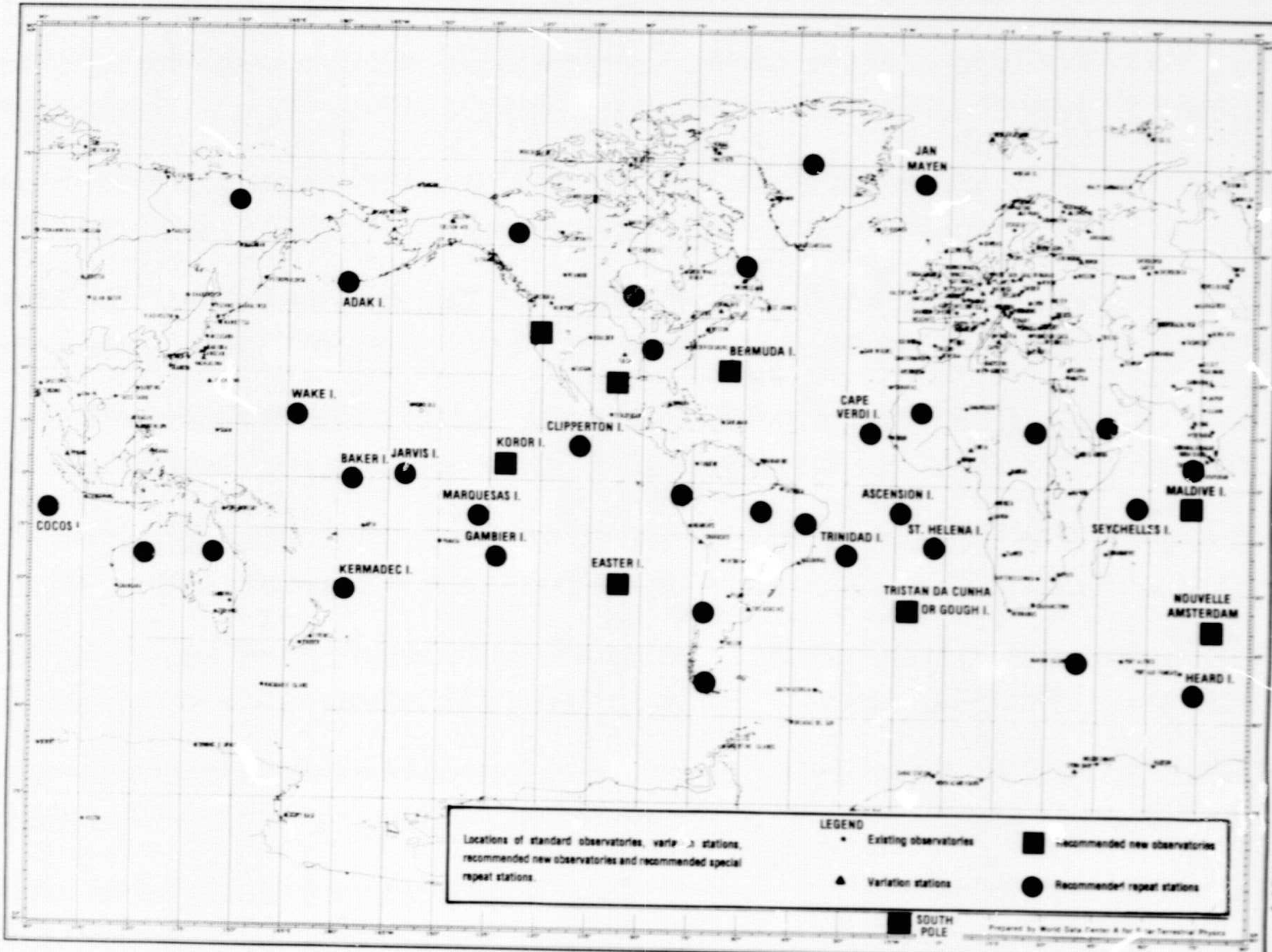
JAN MAYEN
ADAK I.
BERMUDA I.
WAKE I.
CAPE VERDI I.
CLIPPERTON I.
KOROR I.
BAKER I.
JARVIS I.
MARQUESAS I.
ASCENSION I.
MALDIVE I.
COCOS I.
GAMBIER I.
TRINIDAD I.
ST. HELENA I.
SEYCHELLES I.
EASTER I.
KERMADEC I.
TRISTAN DA CUNHA OR GOUGH I.
NOUVELLE AMSTERDAM
HEARD I.
SOUTH POLE
Locations of standard observatories, variation stations, recommended new observatories and recommended special repeat stations.
LEGEND
Existing observatories
Variation stations
Recommended new observatories
Recommended repeat stations
Prepared by World Data Center A for Solar-Terrestrial Physics

Figure 3:

BIBLIOGRAPHIC DATA SHEET

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16. Abstract

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