AGSO

FIVE REGIONAL FIELD MAGNETIC DATA SETS FOR AUSTRALIA

by J D McKnight

Record 1993/55

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AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

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Australian Geological Survey Organisation

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Contents

Tables

Figures

Abstract

Five magnetic data sets covering the Australian region are described. The first data set contains 1-min (11 km) averaged vector values from Project MAGNET flights made over the oceanic part of the region between 1982 and 1986 and 6-s (1.1 km) averaged vector values from Project MAGNET flights made over continental Australia in 1990 while the AWAGS experiment was running. The second data set contains 30-s (1.2 km) averaged values of total magnetic intensity from two low-level (150 m elevation) circuits flown around Australia in 1990 while the AWAGS experiment was running. Both of these data sets have applications in regional field modelling. The third data set contains 6-s sampled vector data from 54 AWAGS stations for the first two months of the experiment (November 19, 1989 to January 23, 1990). The fourth data set contains mean hourly values of total magnetic intensity for several days at each of 56 repeat stations that were reoccupied between 1986 and 1988. For each station, the mean hourly values at the five magnetic observatories in the region (Canberra, Charters Towers, Learmonth, Gnangara and Port Moresby) are included in the data set. The latter two data sets have applications in the study of the spatial variability of temporal variations in the geomagnetic field. The fifth data set is based on the nearly $2x10^6$ marine observations of total magnetic intensity made in the Australian region between 1967 and 1988. These observations have been averaged in 1° bins to produce about $2x10^3$ data points covering 38% of the marine bins in the region. A map of magnetic anomalies is derived from the 1°-averaged data points to illustrate their usefulness.

The Project MAGNET Data Set for Australia

Introduction

This record describes the set of recent vector magnetic observations available from Project MAGNET flights in the Australian region. It details the derivation from this of a set of 1-min (11 km) averaged values over ocean areas and 6-s (1.1 km) averaged values over land areas which is suitable for use in regional field modelling. Project MAGNET, an aeromagnetic survey of all accessible ocean areas of the world, was commenced by the U.S. Naval Oceanographic Office in 1953 and is still running. Its purpose is to maintain an up-to-date set of high-altitude (6-10 km) vector observations for use in geomagnetic field modelling and other geophysical studies. Data from Project MAGNET are made available free of charge through the National Oceanographic and Atmospheric Administration's National Geophysical Data Centre (NGDC) to institutions that contribute to the global pool of geomagnetic data. In addition to global surveying, Project MAGNET also involves special regional surveys. Such a survey was conducted over Australia in 1990 in conjunction with the AWAGS experiment (Chamalaun and Barton, 1990).

Sources of Project MAGNET Data for Australia

Three sources of Project MAGNET data are available (Appendix 1). The first is a set of four magnetic tapes (W13148, W11168, W01229, W11494) obtained from the NGDC in 1990 which contain data from flights made in the greater Australian region in 1982, 1983, and 1986. The second source is a set of three magnetic tapes (PMASC1, PMASC1_02, PMASC1_03) obtained from the Geomagnetic Observatory, DSIR in 1990 which contain data from flights made in the greater New Zealand region in 1982, 1983, and 1984. The third source is a single magnetic tape (PMAWAGS) supplied by the U.S. Naval Oceanographic Office in 1991 which contains data from the flights made over Australia between February 3 and March 16, 1990, coinciding with the AWAGS field experiment. This last data set is not for further dissemination without the permission of the Commanding Officer of the U.S. Naval Oceanographic Office. The eight tapes are lodged with the Geomagnetism Section.

Reading the Project MAGNET Tapes

The Project MAGNET tape format is described in detail in Appendix 2. Each flight comprises several track lines called legs. All data from a flight are stored in a single file. Observations are stored one per 108-byte record in ASCII code. Files on the four NGDC tapes and the U.S. Naval Oceanographic Office tape can be read to disk on the AGSO's Data General computer using the command TAPE_FX_READ (execute the command ADDPRE first to gain access to the commands in BMR:PRERELEASE). This command requires two parameters: the tape name (in the form Fnn, the tape's registration number on the DG) and a command file name. Each line of the command file specifies the tape input file, the disk output file, and the record size, e.g.,

```
1    'PMAG1.DAT'    108/
```

will result in the first file on the tape being read into the disk file PMAG1.DAT.

The DSIR tapes were written by a Vax computer using the COPY command and can be read onto the Data General using the command TAPE_VREAD (execute ADDPRE first). This command requires a single parameter, the tape name in the form Fnn. Project MAGNET files with names like A.PM3075.DAT and B.PM4027.DAT are written from the tape to the disk. The four numerals in the file name correspond to the flight number.

File Structure

Following are the first few records from the first file on PMAWAGS:

PJCT=C32-052 FLGT=5093, MTH=2, DAY=3, YR=1990, JDY=34-TO-34, RCD=17614, NAV=GPS, CMP=RLG
7003

38207.1831	-36.0001	147.4584	22411.	4916.	22943.	-54504.	59136.	12.3735	-67.1712	59154.	21900.
38209.1831	-36.0001	147.4549	22410.	4914.	22943.	-54505.	59136.	12.3670	-67.1723	59154.	21900.
38211.1831	-36.0001	147.4515	22412.	4912.	22944.	-54505.	59137.	12.3609	-67.1713	59155.	21900.
38213.1836	-36.0003	147.4479	22411.	4910.	22943.	-54506.	59138.	12.3569	-67.1730	59155.	21900.
38215.4336	-36.0004	147.4441	22410.	4908.	22941.	-54507.	59138.	12.3530	-67.1750	59155.	21900.
38217.6831	-36.0005	147.4402	22409.	4906.	22940.	-54508.	59139.	12.3491	-67.1762	59155.	21900.

Each file begins with a header record containing the project and flight numbers, date of the flight, number of records, and navigational details. The second record contains the leg number. Subsequent records contain the observations. Each leg is terminated by a zero-filled record. This is followed by the next leg number record and so on. Each data record contains 12 numbers: time in seconds from 0000 UT on the day of the flight, latitude and longitude in decimal degrees, the geomagnetic components X, Y, H, Z, and the vector sum F in nanoteslas and D and I in decimal degrees (X, Y, and Z are observed and H, F, D, and I are derived), observed total magnetic intensity in nanoteslas, and barometric altitude in feet above mean sea level. For a full description of the file structure, see Appendix 2.

Processing the Project MAGNET Data

Each Project MAGNET file is processed separately. A Project MAGNET file can be processed to produce average values along the aircraft's flight track by the program PM_AV.F77 (Appendix 3). This processing is necessary because observations are made at 2-s intervals (about 400 m), resulting in data sets that can be several megabytes in size and are too unwieldy to be used directly. The averaging period is specified interactively by the user when running program PM_AV.F77. Data from the greater Australian and New Zealand regions have been averaged over 1 min, which for a typical aircraft speed of 660 km h^{-1} is equivalent to a distance of 11 km. Data from the 1990 regional survey have been averaged over 6 s, or about 1.1 km. For the purposes of Australian regional studies the region of interest has been defined as being that between 0° and -50° N latitude and 100° and 180° E longitude. Flights lying completely outside this zone are excluded. Tracks for flights in the Australian region that are contained on the tapes are shown in Figure 1.

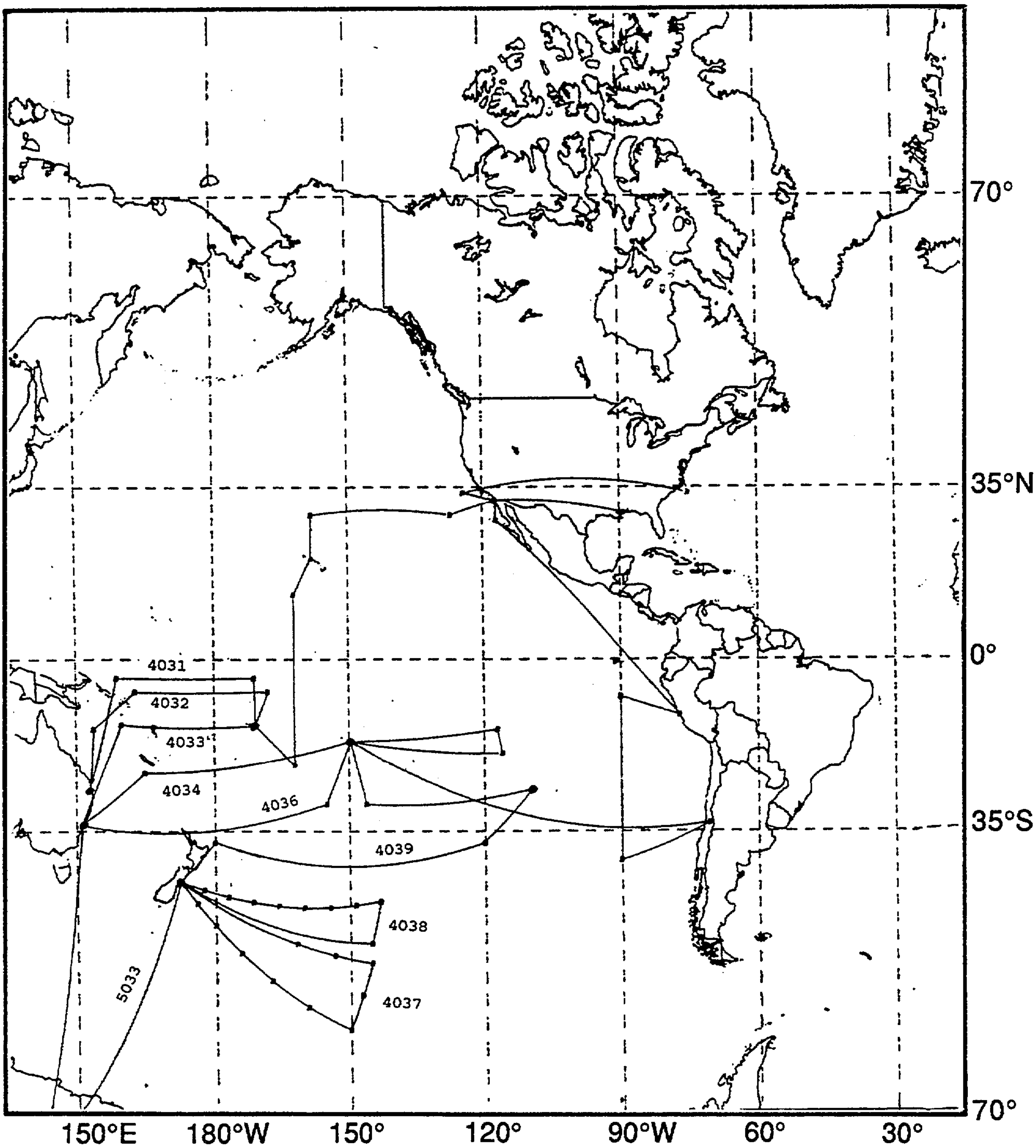

Figure 1(a). Project MAGNET flight tracks for flights recorded on tapes W13148 and W11168.

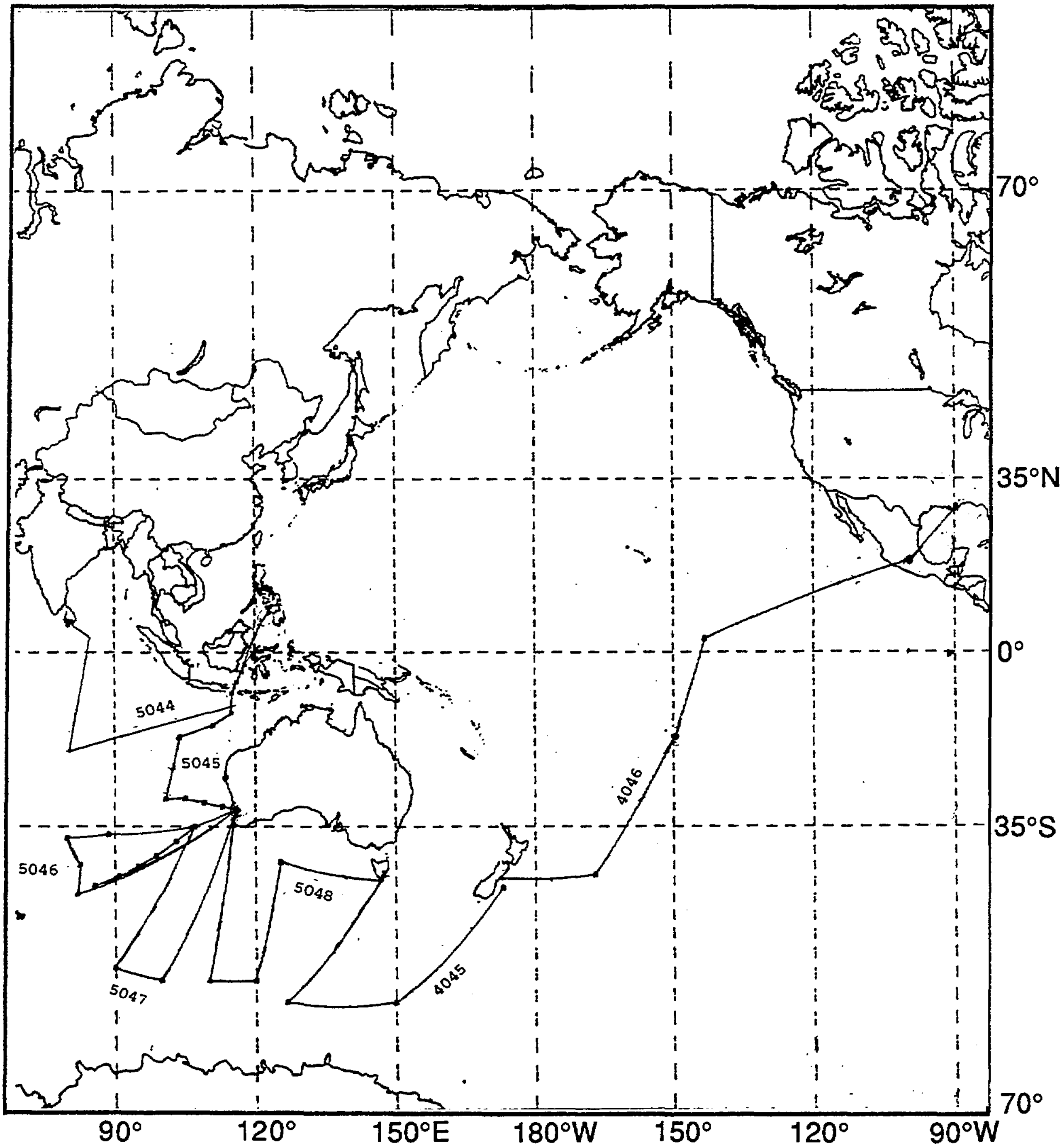

Figure 1(b). Project MAGNET flight tracks for flights recorded on tape W01229.

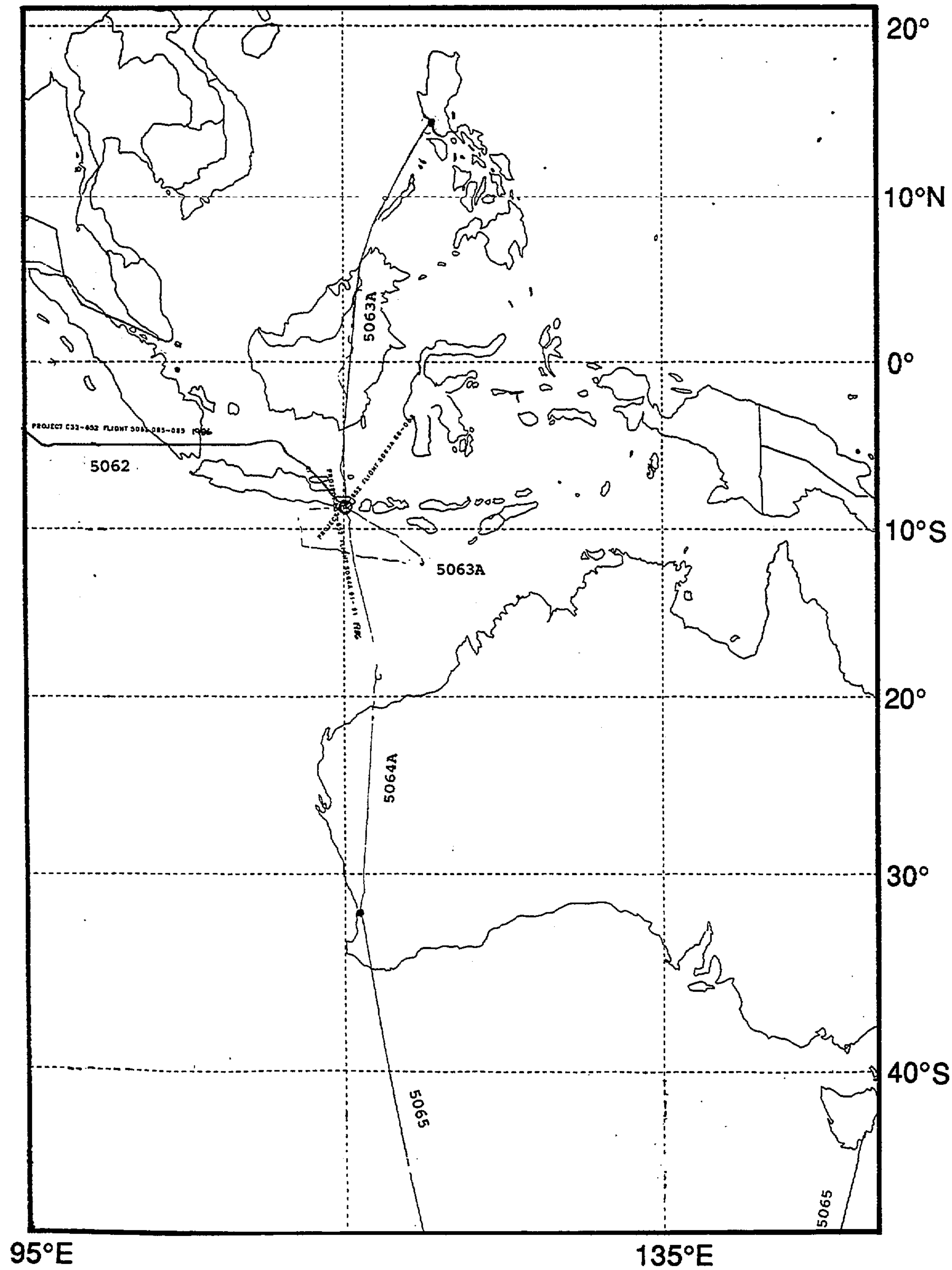

Figure 1(c). Project MAGNET flight tracks for four flights recorded on tape W11494.

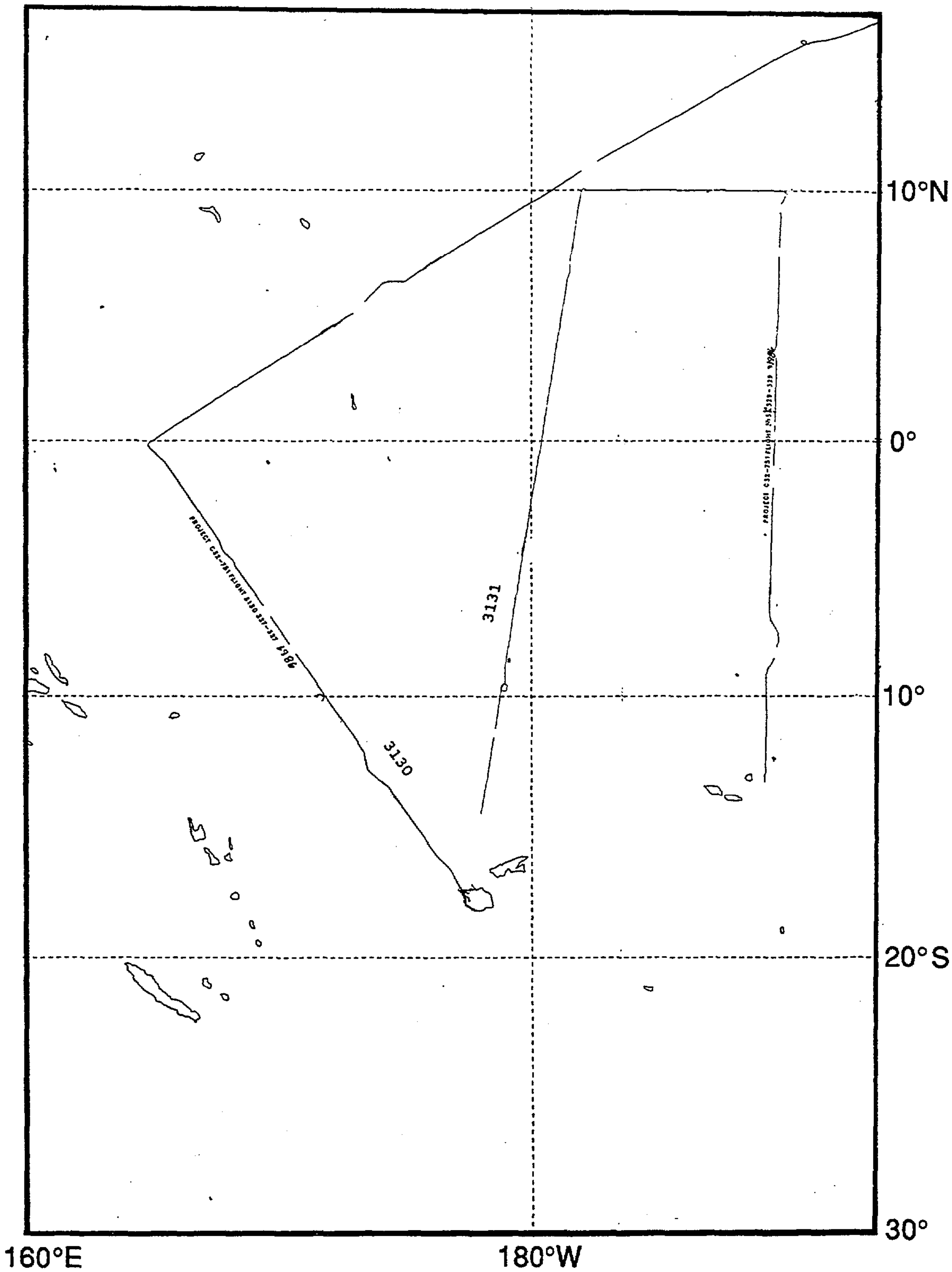

Figure 1(d). Project MAGNET flight tracks for two flights recorded on tape W11494.

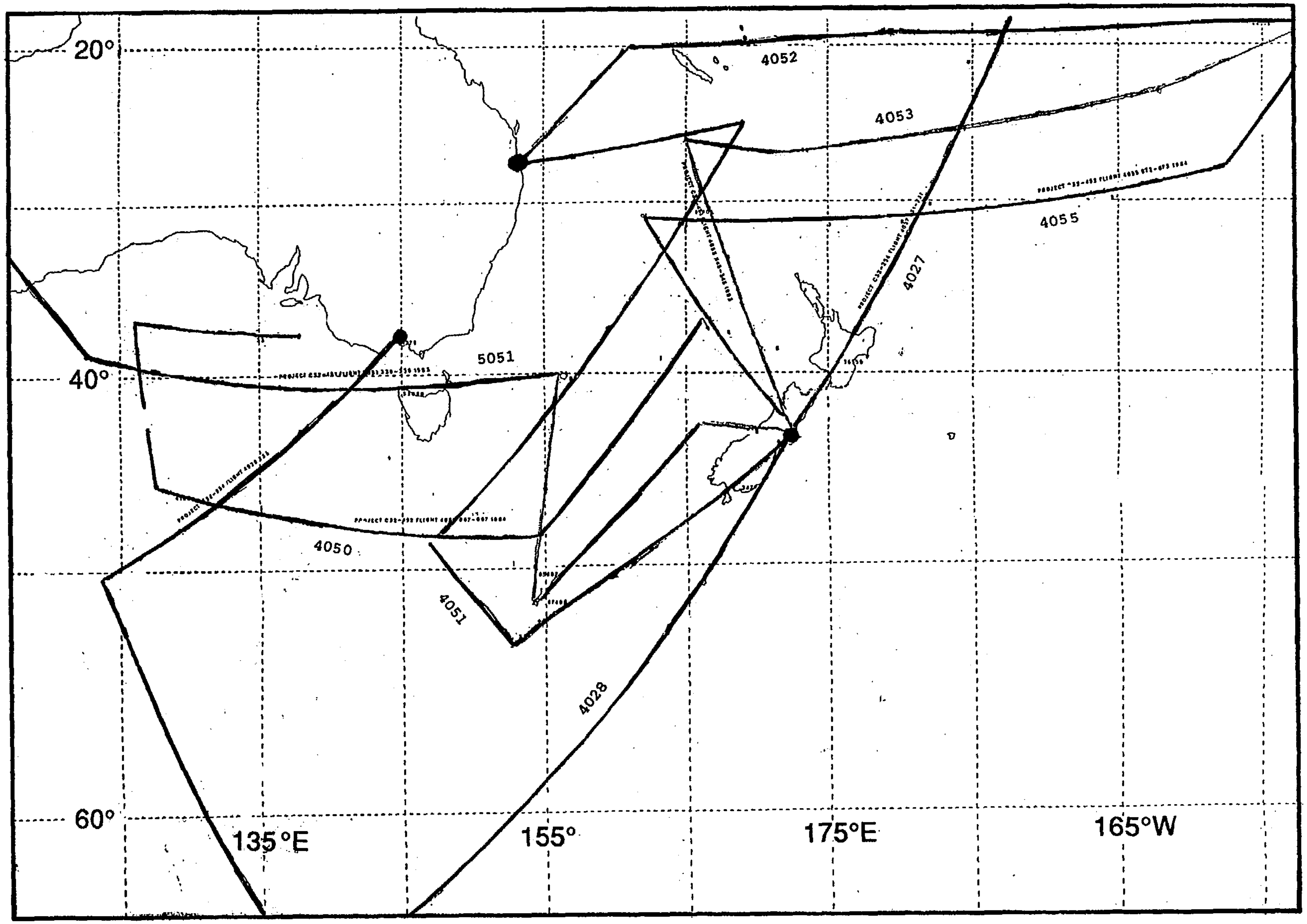

Figure 1(e). Project MAGNET flight tracks for those flights on tapes PMASC1, PMASC1_02, and PMASC1_03 that are used in the record. Flights 4050 and 4055 are of doubtful quality.

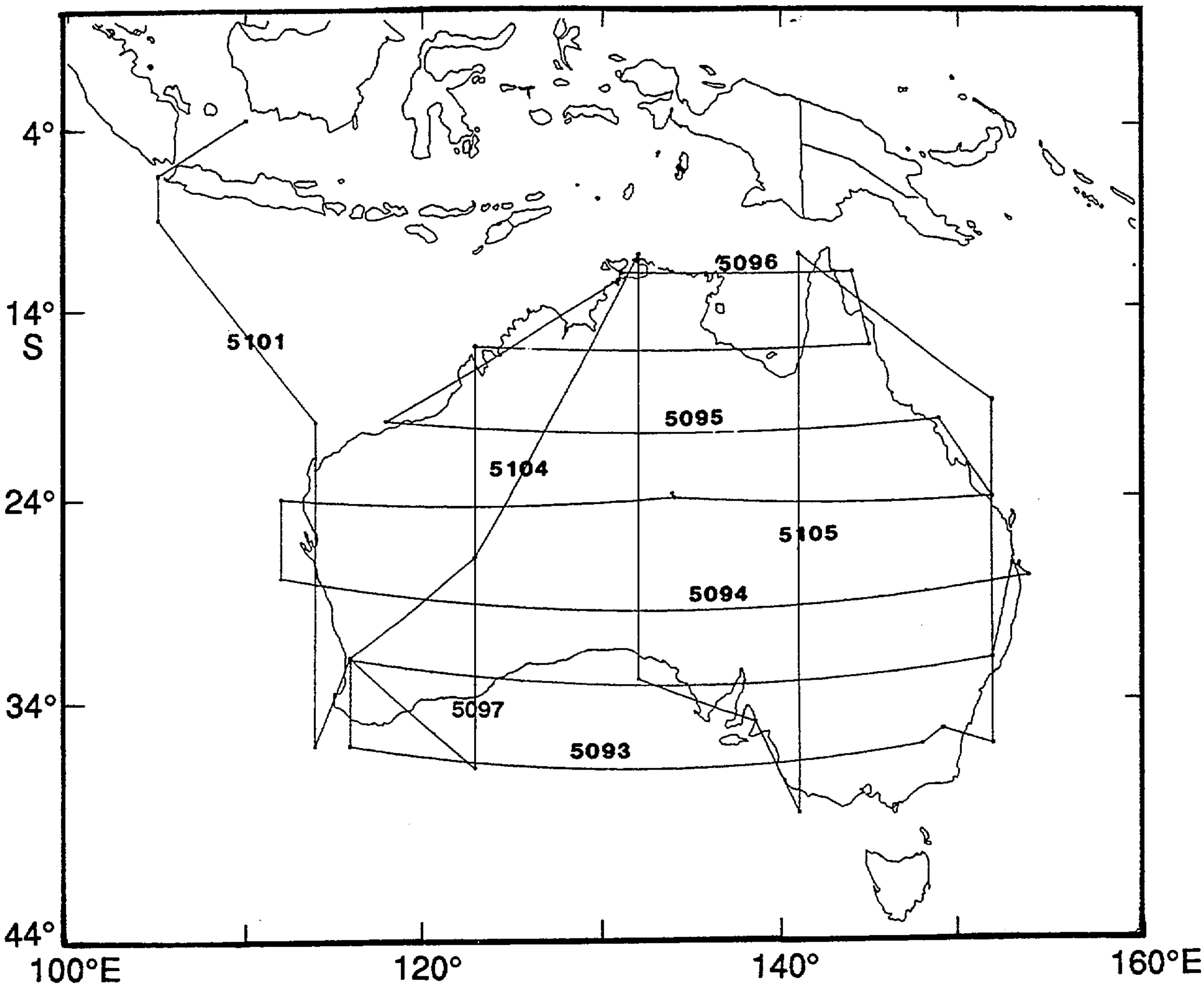

Figure 1(f). Project MAGNET flight tracks for flights in the 1990 Australian survey which are recorded on tape PMAWAGS.

PM_AV.F77 requires the user to specify the names of the input and output files and the date and start time of the flight. The first two records are then read from the Project MAGNET file. The epoch, start time, project number, and flight number are written to the first 64-byte output record in F9.3, 3I7, 6X, 28A1 format. The user is then prompted for the averaging period. Data records are read and averaged over this period. Following are the first few output records for flight 5093, the first flight on PMAWAGS:

```
1990.093  1990   34  38207   PJCT=C32-052   FLGT= 5093
-36.000 147.455  22411.  4914. -54505.  59154.  6.675  38209
-36.000 147.444  22410.  4908. -54507.  59155.  6.675  38215
-36.001 147.433  22406.  4903. -54511.  59156.  6.675  38222
-36.001 147.423  22405.  4898. -54513.  59156.  6.675  38228
-36.001 147.412  22402.  4894. -54514.  59157.  6.675  38234
```

Output is stored in 64-byte records, one set of average values per record, in 2F8.3, 4F8.0, F8.3, I8 format. Values stored for the 1990, 6-s averaged data are latitude and longitude, observed X, Y, Z, and F components, altitude in kilometres, and time at the midpoint of the interval in seconds. The 1-min averaged data sets contain the number of observations averaged in the interval instead of the time at the midpoint of the interval.

A summary of the files containing the averaged values is given in Table 1. These have names with the form of either PM_1MIN_nnnn.DAT or PM_6S_nnnn.DAT, where PM denotes Project MAGNET, 1MIN and 6S indicate the averaging interval, and nnnn corresponds to the flight number. Plots of the locations of the averaged values are given in Figure 2 (1-min averages) and Figure 3 (6-s averages). The two 1984 flights on the DSIR tapes (numbers 4050 and 4055) were excluded because of doubts expressed by Project MAGNET staff about their reliability. The files of averaged values and the processing programs are stored in the directory /geomag/donmk/pmag on the Geomagnetism Section's Sun Sparcstation (Lodestone on the AGSO network).

Errors in the Averaged Project MAGNET Data

The standard deviation of the departure of individual Project MAGNET vector observations from the true values has been estimated as being 14 nT (O. E. Avery, personal communication, 1985). This takes into account uncertainties arising from navigation, instrument, and orientation errors. However it does not cover errors due to external magnetic fields. Because flights were made at night, and only during geomagnetically quiet times, errors due to external fields should, typically, be less than 10 nT. These will be reduced by the averaging of observations, although not by very much unless the averaging is done over time periods longer than those used here. Use can be made of the AWAGS data set to correct the 1990 Australian regional survey for external fields, although any correction is limited by the fact that AWAGS recorded at 1-min intervals at ground level.

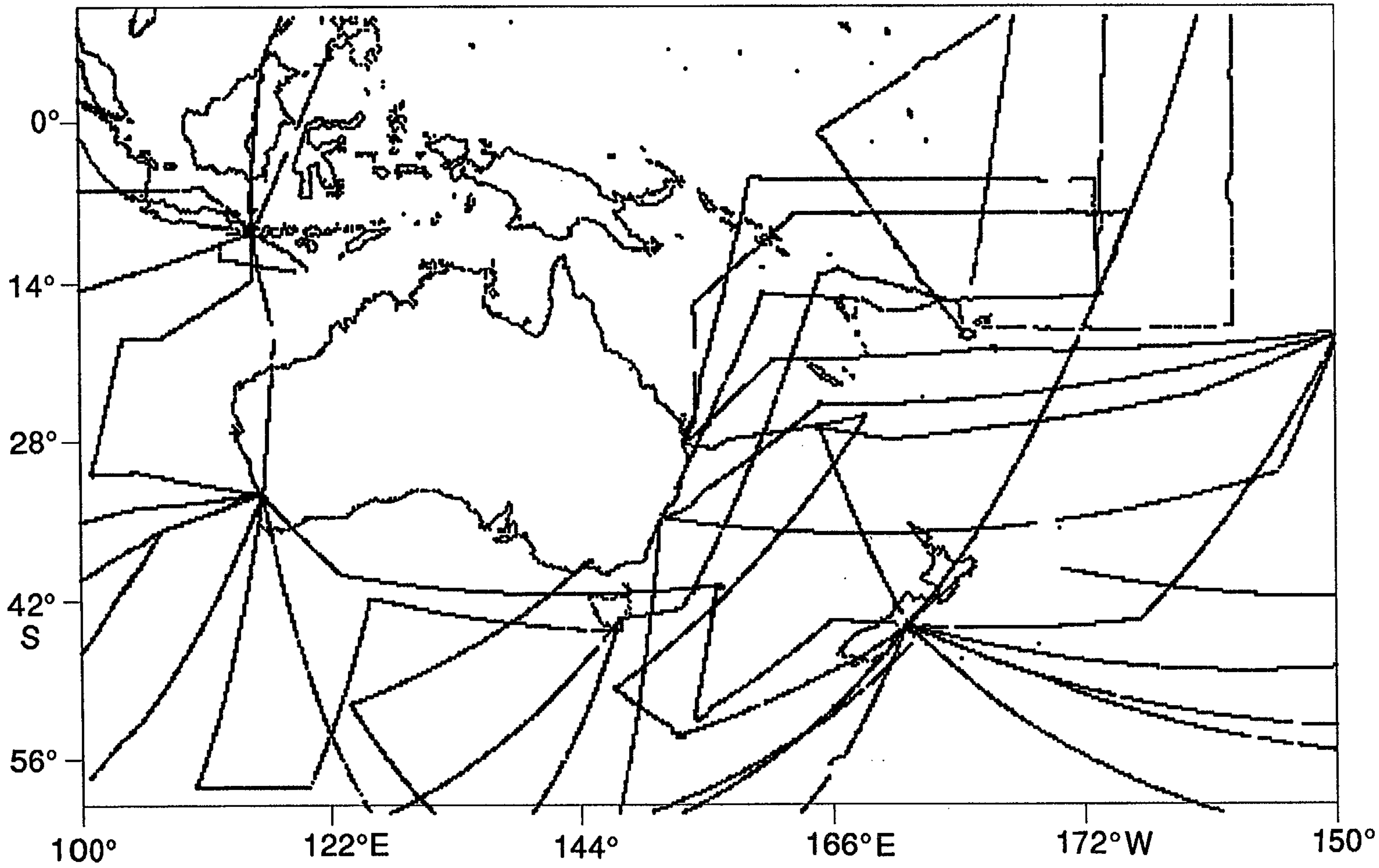

Figure 2. 1-min averaged data points from Project MAGNET flights made between 1982 and 1986. See Figure 1(a-e) for the flight tracks.

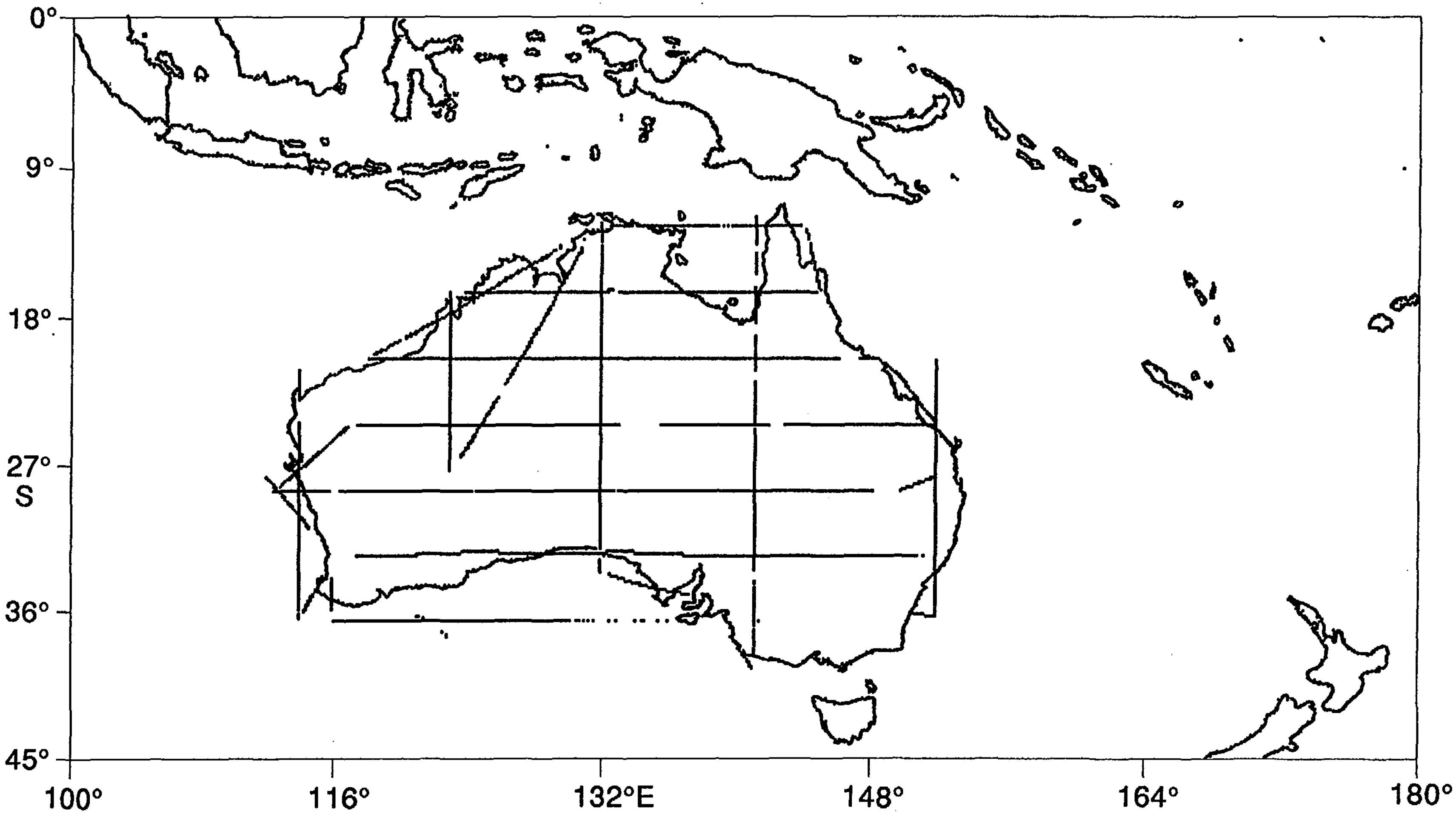

Figure 3. 1-min averaged data points based on 6-s values from Project MAGNET flights in the 1990 Australian survey. See Figure 1(f) for the flight tracks.

The AWAGS Aeromagnetic Data Set

Introduction

Two circuits were flown around Australia between January 27 and February 26, 1990 on which total magnetic intensity was measured at an elevation of 150 m (Figure 4). The two circuits, one coastal and the other inland, were flown for the BMR by Austerex as aeromagnetic project 38. The main purpose of the survey was to provide information for levelling individual aeromagnetic sheets to assemble a magnetic anomaly map for the whole of Australia. Flying the survey at the time the Australia-wide array of geomagnetic stations (AWAGS) field experiment was running (Chamalaun and Barton, 1990) enabled the AWAGS stations to be used as base stations for the survey. In this record the aeromagnetic data set and a set of 30-s averaged values derived from it are described. Errors in the aeromagnetic data are briefly discussed.

The Raw Data Set

Observations were made at intervals of 0.5 s. For a typical aircraft speed of 290 km h^{-1}, the distance between observations is about 40 m. About $6x10^5$ observations were made during the survey, corresponding to about 83 hours of flying time, covering $2.4x10^4$ km of flight track. There are 25 flights in the survey. Data were processed by Austerex and supplied to the BMR in a standard airborne geophysical format on a single 6250 bytes per inch tape containing about 60 megabytes (Mb) of data. A copy of the tape (P38D) is lodged with the Geomagnetism Section. Data are stored in 198 files on the tape, each file corresponding to a flight segment. A flight segment is part of a flight on which a constant heading is maintained.

Files can be read from the tape to disk on the AGSO's Data General computer with the command TAPE_FX_READ (first enter the command ADDPRE to access commands in BMR:PRERELEASE). This command requires two parameters: the tape name (in the form Fnn, the tape's registration number on the DG) and a command file name. Each line of the command file specifies details of a tape input file and a disk output file, e.g.,

    1 'aero1.dat' 5120,'binary'/

will result in the first tape file being read into the disk file aero1.dat. Although the data are in ASCII code it is necessary to specify 'binary' in the command file in order to read trailing blanks.

A detailed description of the file format is given in the ARGUS Users Manual, available from the AGSO Geophysical Mapping Section. Briefly, each tape file consists of three or more 5120-byte ASCII records. The first is a segment directory record (SDR) that contains the project number, flight number, segment number, date and time the segment was flown, bearing flown, altitude, and a description of the type and format of data stored for the

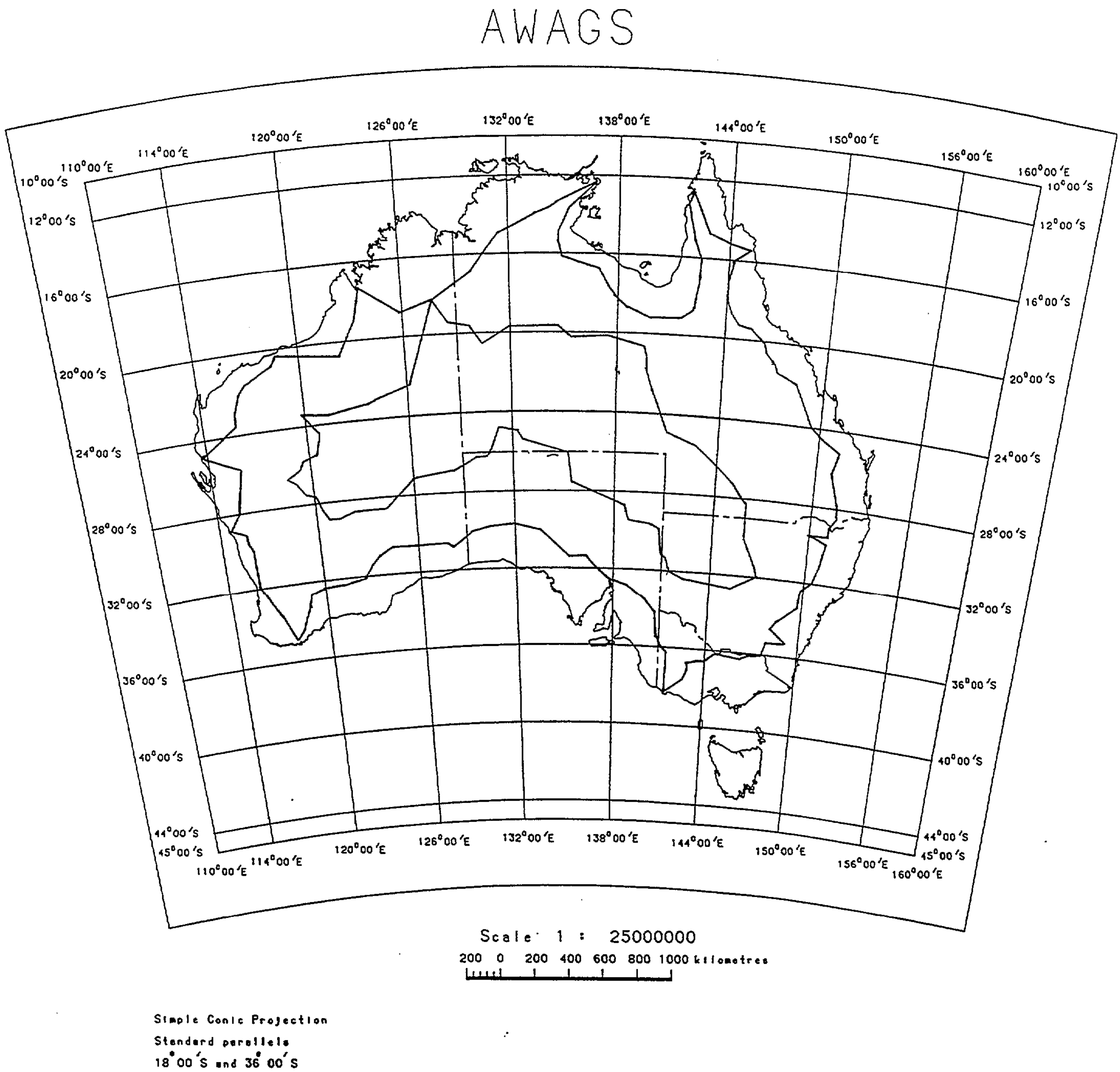

Figure 4. Flight tracks for the 1990 low-level aeromagnetic survey flown at the time of the AWAGS field experiment.

segment. Following the SDR are two sets of data records (DARs) that contain the measured values. The first set of DARs contains the longitude, latitude, height above ground level, height above sea level, and measured total magnetic intensity for each observation, 101 observations per record. This is followed by a second set of DARs that contain the longitude, latitude, measured total magnetic intensity, IGRF total magnetic intensity, and magnetic anomaly in total intensity for each observation, 101 observations per record.

There are two faults in the data set. The first is that in the SDR the time interval between observations is given as 1 s, when in fact it is 0.5 s. The second is that the IGRF values of total magnetic intensity in the DARs were all determined for zero altitude, and consequently are in error by up to 30 nT. Because of this, the second set of DARs is best ignored.

Processing the Raw Data Set

The raw aeromagnetic data set was processed in two stages. The first stage involved generating a set of four binary files on disk (BIN1.DAT,...BIN4.DAT) that contain all the useful information on the tape. It resulted in a reduction in size of the data set from 60 Mb to about 12 Mb. The second stage involved averaging observations along the flight track to produce a data set of a size suitable for applications such as regional geomagnetic field modelling. This resulted in a further reduction in size of the data set from 12 Mb to about 0.4 Mb.

The processing of the raw aeromagnetic data set into the form of binary files was done by the program AERO_BIN.F77 (Appendix 4). The version of the program shown in Appendix 4 processes three raw files that have been read from the tape to disk and creates the binary file BIN.DAT. The full data set is contained in the four binary files BIN1.DAT (first 50 segments), BIN2.DAT (second 50 segments), BIN3.DAT (third 50 segments), and BIN4.DAT (last 48 segments). Each line of one of these binary files contains four real numbers. The first line contains the segment number, the number of observations in the segment (n), the date (YYMMDD), and the observing interval in seconds. The second line contains the time of day at the start of the segment in seconds, the bearing flown on the segment in degrees east of north, the nominal altitude in metres above mean sea level, and the nominal ground clearance in metres. The subsequent n lines each contain the longitude (in decimal degrees east), latitude (in decimal degrees north), altitude (in metres above mean sea level), and total magnetic intensity (in nanoteslas) of an observation. The n lines of observations are followed by the first line of the next segment, and so on.

Further processing of the data set to produce average values along the flight track was done by the program AERO_AV.F77 (Appendix 5). The program was configured to average 60 observations, corresponding to 30 s of flying time, or about 1.2 km of flight track. This can readily be changed by setting the value of the variable RMIN to whatever number of minutes is required to average. Care is taken in the program to exclude the small number of data values that were flagged during the preparation of the raw data files and which indicate gaps in the data. Average values are stored in the file AV.DAT, one set per line, in 2F9.3,F7.0,F9.1 format. Longitude, latitude, altitude, and total magnetic intensity are stored. There are 10,023 sets of 30-s averaged values. The processed data files and the programs used to produce them are stored in the directory /geomag/donmk/aero on the Geomagnetism Section's Sun Sparcstation (Lodestone on the AGSO network).

Errors in the Data Set

No corrections, other than the removal of spikes and baseline shifts and the flagging of gaps, were applied to the original data set by Austerex. With the location of the aircraft known to better than 50 m, any error in magnetic anomalies due to incorrect location will be less than 1 nT. Aircraft fields were minimized, and those that remain should be steady on any flight segment because a constant bearing was maintained. The main source of error will be external geomagnetic fields, particularly diurnal variation, which, typically, can cause departures from the undisturbed midnight level in total magnetic intensity of up to 50 nT in Australia. Geomagnetic storms can cause departures of order 100 nT. During the survey the external field was monitored at Canberra by the BMR. There was only one significantly disturbed period (between February 14 and 17, 1990) and flying was halted for this time. The data set from the 57 AWAGS stations, many of which were overflown, has the potential to enable the correction of the aeromagnetic data set for external fields with periods of more than a few minutes.

An AWAGS Data Set

Introduction

The data set described in this record covers the first two months of the AWAGS experiment (Chamalaun and Barton, 1990). The AWAGS experiment commenced in November 1989 and involved the recording of the vector geomagnetic field at 1-min intervals at 57 sites throughout continental Australia (Figure 5 and Table 2). Four of the sites were geomagnetic observatories, while at the other 53 sites self-contained magnetometers were run. The length of the experiment was dictated by the life of the batteries in the magnetometers, and was nominally four months. Most magnetometers did not last that long, however almost all of them operated continuously for the first two months. In March and April 1990 the magnetometers were serviced and set running for another four months, and a small number were serviced again in August 1990 and set running for a further four months.

The AWAGS Data Set

Dr F.H. Chamalaun of Flinders University supplied twenty-three 1.44 Mb, 3.5 inch floppy disks that contain full data sets from 54 of the AWAGS stations for the first four-month run of the experiment. Of the other three stations, CVN and CRO failed to operate and data from GNA were not yet available. The disks contain .ZIP files, each of which holds a .MAG file that has been compressed by the utility PKZIP. File names have the form XYZnnA.ZIP (or XYZnnA.MAG), where XYZ is a three-letter station code (see Table 2), nn is a two-digit integer corresponding to the number of the magnetometer used (00 for observatories), and A is a version code for the data set, subsequent versions being B, C etc. The .MAG file can be recovered using PKUNZIP. Each .MAG file contains 1-min vector values in 1-hour blocks for a station and is typically 2 Mb in size cf. 0.5 Mb in its .ZIP form.

Sampling the AWAGS Data Set

The program SELECT.C extracts a subset of data from the .MAG files. It requires nine parameters: the input file, of type .ZIP; the day, month, year, hour, and minute at the start of the period over which data are to be sampled; the number of observations required; the output file name, of type .FIL; and the sampling interval in minutes. Executing the command

```
SELECT BUK39A.ZIP 19 11 89 0 0 5460 BUK1.FIL 6
```

will result in 5460 observations at 6-min intervals starting at 0000 UT on November 19, 1989 being extracted from the file BUK39A.MAG and placed in the file BUK1.FIL. Following are the first few lines from BUK1.FIL:

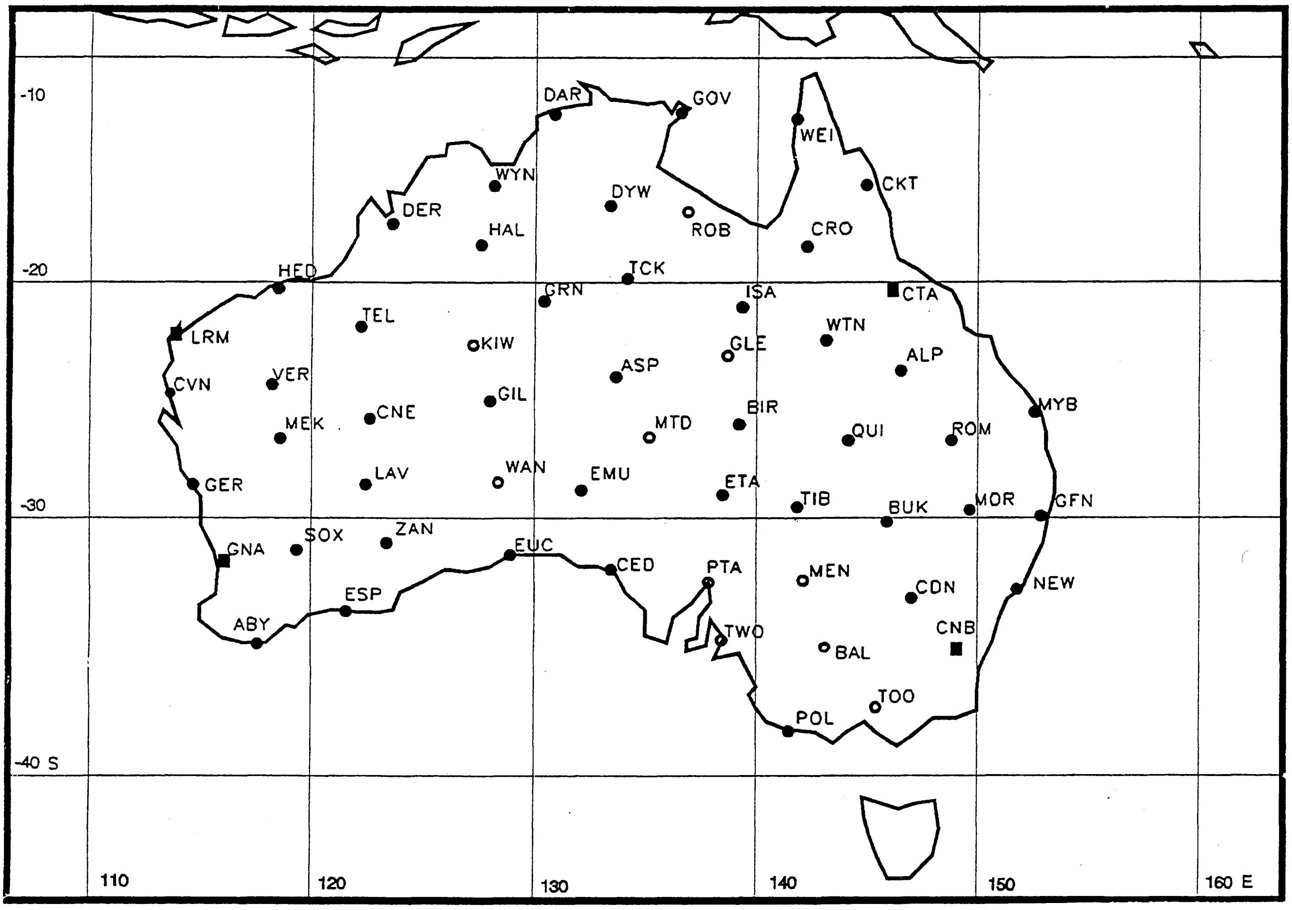

Figure 5. The 57 stations in the AWAGS experiment. Solid squares represent AGSO magnetic observatories, solid circles represent AGSO magnetic repeat stations, and open circles represent non-repeat stations. See Table 2 for station names and coordinates.

```
buk39a.mag 19 11 89 0 0 5460   6.00
 25888.0   3807.0 -49230.0  55621.8    0.0
 25888.0   3809.0 -49230.0  55621.8    6.0
 25886.0   3810.0 -49230.0  55620.9   12.0
 25886.0   3811.0 -49230.0  55620.9   18.0
 25885.0   3814.0 -49229.0  55619.6   24.0
 25882.0   3816.0 -49229.0  55618.2   30.0
```

The output file has a header line giving the name of the source .MAG file, the start time, the number of observations, and the sampling interval, and is followed by the sampled data, one set per line. The sampled data are the observed X, Y, and Z components and the derived total magnetic intensity, all in nanotesla, and the time in minutes from the start time. In the present case a sampling interval of 6 min was chosen and 66 days of the first run were sampled, corresponding to a period when almost all of the magnetometers recorded continuously. Sampling was done in three lots of 22 days because of size restrictions imposed by SELECT.C. The output files are named XYZn.FIL, where XYZ is the station code and n is the number of the 22-day period (1, 2 or 3).

Of the 54 stations sampled, 52 are each represented by three .FIL files covering the period November 19, 1989 to January 23, 1990 (start dates: November 19, 1989; December 11, 1989; January 2, 1990). TOO1.FIL and TWO1.FIL contain some bad data at the start and MYB3.FIL contains some bad data at the finish. Seven of these 52 stations (ALP, ASP, BIR, GLE, QUI, ROM, and WTN) have a fourth file associated with them (XYZ4.FIL) that contains sampled data for 15 days beginning on January 24, 1990. Of the remaining two stations of the 54, ROB recorded at 20-s intervals and failed early, resulting in data for the first two 22-day intervals only, and GOV (Gove) did not start recording until March 1990 and resulted in a single data set, GOV5.FIL, for the period March 9, 1990 to March 23, 1990. DAR5.FIL contains a data set for the same period for the station at Darwin.

The .FIL files were generated in the directory C:\AWAGS:\SQ on the T3100SX computers in the Geomagnetism Section. Batch files for running SELECT.C (e.g., RSEL1.BAT) are in this directory. Table 3 summarizes the set of .FIL files. All 167 .FIL files are stored in the directory /geomag/donmk/awags on the Geomagnetism Section's Sun Sparcstation (Lodestone on the AGSO network). With a typical size of 0.25 Mb each, their collective size is about 40 Mb.

A Set of Mean Hourly Values at Repeat Stations and Observatories

Introduction

In this record a data set is described that contains mean hourly values (MHVs) of total magnetic intensity (F) at 56 repeat stations in the Australian region and concurrent values at each of the five observatories in the region. Values are given for each day on which continuous recordings were made at the repeat stations during their most recent (1986-1988) reoccupation. Such a data set enables comparisons to be made between the temporal variation of the field at various sites.

In the period between June 1986 and May 1988 sixty-two stations in the Australian repeat station network were reoccupied. Reoccupation involved recording the field continuously for several days using both scalar and vector instruments and making absolute observations, the absolute observations serving to calibrate the continuous recordings. Of the 62 stations that were reoccupied, problems with equipment meant that continuous recordings of F were made at only 56 (Figure 6). Mean hourly values (MHVs) of the continuous recordings made at each site were published by Hitchman (1990).

Preparation of the Data Set

MHVs at the repeat stations were taken from Hitchman (1990). MHVs at the five observatories (Canberra [CNB], Charters Towers [CTA], Learmonth [LRM], Gnangara [GNA], and Port Moresby [PMG]) were supplied by the Geomagnetism Section of the BMR. Data from each of the observatories were edited to leave MHVs for only those days on which a recording was made at a repeat station. The six data sets (one for the repeat stations and five for the observatories) were combined by the program DV.F77 to produce the file DV.ALL, an extract from which is given below:

```
3  57000    -32.9   147.2       Condobolin     23/06-25/06   1986         Q_Q
     0     0     0     0     0     0     0   889   886   886   887   890
   890   891   891   891   892   891   891   892   891   891   894   893
CNB8606F23
58703 58698 58700 58703 58703 58706 58708 58707 58706 58706 58707 58708
58709 58709 58710 58710 58710 58709 58709 58709 58708 58707 58706 58706
CTA8606F23
49747 49745 49742 49739 49737 49736 49740 49745 49747 49748 49750 49750
49750 49749 49747 49747 49749 49749 49751 49753 49753 49757 49760 49758
LRM8606F23
99999 99999 99999 99999 99999 99999 99999 99999 99999 99999 99999 99999
99999 99999 99999 99999 99999 99999 99999 99999 99999 99999 99999 99999
GNA8606F23
58604 58603 58600 58594 58590 58587 58586 58596 58597 58600 58602 58601
```

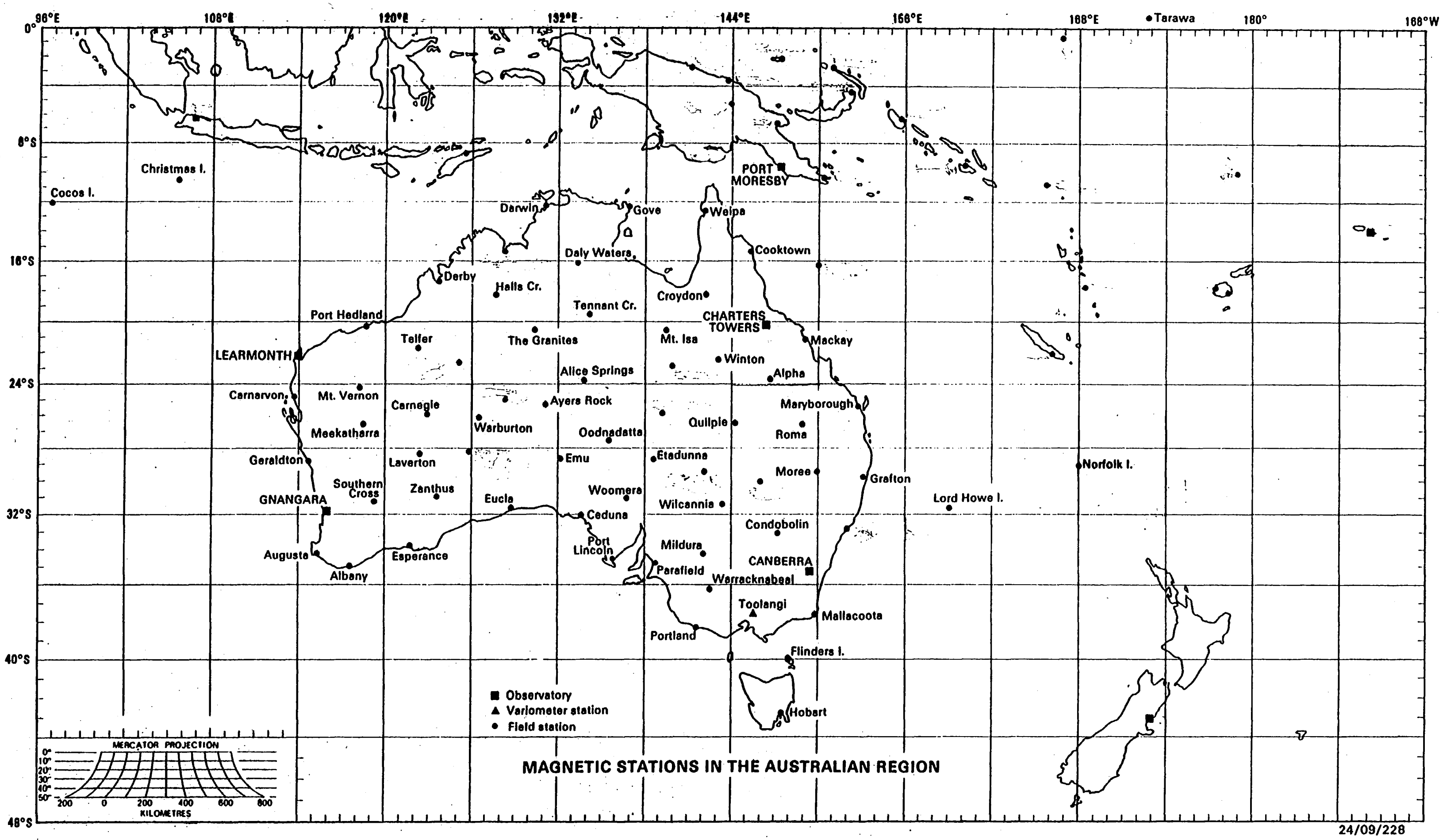

Figure 6. Magnetic stations in the Australian region. The stations named are those at which continuous recordings of total magnetic intensity were made during the 1986-1988 reoccupations.

58602 58597 58595 58593 58591 58588 58587 58589 58593 58596 58598 58596
PMG8606F23
43062 43061 43057 43056 43052 43047 43046 43049 43051 43051 43053 43054
43054 43055 43054 43055 43056 43055 43057 43059 43058 43061 43065 43068
889 888 886 884 884 888 894 892 890 891 888 886
888 889 886 885 885 887 888 888 890 890 886 886
CNB8606F24
58707 58707 58706 58706 58708 58710 58713 58710 58710 58708 58707 58707
58707 58708 58708 58707 58707 58708 58708 58708 58708 58707 58706 58706

For each repeat station there is a header line followed by one or more sets of 17 lines of data, each set representing 1 day. The header line contains the number of days of recording at the station, the number that has been subtracted from the F values observed at the station, the latitude, longitude, and name of the station, the UT date of the reoccupation, and a set of codes indicating whether the days were geomagnetically quiet (Q), disturbed (D), or neither (_). Then follow 24 MHVs of F at the station (0 indicates no recording) and five sets of observatory MHVs for the first day of the reoccupation. Each observatory set starts with a header line with the form XYZyymmFdd, where XYZ is the observatory code (CNB, CTA, LRM, GNA, or PMG), yy, mm, and dd are the year, month, and day (UT) in the form of two-digit integers, and F denotes total magnetic intensity. Then follow 24 MHVs of F. After data for the last day of the reoccupation there is a blank line before the next repeat station header record. All processing programs and the resulting data files are stored in the directory /geomag/donmk/reps on the Geomagnetism Section's Sun Sparcstation (Lodestone on the AGSO network).

An Example of Use of the Data Set

One use of the data set is to compare the temporal variation of the field at different locations. Because observations are hourly averages, temporal variations will usually be dominated by diurnal variation and thus should be similar at nearby stations. The program xyzDV.F77, where xyz is one of the observatory codes (e.g., CNB), extracts the MHVs for each repeat station in the vicinity of the particular observatory. It then stores the MHVs for the observatory and the repeat station and their differences in a text file (xyz.TXT) and a file that produces plots on a line printer (xyz.PLO). Below is an extract from the file CTA.TXT covering the 3-day reoccupation of the station at Quilpie and using the observatory record from Charters Towers:

Quilpie -26.500 144.300

99999	99999	0	-4	-1	8	15	21	31	30	30	37
36	34	32	33	36	38	38	38	41	45	44	41
29	22	29	25	16	17	18	27	25	33	35	35
31	35	32	27	33	35	37	38	39	43	43	42
38	32	30	32	29	36	36	30	26	28	32	36
47	50	34	32	32	35	37	39	41	44	43	99999

99999	99999	0	-3	-1	6	9	15	22	21	22	26
24	24	23	24	26	27	28	27	29	30	30	29
24	23	25	20	14	15	15	20	21	25	26	24
23	26	22	21	25	27	28	28	29	30	30	27
25	20	18	18	17	24	25	22	20	21	23	26
35	33	24	25	24	26	27	28	28	31	29	99999

99999	99999	0	1	0	-2	-6	-6	-9	-9	-8	-11
-12	-10	-9	-9	-10	-11	-10	-11	-12	-15	-14	-12
-5	1	-4	-5	-2	-2	-3	-7	-4	-8	-9	-11
-8	-9	-10	-6	-8	-8	-9	-10	-10	-13	-13	-15
-13	-12	-12	-14	-12	-12	-11	-8	-6	-7	-9	-10
-12	-17	-10	-7	-8	-9	-10	-11	-13	-13	-14	99999

Figure 7 shows the result of plotting the equivalent part of CTA.PLO. The first set of numbers/first plot shows t%%[PrinterError: out of paper]%%¼¼%%[PrinterError: out of paper]%%¼ repeat station, and the third shows the difference between the first two. The first MHV in the series is taken as the reference level. It is clear from the results of this crude comparison that similar temporal variations occur at the two sites but that their amplitude and phase differ.

Quilpie -26.5 144.3

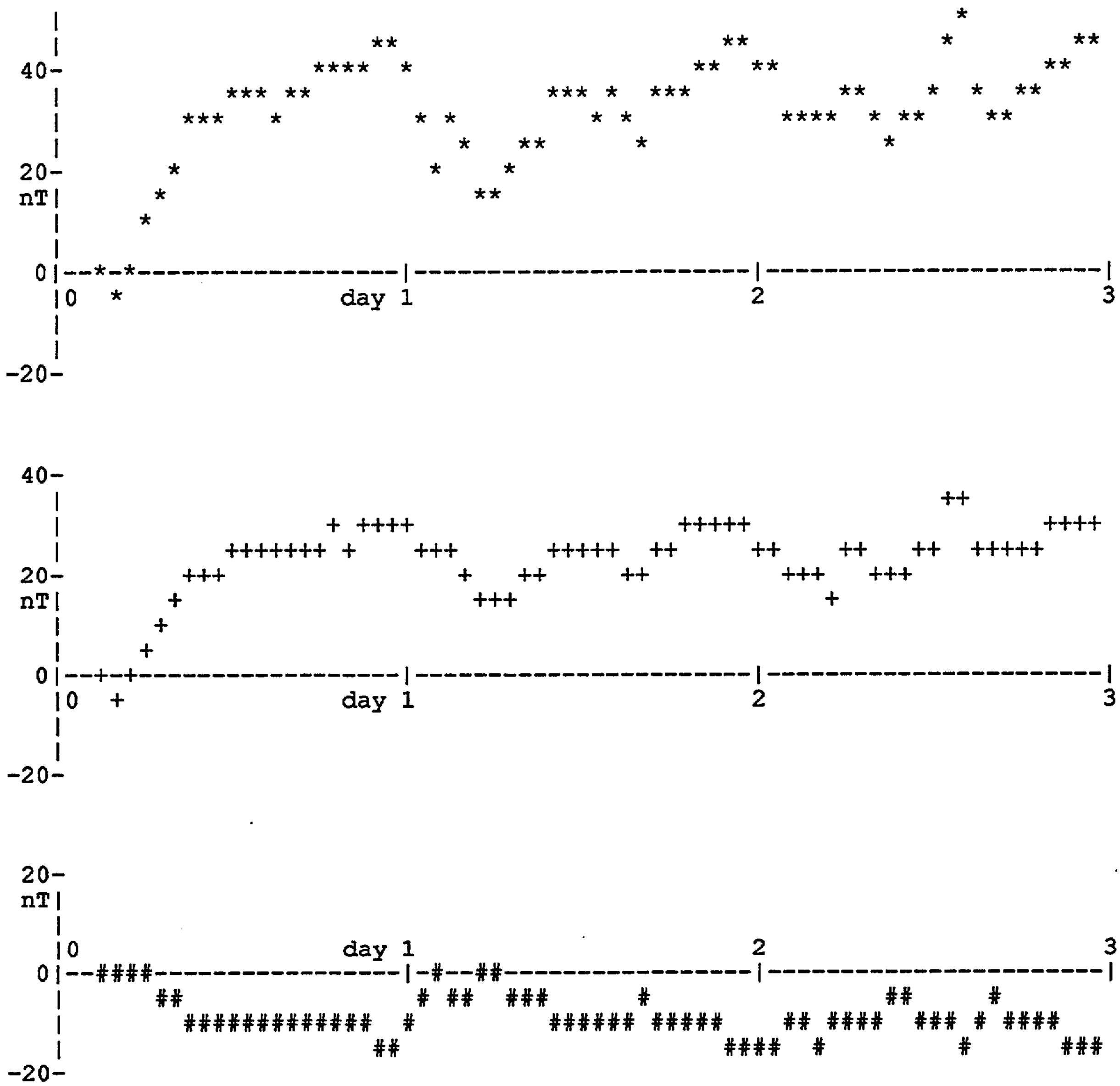

Figure 7. The temporal variation in total magnetic intensity at Charters Towers observatory (top) and Quilpie (middle) and their difference (bottom) for the period 25-08-86 to 27-08-86 inclusive. The x-axis is graduated in days and the y-axis in 20 nT steps.

A Marine Magnetic Regional Field Data Set for Australia

Introduction

This record describes the Australian marine magnetic data set, and a smoothed version of it that results in a reduction in the number of data points from around $2x10^6$ to around $2x10^3$. One of the uses of the smoothed marine magnetic data set is for modelling the Australian regional geomagnetic field. It has the potential to be particularly useful in constraining a field model in the outer parts of the region.

A large number of observations of total magnetic intensity have been made in the course of marine geophysical surveys in the Australian region. Observations are made using one, and occasionally two, proton precession magnetometers towed by a vessel. Observations are stored together with information on the position, time, and date of each observation. The current (1991) marine magnetic data set for Australia contains data from three different series of surveys: Continental Margin Surveys, CMS (1967-1972), Vema surveys (1975-1977), and Rig Seismic surveys (1985-1988). Survey work on the Rig Seismic is ongoing, and data from post-1988 surveys are available from the Marine Division, AGSO.

The Marine Magnetic Data Set

The marine magnetic data set consists of 41 files containing data from 40 surveys that are stored on 12 magnetic tapes (see Figures 8, 9, and 10 and Table 4). The tapes are lodged with the Geomagnetism Section, AGSO. Each observation is stored as an 80-byte ASCII record, a record consisting of a survey number (two digits for CMS and Rig Seismic surveys, four digits for Vema surveys), day number (day number of the year for some surveys, survey day number for others), hour and minute, latitude and longitude in decimal degrees, and one or two values of total magnetic intensity in nanotesla.

Data files can be read from tape to disk on the AGSO's Data General computer using the command TAPE_FX_READ (first enter the command ADDPRE to access commands in BMR:PRERELEASE). This command requires two parameters: a tape name, usually in Fnn format, and a command file name. The command file must contain information on the tape input files and the disk output files. Each line has the form: tape file number, disk file name in quotes, number of bytes per record, and a slash. A command file named MARINE for use in reading the first two files from a marine tape named F5 to the disk files CMS3.DAT and CMS4.DAT would be:

```
1   'CMS3.DAT'   80/
2   'CMS4.DAT'   80/
```

The command to read these files would be:

```
TAPE_FX_READ  F5  MARINE
```

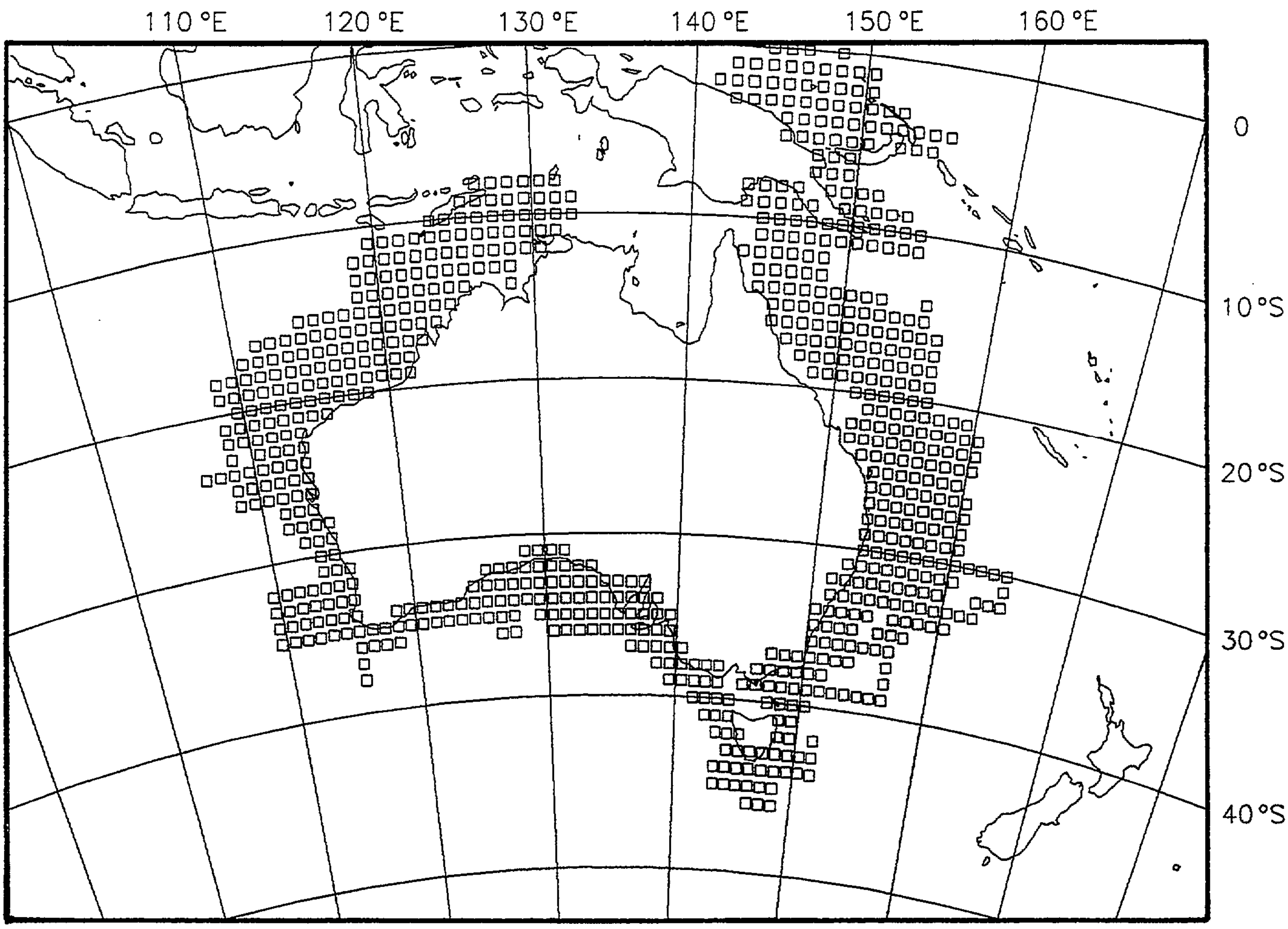

Figure 8. 1°x1° bins containing magnetic observations made on Continental Margin Surveys.

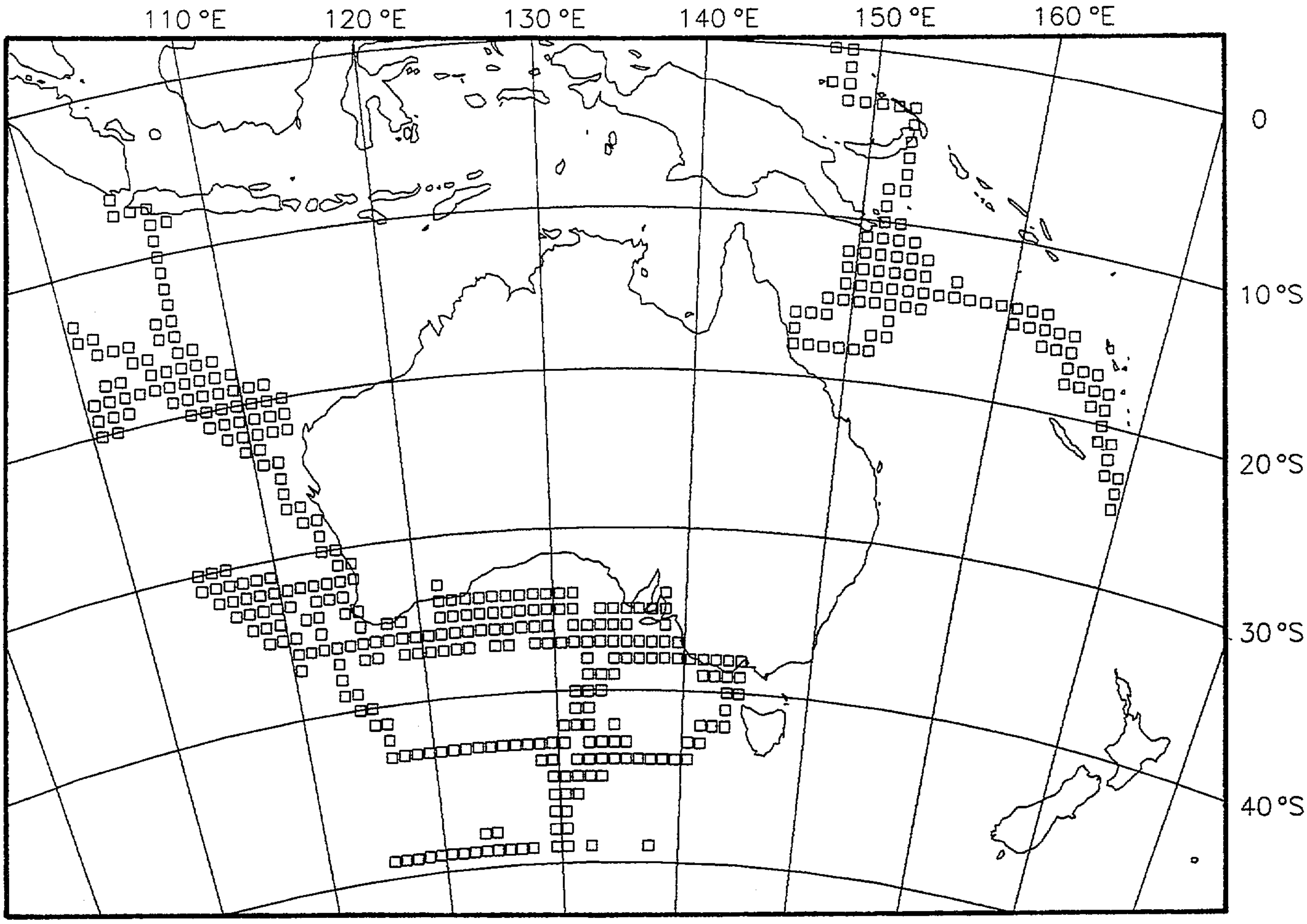

Figure 9. 1°x1° bins containing magnetic observations made on Vema surveys.

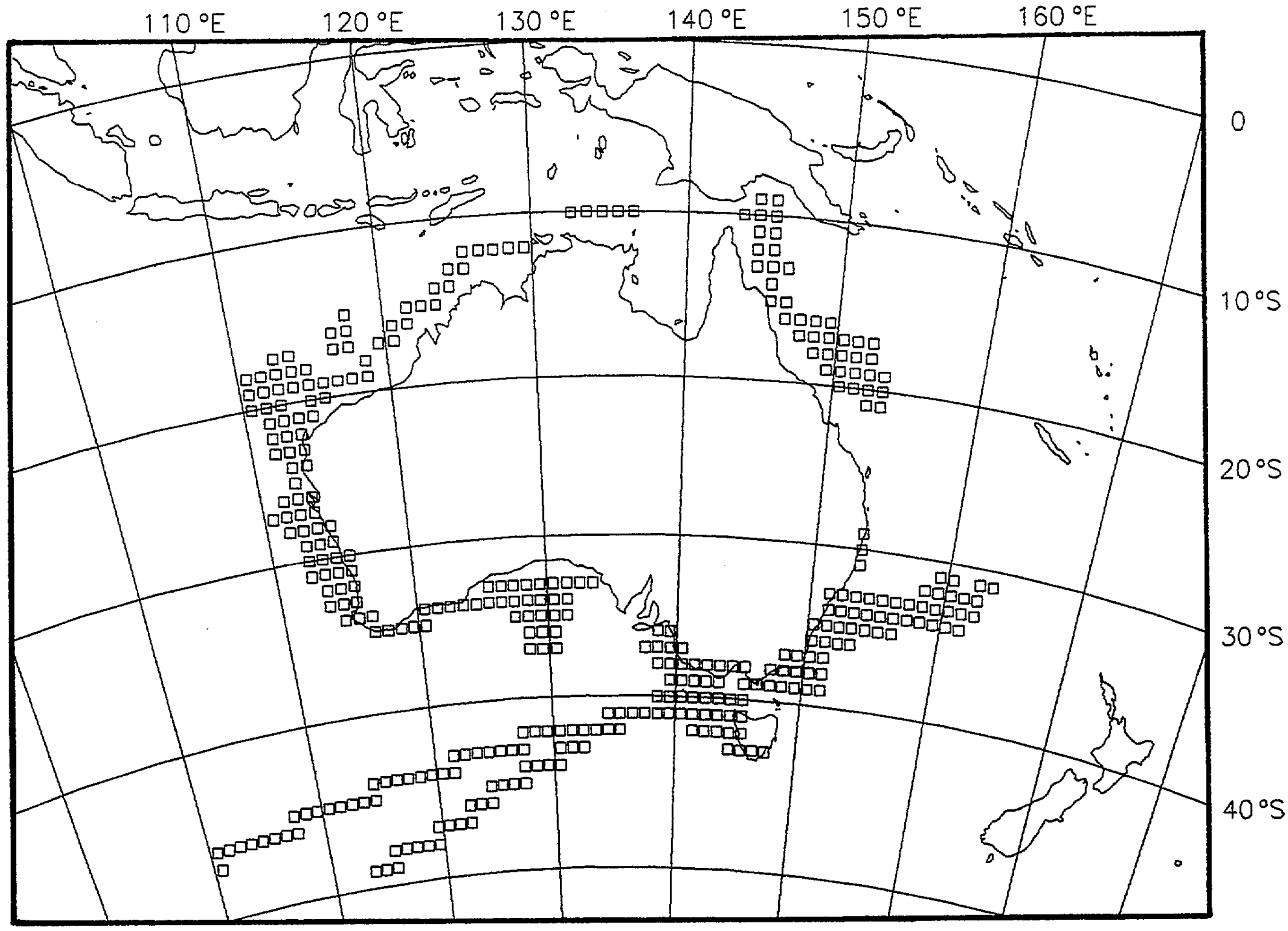

Figure 10. 1°x1° bins containing magnetic observations made on Rig Seismic surveys.

Processing the Marine Magnetic Data Set

The marine magnetic data set consists of about $1.8x10^6$ observations, mostly made at 1-min intervals (typical separation of observations is about 100 m). The number of data points must be reduced before the data set can be used for regional field modelling. A simple means of doing this is to average the data from each survey in 1°x1° latitude/longitude bins. This results in data points with a separation of around 100 km, quite adequate for use in deriving a regional field model with a spatial resolution of order 1000 km. Averaging of the data is done by the program MAV.F77 (Appendix 6). This program excludes outlying observations by determining the mean and standard deviation of all observations in each bin, and then recalculates these values with observations lying more than two standard deviations from the mean excluded.

Before running MAV.F77, two parameters and four file names that uniquely identify the particular survey must be set within the program. The first parameter is the epoch of the survey. This can be obtained by reading the day number from the first and last survey records and combining the day number of the midpoint of the survey with the year and, if necessary, the starting date of the survey. The second parameter is the number of usable records in the file. This can be readily obtained by examining the end of the file using the SLATE text editor. It is necessary to specify this parameter because some data files have non-standard records at their end.

Output from MAV.F77 is stored in a file named *.MAV, where * is a survey identifier (e.g., CMS10.MAV, which corresponds to Continental Margin Survey 10). The 1°-averaged values are stored one per line in I5, 3F9.2, F9.1, I6, F8.1 format, e.g.,

```
    3  1967.89   -9.50  126.50  44749.8    79   130.9
```

These values represent the survey number, epoch, latitude, longitude, average total magnetic intensity, number of observations in the bin, and standard deviation of the observations in the bin respectively. The region of interest is restricted to 0° and -50° N latitude and 100° and 170° E longitude. Processing all of the marine magnetic data to produce 1°-averaged values resulted in 41 *.MAV files containing 1963 data points. This represents data in 1065 different 1°x1° bins, or 38% of the total number of possible marine bins in the region of interest. 537 bins contain data points from more than one survey; the reason for not averaging the points in each of these bins is that each point corresponds to a different epoch. The 41 *.MAV files were concatenated into three further files (CMS.MAV, VEMA.MAV, and RIGS.MAV), one for each series of surveys.

An Example of Use of the Averaged Marine Magnetic Data

One way in which 1°-averaged marine magnetic data might be used is to produce a set of magnetic anomalies for the region by removing an estimate of the core field and its secular variation. Program MDF.F77 (Appendix 7) does this using the International Geomagnetic Reference Field (IGRF). It averages the resulting anomalies in 2°x2° latitude/longitude bins.

The resulting magnetic anomaly pattern is illustrated in Figure 11. The choice of a 2°x2° interval results in an anomaly map comparable with those produced for continental Australia by Wellman et al. (1985). The 2°-averaged anomalies have a mean value of 5 nT and a standard deviation of 109 nT. The average number of original marine magnetic data points per 2° bin is 3210, with a standard deviation of 3433 points. The only data selection condition used was that the standard deviation of the 1°-averaged data did not exceed 700 nT. This excluded four data points that clearly were affected by errors in the original data set. More stringent conditions, such as requiring a minimum number of observations per 2° bin or requiring a certain level of agreement between observations made in the same bin at different epochs, could be set.

An Estimate of Errors in Marine Magnetic Data

The magnetic field observed at sea is the sum of internal, external and ship's fields, of which only the internal field is of interest. Bullard and Mason (1963) estimated that the ship's field is usually less then 15 nT, although this obviously depends on the ship and the sensor configuration. The ship's field varies with heading, so that averaging a large number of observations should lead to a reduction in the error. Based on these considerations, the error from the ship's field in the 1°-averaged marine values is unlikely to exceed 10 nT.

External magnetic fields are due to ionospheric and magnetospheric electric current systems, which vary both regularly and irregularly under solar influence. The regular external field, known as the diurnal variation, peaks around local midday. It can cause a depression in total magnetic intensity relative to the night-time level of up to 50 nT in the Australian region. This can cause serious problems in aeromagnetic surveys, where large areas might be surveyed in the few hours when the field is disturbed (Lilley, 1982). However marine data were collected at a ship-speed of around 6 km hr^{-1}, so that in most cases averaging observations in a 1°x1° bin will correspond to averaging over about a day. The resulting uncertainty due to diurnal variation will be considerably less than 50 nT. LaBrecque et al. (1985) found the typical diurnal content of their filtered marine anomalies from the North Pacific to be in the range -10 nT to 10 nT. The typical error in the 1°-averaged marine data due to diurnal variation is thus likely to be around 10 nT.

Irregular external fields are more difficult to deal with, but again the averaging of observations in 1°x1° bins will lead to a reduction in their effect. LaBrecque et al. (1985) used an external field activity index, Ap, to reject observations made during extremely disturbed periods, and an external field strength index, Dst, to estimate the irregular external field at other times. Moderate magnetic storms can cause total magnetic intensity to be depressed by up to 30 nT for several days, and thus could affect the value of a 1°-average by a similar amount (averaging in 1° bins is roughly equivalent to averaging over a day of sailing).

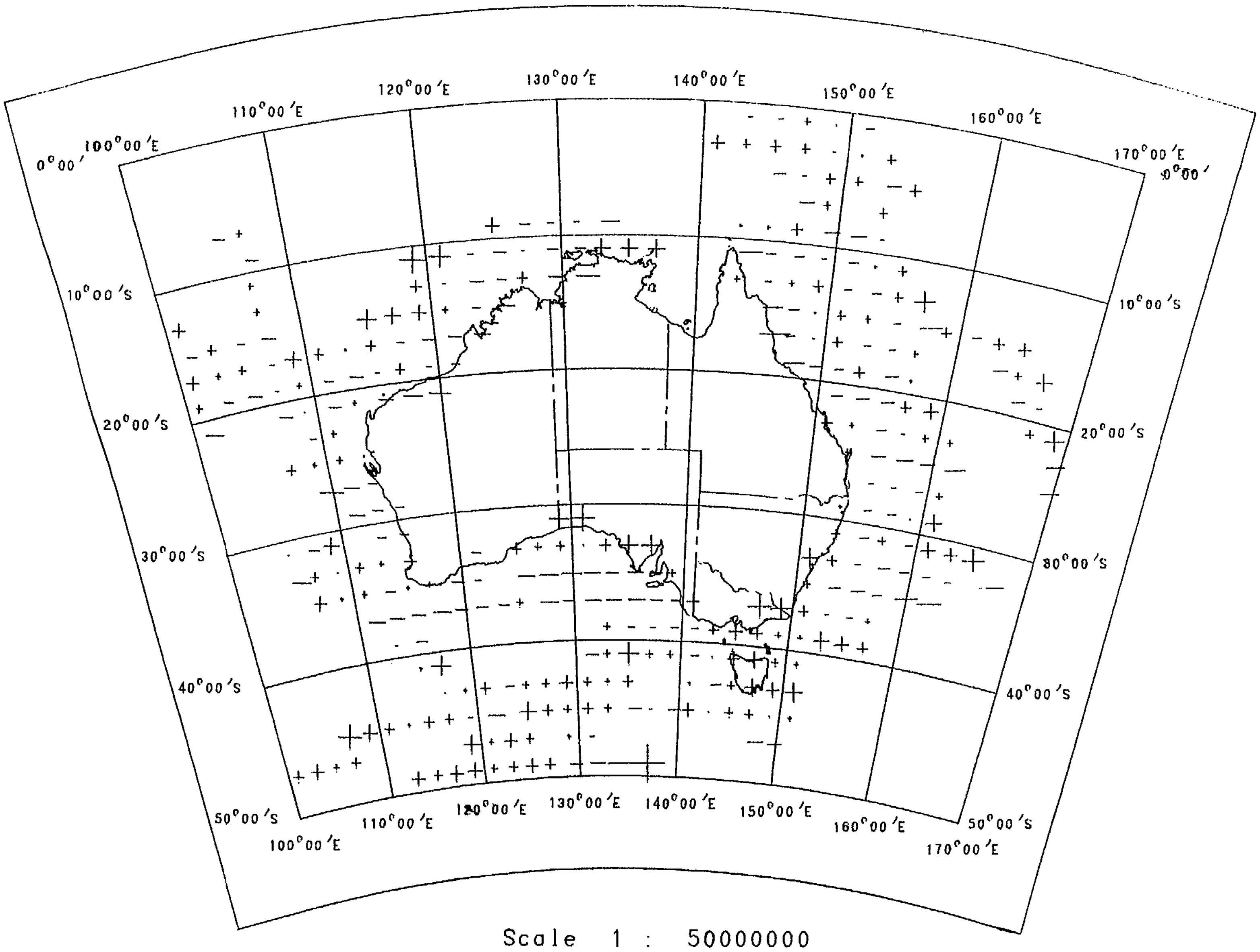

Figure 11. Average anomalies in total magnetic intensity in 2°x2° bins relative to the IGRF and based on 1°-average values. The sign of the anomaly only is given, the relative size of the sign indicating the relative amplitude of the anomaly. Anomalies range between -539 nT and 728 nT.

Another source of uncertainty in the marine data is error in location of the ship. This is of order 1 km for earlier data and 100 m for later data. These errors will lead to incorrect values of a normal field being used in the calculation of anomalies, however with the typical normal field gradient being around 3 nT km^{-1}, errors are only going to be of order 1 nT.

The marine anomalies in Figure 11 range between -539 nT and 728 nT but usually are less than 100 nT in amplitude. Even so, uncertainties in the 1°-averaged marine data set, which have been shown to be of order 10 nT, should not prevent the use of the data set in its present form (provided of course that the original observations are well-distributed within each bin). However, for regional field modelling at wavelengths of order 1000 km, when anomaly amplitudes are typically much less than 100 nT, external fields with periods of several days and amplitudes of order 10 nT are likely to become significant. Correction of the approximately 1.8×10^6 marine magnetic data points would be a major task, although not an unreasonable one if files of the Ap and Dst indices were available on computer.

Location of the Processed Data Sets

The processed data sets described in this record and the programs used to produce them are stored in the directory /geomag/donmk/marine on the Geomagnetism Section's Sun Sparcstation node (Lodestone on the AGSO network).

Acknowledgements

The tapes containing the marine magnetic data set were prepared by Ray Tracey and John Mowat of the Marine Division, AGSO.

References

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Appendix 1. Project MAGNET Flights on Magnetic Tapes

Tape name	Flights
W13148	1097, 3074, 3075, 4031, 4032, 4033, 4034, 4035, 4036, 5033, 4037
W11168	4038, 4039, 4040, 4041, 4042, 4044, 1098
W01229	1089, 1090, 1099, 1100, 4045, 4046, 4048, 5044, 5045, 5046, 5047, 5048
W11494	5056, 5057, 5058, 5059A, 5059B, 5059C, 5059D, 5060, 5061, 5062, 5063A, 5064A, 5065, 5067, 5068, 1128, 2019, 3123, 3124, 4085, 3130, 3131, 3132, 3133, 3134, 3135, 3136, 3138, 3140, 3141, 3142
PMASC1	3075, 4027, 4028, 4031, 4033, 4034, 4036, 4037, 4038
PMASC1_02	4039, 4040, 4045, 4046, 4050, 4051, 4052, 4053, 4055, 5033
PMASC1_03	5051
PMAWAGS	5093, 5094, 5095A, 5095B, 5096, 5097, 5101, 5104, 5105

Appendix 2. Project MAGNET Magnetic Tape Description

These specifications apply to all the Project MAGNET tapes (see Appendix 1).

Tape Specifications (9-track tape)

Density	- 1600 BPI
Coding	- ASCII
Record length	- 108 characters
Blocking	- 1080 characters or 10 records per block

Tape Contents

Data sets include navigation and magnetic data collected during Project MAGNET vector survey operations. Magnetic data comprise: X-component, Y-component, horizontal intensity, Z-component, vector total intensity, declination, inclination, and scalar total intensity.

Tape Structure

The tape structure consists of physical records organized into files. Each file corresponds to one flight. Single end-of-file marks (EOFs) separate each file. A double EOF mark follows the last file on the tape.

file header record	(one physical record)	File #1
leg number	(one physical record)	
physical data records	(as many records as needed)	
:		
EOF		
file header record	(one physical record)	File #2
leg number	(one physical record)	
physical data records	(as many records as needed)	
:		
EOF		
:		
:		
file header record	(one physical record)	File #n (last file)
leg number	(one physical record)	
physical data records	(as many records as needed)	
:		
EOF		
EOF		

File Structure

Each file on tape corresponds to a flight. Each flight is made up of several track lines called legs. Within a file, each leg is designated with an I4 formatted record (example: 1003), and each leg ends with a zero-filled record. The following sequence of unique records are contained within each file.

Header Record - The first logical record of each file is a header record consisting of 108 alphanumeric characters. Information contained within the record are: project number; flight number; month, day, year, and Julian day of the flight; number of physical data records; navigational device (example: ESG - electrostatical suspended gyro); navigational compensation device (example: RLG - ring laser gyro).

Leg Number Record - The second logical record of each file is a leg number consisting of a four-digit integer number.

Data Records - Each logical data record contains the following information in format 3F10.4, 5F8.0, 2F10.4, 2F9.0.

Columns 1-10	UT in seconds from 0000 UT of the header record's Julian date.
Columns 11-20	Latitude in decimal degrees, negative in southern hemisphere.
Columns 21-30	Longitude in decimal degrees, negative in western hemisphere.
Columns 31-38	X-component in nanoteslas.
Columns 39-46	Y-component in nanoteslas.
Columns 47-54	Horizontal intensity in nanoteslas.
Columns 55-62	Z-component in nanoteslas.
Columns 63-70	Computed total intensity from X, Y, and Z vectors.
Columns 71-80	Declination in decimal degrees.
Columns 81-90	Inclination in decimal degrees.
Columns 91-99	Observed scalar total magnetic intensity in nanoteslas.
Columns 100-108	Barometric altitude in feet above mean sea level.

Appendix 3. Listing of Program PM_AV.F77

```
      program PM_AV
c
c   Averages Project MAGNET data along the flight track over a
c   specified time interval.
c
c   Written by J. D. McKnight for the DG.  Revised on 21/6/91.
c
      character*32 filename
      logical*1 b(108)
      dimension v(12),t(7)
      data ntot,v9 /0,99900./
c
      print *,' enter the input file name                        '
      read(*,'(a)') filename
      open(unit=21,file=filename,status='old')
      print *,' enter the output file name                       '
      read(*,'(a)') filename
      open(unit=22,file=filename,status='new')
c
      print 500
      read *,nyear,nday,nsecs
      epoch=nyear+float(nday)/365.
      read(21,200) b
      write(22,400) epoch,nyear,nday,nsecs,(b(i),i=1,28)
      print *,' enter the averaging period in seconds     '
      read *,intsec
      goto 11
c
c  read and process each observation record
5     read(21,7,end=100) v
      if(v(1).gt.0.) goto 8
c
11    read(21,9,end=100) legno
      print *,' leg number is ',legno
      secup=0.
      nobs=0
      nobf=0
      do 17 i=1,7
      t(i)=0.
17    continue
      goto 5
c
8     if(secup.eq.0.) secup=v(1)+intsec-1.
      if(v(1).lt.secup-8.e4) secup=secup-8.64e4
      if(rlong.lt.0.) rlong=rlong+360.
      if(v(1).lt.secup) goto 50
c
c  average the accumulated values over the interval
      if(nobs.eq.0.or.t(1).eq.0..or.t(2).eq.0..or.t(3).eq.0..or.
     +   t(4).eq.0..or.t(5).eq.0..or.t(7).eq.0.) then
         print *,' no valid observations in interval'
      else
         do 20 i=1,5
         t(i)=t(i)/float(nobs)
20       continue
```

```
         if(nobf.gt.0) t(6)=t(6)/float(nobf)
         if(nobf.eq.0) t(6)=0.
         t(7)=t(7)/(nobs*3280.84)
         write(22,300) t,nint(secup-float(intsec)/2.)
         ntot=ntot+1
      end if
      nobs=0
      nobf=0
      do 30 i=1,7
      t(i)=0.
30    continue
      secup=v(1)+intsec-1.
50    if(abs(v(4)).gt.v9.or.abs(v(5)).gt.v9.or.abs(v(7)).gt.v9) goto 5
c
c  increment the totals if the observation is valid
      nobs=nobs+1
      do 60 i=1,4
      t(i)=t(i)+v(i+1)
60    continue
      t(5)=t(5)+v(7)
      t(7)=t(7)+v(12)
      if(v(11).gt.8.e4.or.v(11).lt.0.) goto 5
      nobf=nobf+1
      t(6)=t(6)+v(11)
      goto 5
c
100   print *,' total number of sets of average values: ',ntot
      close(unit=21)
      close(unit=22)
500   format(' enter year, Julian day number, and time of start of
     + flight in seconds'/)
7     format(3f10.4,5f8.0,2f10.4,2f9.0)
9     format(i4)
200   format(108a1)
300   format(2f8.3,4f8.0,f8.3,i8)
400   format(f9.3,3i7,6x,28a1)
      end
```

Appendix 4. Listing of Program AERO_BIN.F77

```
      program AERO_BIN
c
c   Takes aeromagnetic data files read from tape in 5120 character
c   records and stores lat, long, alt, and F values, one set per line,
c   in a binary file.
c
c   Written by J. D. McKnight for the DG.  Revised on 20/6/91.
c
      dimension ival(5,101)
      open(unit=3,file='BIN.DAT',status='new',recfm='variable',
     +     form='unformatted',access='sequential',maxrecl=20)
c
      do 2000 nf=1,3
      if(nf.eq.1) open(unit=1,file='AERO1.DAT',status='old',
     +                 mode='binary')
      if(nf.eq.2) open(unit=1,file='AERO2.DAT',status='old',
     +                 mode='binary')
      if(nf.eq.3) open(unit=1,file='AERO3.DAT',status='old',
     +                 mode='binary')
c
c   read the Segment Directory Record
      read(1,100) iproj,igrp,iseg,ich,idate,idt,it0,ibrg,
     +              iasl,iagl,nch,ned,ndt,ndps,nrf,nrl,ntf,ntl
      write(3) float(iseg),float(ntl),float(idate),float(idt)/2.
      write(3) float(it0),float(ibrg),float(iasl),float(iagl)
c
c   read each Data Record
      icnt=0
      do 1400 ir=nrf,nrl
      read(1,100) ntf,ntl,ival
      do 1400 line=1,101
      if(ival(1,line).eq.0) goto 1400
      write(3) float(ival(1,line))/1.e6,float(ival(2,line))/1.e6,
     +          float(ival(4,line)),float(ival(5,line))/1.e3
      icnt=icnt+1
1400  continue
      print *,' obsvns expected/read :',ntl,icnt
      close(unit=1)
2000  continue
      close(unit=3)
100   format(2i9,509i10,i12)
      end
```

Appendix 5. Listing of Program AERO_AV.F77

```
      program AERO_AV
c
c   Takes 0.5-s AWAGS aeromagnetic data in binary files and determines
c   average value over RMIN minutes.
c
c   Written by J. D. McKnight for the DG.  Revised on 20/6/91.
c
      dimension r(4),rsum(4),top(4),bot(4),nsum(4)
      data top,bot /156.,-10.,3000.,70000.,110.,-40.,0.,30000./
c
c  ***  set the averaging period RMIN in minutes   ***
      rmin=0.5
      nobs=int(rmin*120.)
c
      open(unit=2,file='AV.DAT',status='new')
      do 111 nfile=1,4
      if(nfile.eq.1)
     + open(unit=3,file='BIN1.DAT',status='old',recfm='variable',
     +      form='unformatted',access='sequential',maxrecl=20)
      if(nfile.eq.2)
     + open(unit=3,file='BIN2.DAT',status='old',recfm='variable',
     +      form='unformatted',access='sequential',maxrecl=20)
      if(nfile.eq.3)
     + open(unit=3,file='BIN3.DAT',status='old',recfm='variable',
     +      form='unformatted',access='sequential',maxrecl=20)
      if(nfile.eq.4)
     + open(unit=3,file='BIN4.DAT',status='old',recfm='variable',
     +      form='unformatted',access='sequential',maxrecl=20)
c
10    read(3,end=1000) r
      nseg=int(r(1))
      ntot=int(r(2))
      read(3) r
      icnt=0
      do 15 j=1,4
      rsum(j)=0.
      nsum(j)=0
15    continue
c
      do 100 i=1,ntot
      read (3) r
      icnt=icnt+1
      do 120 j=1,4
      if(r(j).lt.top(j).and.r(j).gt.bot(j)) then
         rsum(j)=rsum(j)+r(j)
         nsum(j)=nsum(j)+1
      else
         print *,' data outside range',nseg,j,r(j)
      end if
120   continue
      if(icnt.lt.nobs) goto 100
c
      do 70 j=1,4
      if(nsum(j).gt.0) then
         rsum(j)=rsum(j)/float(nsum(j))
      else
```

```
               print *,' no obsvns',nseg,j
               rsum(j)=-999.
            end if
70          continue
            write(2,200) rsum
            icnt=0
            do 110 j=1,4
            rsum(j)=0.
            nsum(j)=0
110         continue
100         continue
            goto 10
c
1000        close(unit=3)
111         continue
            close(unit=2)
200         format(2f9.3,f7.0,f9.1)
            end
```

```
      program MAV
c
c   Reads marine total intensity observations, averages in 1-degree
c   bins and stores in survey file.
c
c   Suitable for CMS, VEMA, and RIG SEISMIC survey formats.
c
c   Written by J. D. McKnight for the DG.   Revised 19/6/91.
c
      dimension nb(200000),nf(50,70),sd(50,70),fb(50,70)
      logical*1 e
      logical vema
      character*10 a,b
      character*7  c,d
      double precision sx(50,70),sxx(50,70),diff
      data nf,sd,fb,sx,sxx,vema /3500*0,7000*0.,7000*0D0,.false./
c
c
c   set the following two parameters for each survey, + 4 filenames.
      epoch=1977.09
      nobs=39631
c
c
      print *,' Is this a Vema survey?  (y or n)     '
      read 5,e
      if(e.eq.'y'.or.e.eq.'Y') vema=.true.
c
      open(unit=1,file='vema1043.dat',status='old')
      do 10 i=1,nobs
      if(.not.vema) read(1,20) ncr,ndat,ntime,a,b,c,d
      if(vema) read(1,22) ncr,ndat,ntime,a,b,c,d
      nb(i)=1
      if(a.eq.'**********'.or.b.eq.'**********'.or.
     +   c.eq.'       ') nb(i)=0
      if(d.ne.'       ') nb(i)=2
10    continue
100   close(unit=1)
      print *,' first reading completed, ',nobs,' observations'
c
      open(unit=1,file='vema1043.dat',status='old')
      do 400 i=1,nobs
      if(nb(i).eq.0) goto 200
      if(nb(i).eq.1) goto 220
      if(nb(i).eq.2) goto 240
      print *,' error in nb(i)'
      stop
200   if(.not.vema) read(1,300)
      if(vema) read(1,302)
      goto 400
220   if(.not.vema) read(1,300) ncr,nday,ntime,rlat,rlong,nf1
      if(vema) read(1,302) ncr,nday,ntime,rlat,rlong,nf1
      nf2=0
      goto 260
240   read(1,300) ncr,nday,ntime,rlat,rlong,nf1,nf2
260   lat=int(rlat+1.)
      long=int(rlong-99.)
```

```
      if(lat.lt.1.or.lat.gt.50) goto 400
      if(long.lt.1.or.long.gt.70) goto 400
      nf(lat,long)=nf(lat,long)+1
      if(nf2.gt.0) nf(lat,long)=nf(lat,long)+1
      sx(lat,long)=sx(lat,long)+dble(nf1)+dble(nf2)
      sxx(lat,long)=sxx(lat,long)+dble(nf1)**2+dble(nf2)**2
400   continue
      close(unit=1)
c
c  determine average values in 1-degree bins
      do 500 i=1,50
      do 500 j=1,70
      if(nf(i,j).eq.0) goto 500
      diff=sxx(i,j)/dble(nf(i,j))-(sx(i,j)/dble(nf(i,j)))**2
      sd(i,j)=real(dsqrt(diff))
      fb(i,j)=real(sx(i,j)/dble(nf(i,j)))
500   continue
c
c   recalc. 1-degree averages without data outside 2 sigma
      open(unit=1,file='vema1043.dat',status='old')
      do 1100 i=1,50
      do 1100 j=1,70
      nf(i,j)=0
      sx(i,j)=0d0
      sxx(i,j)=0d0
1100  continue
      do 1400 i=1,nobs
      if(nb(i).eq.0) goto 1200
      if(nb(i).eq.1) goto 1220
      if(nb(i).eq.2) goto 1240
      print *,' error in nb(i)'
      stop
1200  if(.not.vema) read(1,300)
      if(vema) read(1,302)
      goto 1400
1220  if(.not.vema) read(1,300) ncr,nday,ntime,rlat,rlong,nf1
      if(vema) read(1,302) ncr,nday,ntime,rlat,rlong,nf1
      nf2=0
      goto 1260
1240  read(1,300) ncr,nday,ntime,rlat,rlong,nf1,nf2
1260  lat=int(rlat+1.)
      long=int(rlong-99.)
      if(lat.lt.1.or.lat.gt.50) goto 1400
      if(long.lt.1.or.long.gt.70) goto 1400
      if(abs(real(nf1)-fb(lat,long)).gt.(2.*sd(lat,long))) nf1=0
      if(nf1.gt.0) nf(lat,long)=nf(lat,long)+1
      if(abs(real(nf2)-fb(lat,long)).gt.(2.*sd(lat,long))) nf2=0
      if(nf2.gt.0) nf(lat,long)=nf(lat,long)+1
      sx(lat,long)=sx(lat,long)+dble(nf1)+dble(nf2)
      sxx(lat,long)=sxx(lat,long)+dble(nf1)**2+dble(nf2)**2
1400  continue
      close(unit=1)
c
      open(unit=1,file='vema1043.mav',status='new')
      do 1500 i=1,50
      do 1500 j=1,70
      if(nf(i,j).eq.0) goto 1500
      diff=sxx(i,j)/dble(nf(i,j))-(sx(i,j)/dble(nf(i,j)))**2
```

```
      sd(i,j)=real(dsqrt(diff))
      sx(i,j)=sx(i,j)/dble(nf(i,j))
      rlat=-i+0.5
      rlong=j+99.5
      write(1,1600) ncr,epoch,rlat,rlong,real(sx(i,j)),
     +              nf(i,j),sd(i,j)
1500  continue
      close(unit=1)
5     format(a1)
20    format(i2,1x,i3,1x,i4,1x,a10,1x,a10,2a7)
22    format(i4,1x,i3,1x,i4,1x,a10,1x,a10,2a7)
300   format(i2,1x,i3,1x,i4,2f11.6,2i7)
302   format(i4,1x,i3,1x,i4,2f11.6,2i7)
1600  format(i5,3f9.2,f9.1,i6,f8.1)
      end
```

Appendix 7. Listing of Program MDF.F77

```
      program MDF
c
c Determines mean delta F in 2-degree bins using 1-degree averaged
c marine observations.  IGRF is the reference field.  1-degree data
c are rejected if std deviation > 700 nT.
c
c    *** LINK with SCAP10 and SNORM ***
c
c Written by J. D. McKnight for the DG.  Revised 19/6/91.
c
      dimension f(50,70),nf(50,70)
      data f,nf /3500*0.,3500*0/
c
c sum the anomalies in each 1-degree bin for data in cr.all
c (cr.all contains all 41 *.MAV files)
      open(unit=11,file='cr.all',status='old')
10    read(11,300,end=200) ncr,epoch,rlat,rlong,fb,nobs,sigma
c
      if(sigma.lt.700.) goto 20
      print *,'                    ',ncr,nobs, ' sigma = ',sigma
      goto 10
c
20    call GEOCENF(rlat,0.,0.,0.,clat,ralt,x,z)
      call NORM(clat,rlong,ralt,epoch,xn,yn,zn)
c
      fn=sqrt(xn**2+yn**2+zn**2)
      df=fb-fn
      if(abs(df).gt.500.) print *,ncr,df,sigma
      i=int(-rlat+0.6)
      j=int(rlong-99.)
      nf(i,j)=nf(i,j)+nobs
      f(i,j)=f(i,j)+nobs*df
      goto 10
200   close(unit=11)
c
c average anomalies in 2-degree bins and write values in cr.grd
      do 250 i=1,49,2
      do 250 j=1,69,2
      nf(i,j)=nf(i,j)+nf(i+1,j)+nf(i,j+1)+nf(i+1,j+1)
      f(i,j)=f(i,j)+f(i+1,j)+f(i,j+1)+f(i+1,j+1)
      if(nf(i,j).ne.0) f(i,j)=f(i,j)/real(nf(i,j))
250   continue
c
      open(unit=11,file='cr.grd',status='new')
      write(11,400) ((int(f(i,j)),j=1,69,2),i=1,49,2)
      write(11,400) ((nf(i,j),j=1,69,2),i=1,49,2)
      close(unit=11)
300   format(i5,3f9.2,f9.1,i6,f8.1)
400   format(/12i6/12i6/11i6)
      end
```

Table 1(a). Project MAGNET Flights Processed (1-min Averages) and Their Sources

Flight	Date	File name	T_{av} (s)	N_{obsvns}	Tape
4031	05-11-82	PM_1MIN_4031.DAT	60	604	W13148
4032	08-11-82	PM_1MIN_4032.DAT	60	662	W13148
4033	10-11-82	PM_1MIN_4033.DAT	60	534	W13148
4034	16-11-82	PM_1MIN_4034.DAT	60	604	W13148
4036	20-11-82	PM_1MIN_4036.DAT	60	649	W13148
5033	23-11-82	PM_1MIN_5033.DAT	60	712	W13148
4037	28-11-82	PM_1MIN_4037.DAT	60	690	W13148
4038	30-11-82	PM_1MIN_4038.DAT	60	653	W11168
4039	03-12-82	PM_1MIN_4039.DAT	60	608	W11168
4045	28-03-83	PM_1MIN_4045.DAT	60	506	W01229
4046	01-04-83	PM_1MIN_4046.DAT	60	410	W01229
5044	10-03-83	PM_1MIN_5044.DAT	60	703	W01229
5045	16-03-83	PM_1MIN_5045.DAT	60	627	W01229
5046	19-03-83	PM_1MIN_5046.DAT	60	691	W01229
5047	22-03-83	PM_1MIN_5047.DAT	60	641	W01229
5048	25-03-83	PM_1MIN_5048.DAT	60	650	W01229
5062	26-03-86	PM_1MIN_5062.DAT	60	587	W11494
5063A	29-03-86	PM_1MIN_5063A.DAT	60	359	W11494
5064A	01-04-86	PM_1MIN_5064A.DAT	60	464	W11494
5065	05-04-86	PM_1MIN_5065.DAT	60	618	W11494
3123	11-04-86	PM_1MIN_3123.DAT	60	538	W11494
4085	08-04-86	PM_1MIN_4085.DAT	60	443	W11494
3130	23-11-86	PM_1MIN_3130.DAT	60	605	W11494
3131	25-11-86	PM_1MIN_3131.DAT	60	553	W11494
4027	19-08-82	PM_1MIN_4027.DAT	60	743	PMASC1
4028	21-08-82	PM_1MIN_4028.DAT	60	738	PMASC1
4051	06-12-83	PM_1MIN_4051.DAT	60	731	PMASC1_02
4052	09-12-83	PM_1MIN_4052.DAT	60	600	PMASC1_02
4053	11-12-83	PM_1MIN_4053.DAT	60	720	PMASC1_02
5051	02-12-83	PM_1MIN_5051.DAT	60	655	PMASC1_03

Table 1(b). Project MAGNET Flights Processed (6-s Averages) and Their Sources

Flight	Date	File name	T_{av} (s)	N_{obsvns}	Tape
5093	03-02-90	PM_6S_5093.DAT	6	5867	PMAWAGS
5094	06-02-90	PM_6S_5094.DAT	6	5638	PMAWAGS
5095A	09-02-90	PM_6S_5095A.DAT	6	1925	PMAWAGS
5095B	12-02-90	PM_6S_5095B.DAT	6	4254	PMAWAGS
5096	14-02-90	PM_6S_5096.DAT	6	5304	PMAWAGS
5097	18-02-90	PM_6S_5097.DAT	6	395	PMAWAGS
5101	08-03-90	PM_6S_5101.DAT	6	1565	PMAWAGS
5104	11-03-90	PM_6S_5104.DAT	6	4363	PMAWAGS
5105	16-03-90	PM_6S_5105.DAT	6	4638	PMAWAGS

Table 2. List of AWAGS Stations

		lat(°N)	long(°E)
BMR Magnetic Observatories			
CNB	Canberra	-35.315	149.363
CTA	Charters Twrs	-20.088	146.253
GNA	Gnangara	-31.780	115.950
LRM	Learmonth	-32.217	114.100
BMR Magnetic Repeat Stations			
DAR	Darwin	-12.417	130.870
GOV	Gove	-12.377	136.740
WEI	Weipa	-12.680	141.925
WYN	Wyndham	-15.510	128.147
DYW	Daly Waters	-16.273	133.373
CRO	Croydon	-18.215	142.253
CKT	Cooktown	-15.477	145.187
DER	Derby	-17.370	123.663
HAL	Halls Creek	-18.233	127.667
TCK	Tennant Creek	-19.627	134.183
ISA	Mt. Isa	-20.667	139.490
HED	Pt. Hedland	-20.377	118.630
GRN	The Granites	-20.560	130.355
TEL	Telfer	-21.705	122.228
ASP	Alice Springs	-23.807	133.898
VER	Mt. Vernon	-24.230	118.237
CNE	Carnegie	-25.803	122.945
GIL	Giles	-25.035	128.300
MEK	Meekathara	-26.610	118.545
CVN	Carnarvon	-24.882	113.665
WTN	Winton	-22.367	143.082
ALP	Alpha	-23.655	146.587
BIR	Birdsville	-25.910	139.352
QUI	Quilpie	-26.608	144.253
ROM	Roma	-26.550	148.775
EMU	Emu	-28.630	132.198
ETA	Etadunna	-28.718	138.633
EUC	Eucla	-31.682	128.880
CED	Ceduna	-32.130	133.713
POL	Portland	-38.313	141.467
MYB	Maryborough	-25.523	152.728

		lat(°N)	long(°E)
GER	Geraldton	-28.797	114.703
LAV	Laverton	-28.612	122.422
SOX	Southern Cross	-31.242	119.358
ZAN	Zanthus	-31.037	123.568
ABY	Albany	-34.945	117.805
ESP	Esperance	-33.685	121.822
TIB	Tibooburra	-29.448	142.053
BUK	Bourke	-30.052	145.952
MOR	Moree	-29.498	149.847
GFN	Grafton	-29.767	153.020
CDN	Condobolin	-33.063	147.213
NEW	Newcastle	-32.797	151.835

Non-repeat stations

BAL	Balranald	-35.617	143.567
GLE	Glenormiston	-22.883	138.817
KIW	Kiwirrkurra	-22.867	127.550
MEN	Menindee	-32.400	142.417
TWO	Tennyson-Woods, Flinders	-34.	138.
PTA	Pt. Augusta	-32.483	137.750
ROB	Robinson River	-16.717	136.950
WAN	Serpentine Lakes	-28.51	129.000
TOO	Toolangi	-37.533	145.467
MTD	Mt.Dare	-26.500	135.250

Table 3. 6-min Files From the First Run of AWAGS.

Station (%)	%1.FIL	%2.FIL	%3.FIL	%4.FIL	%5.FIL
ABY	*	*	*	-	-
ALP	*	*	*	*	-
ASP	*	*	*	*	-
BAL	*	*	*	-	-
BIR	*	*	*	*	-
BUK	*	*	*	-	-
CED	*	*	*	-	-
CKT	*	*	*	-	-
CNB	*	*	*	-	-
CDN	*	*	*	-	-
CNE	*	*	*	-	-
CTA	*	*	*	-	-
DAR	*	*	*	-	*
DER	*	*	*	-	-
DYW	*	*	*	-	-
EMU	*	*	*	-	-
ESP	*	*	*	-	-
ETA	*	*	*	-	-
EUC	*	*	*	-	-
GER	*	*	*	-	-
GFN	*	*	*	-	-
GIL	*	*	*	-	-
GLE	*	*	*	*	-
GOV	-	-	-	-	*
GRN	*	*	*	-	-
HAL	*	*	*	-	-
HED	*	*	*	-	-
ISA	*	*	*	-	-
KIW	*	*	*	-	-
LAV	*	*	*	-	-
LRM	*	*	*	-	-
MEK	*	*	*	-	-
MEN	*	*	*	-	-
MOR	*	*	*	-	-
MTD	*	*	*	-	-
MYB	*	*	*	-	-
NEW	*	*	*	-	-
POL	*	*	*	-	-

Station (%)	%1.FIL	%2.FIL	%3.FIL	%4.FIL	%5.FIL
PTA	*	*	*	-	-
QUI	*	*	*	*	-
ROB	*	*	-	-	-
ROM	*	*	*	*	-
SOX	*	*	*	-	-
TCK	*	*	*	-	-
TEL	*	*	*	-	-
TIB	*	*	*	-	-
TOO	*	*	*	-	-
TWO	*	*	*	-	-
VER	*	*	*	-	-
WAN	*	*	*	-	-
WEI	*	*	*	-	-
WTN	*	*	*	*	-
WYN	*	*	*	-	-
ZAN	*	*	*	-	-

Table 4. Details of Files in the Marine Magnetic Data Set

Tape	File	Survey	Days	Year	Epoch	Records	Series
1	1	3	281 - 369	1967	1967.89	9041	CMS
1	2	4	268 - 342	1968	1968.84	9920	CMS
1	3	5	247 - 341	1970	1970.81	98100	CMS
1	4	10	255 - 263	1970	1970.71	11453	CMS
1	5	11	11 - 42	1971	1971.07	20712	CMS
1	6	12	95 - 174	1971	1971.37	81627	CMS
2	1	12	174 - 178	1971	1971.48	4705	CMS
2	2	13	183 - 279	1971	1971.63	84424	CMS
2	3	14	286 - 356	1971	1971.88	68060	CMS
3	1	15	363 - 448	1971	1972.11	56888	CMS
3	2	16	90 - 176	1972	1972.36	85884	CMS
3	3	17	187 - 270	1972	1972.62	81160	CMS
4	1	18	270 - 343	1972	1972.84	71411	CMS
4	2	19	349 - 371	1972	1972.99	28037	CMS
5	1	1034	321 - 350	1975	1975.92	41863	Vema
5	2	1035	355 - 381	1975	1976.01	38407	Vema
5	3	1036	20 - 49	1976	1976.10	41851	Vema
5	4	1037	54 - 78	1976	1976.18	35269	Vema
6	1	1038	78 - 106	1976	1976.25	41035	Vema
6	2	1039	167 - 200	1976	1976.50	46981	Vema
6	3	1042	355 - 382	1976	1977.01	39295	Vema
7	1	1043	21 - 48	1977	1977.09	39631	Vema
8	1	46	34 - 42	1985	1985.10	-	Rig S.
8	2	47	66 - 119	1985	1985.25	-	Rig S.
8	3	48	165 - 191	1985	1985.49	-	Rig S
9	1	50	263 - 290	1985	1985.76	-	Rig S.
9	2	51	315 - 343	1985	1985.90	-	Rig S.
9	3	53	10 - 39	1986	1986.07	-	Rig S.
9	4	55	70 - 100	1986	1986.23	-	Rig S.

Tape	File	Survey	Days	Year	Epoch	Records	Series
10	1	56	100 - 127	1986	1986.31	-	Rig S.
10	2	57	184 - 211	1986	1986.54	-	Rig S.
10	3	65	287 - 313	1986	1986.82	-	Rig S.
11	1	66	316 - 340	1986	1986.90	-	Rig S.
11	2	67	14 - 41	1987	1987.08	-	Rig S.
11	3	68	79 - 104	1987	1987.25	-	Rig S.
11	4	71	128 - 144	1987	1987.37	-	Rig S.
11	5	77	47 - 64	1988	1988.15	-	Rig S.
12	1	75	246 - 278	1987	1987.72	-	Rig S.
12	2	76	303 - 327	1987	1987.86	-	Rig S.
12	3	78	84 - 108	1988	1988.26	-	Rig S.
12	4	81	259 - 283	1988	1988.74	-	Rig S.