

NOAA Technical Memorandum NOS NGS 28



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STORAGE OF SATELLITE ALTIMETER DATA

Rockville, Md.  
December 1980

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**U.S. DEPARTMENT OF  
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Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys. Federal Geodetic Control Committee, Department of Commerce, NOAA, NOS, 1974, reprinted June 1980, 12 pp. (A single free copy can be obtained from the National Geodetic Survey, OA/C18x2, NOS/NOAA, Rockville, MD 20852. Multiple copies may be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.)

Specifications To Support Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys. Federal Geodetic Control Committee, Department of Commerce, NOAA, NOS, 1975, revised June 1980. (A single free copy can be obtained from the National Geodetic Survey, OA/C18x2, NOS/NOAA, Rockville, MD 20852. Multiple copies may be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.)

Proceedings of the Second International Symposium on Problems Related to the Redefinition of North American Geodetic Networks. Sponsored by U.S. Department of Commerce; Department of Energy, Mines and Resources (Canada); and Danish Geodetic Institute; Arlington, Va., 1978, 658 pp (GPO #003-017-0426-1).

### NOAA Technical Memorandums, NOS/NGS subseries

- NOS NGS-1 Leffler, R. J., Use of climatological and meteorological data in the planning and execution of National Geodetic Survey field operations, 1975, 30 pp (PB249677).
- NOS NGS-2 Spencer, J. F., Jr., Final report on responses to geodetic data questionnaire, 1976, 39 pp (PB254641).
- NOS NGS-3 Whiting, M. C., and Pope, A. J., Adjustment of geodetic field data using a sequential method, 1976, 11 pp (PB253967).
- NOS NGS-4 Snay, R. A., Reducing the profile of sparse symmetric matrices, 1976, 24 pp (PB258476).
- NOS NGS-5 Dracup, Joseph F., National Geodetic Survey data: availability, explanation, and application, Revised 1979, 45 pp (PB80 118615).

(Continued at end of publication)

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DEPARTMENT OF COMMERCE  
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NATIONAL OCEANIC AND  
ATMOSPHERIC ADMINISTRATION  
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# STORAGE OF SATELLITE ALTIMETER DATA

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ABSTRACT. Software has been developed for storing any amount of satellite altimeter data on tape and disk devices with the ability to select parts of existing data sets and form new ones as required. The same data set structure is employed for storage and applications. Users are encouraged to run the maintenance software to tailor altimeter data sets to their specific needs. These features were designed to provide sufficient data manipulation capability for research without the extensive developmental effort needed for a true data base. The system is written in IBM FORTRAN. Instructions for the user are not provided because they are subject to change.

## INTRODUCTION

The placement of altimeters on Earth-orbiting satellites has caused large amounts of observational data to be sent to NOAA's National Ocean Survey, Geodetic Research and Development Laboratory (GRDL). Currently, several million data points from the Seasat and Geos-3 altimeters have been received, and future satellite altimeter measurements are expected to outnumber these. Consequently, a method for storing and sifting through altimeter data is necessary.

## DATA STORAGE

The most acceptable data storage concept is a data base. However, the goal of having one base containing all altimeter observations carries a high price in developmental effort which cannot be justified in light of the small user community envisioned. Thus, the data are stored in pieces. The software designed for the altimeter pieces, or data sets, was predicated upon a few obvious needs. The data had to be arranged chronologically, conveniently summarized, and easily divisible into subsets to meet arbitrary research requirements. The software, initially developed for Seasat measurements, is satellite specific. When new Geos-3 releases of altimeter data arrived, the programs were slightly modified to handle the different information. Therefore, each satellite has its own software, but the storage concept is shared.

Given the restrictions of available computer resources, 6250 bit-per-inch magnetic tapes were chosen as the primary means of data storage. To increase the carrying capacity of these high density tapes, large block sizes and binary data records were used. To provide flexibility and facilitate the storage of data chronologically, direct access disks were selected as secondary storage devices.

The structure of the altimeter data records is designed for near maximal compression without sacrificing simplicity. Each binary integer field is either 32, 16, or occasionally 8 bits long. In addition to avoiding the space wastage of floating point numbers, integer usage circumvents potential problems of interpretation of the data set on non-IBM equipment; Seasat data sets have been read without any prior modification on a UNIVAC 1100/42. Tables 1 and 2 show the Geos-3 and Seasat altimeter record content. For an explanation of their contents, see NASA Reference Publication 1066 (Stanley and Dwyer 1980) and Seasat GDR Users Handbook (Ronai 1980).

Table 1.--Geos-3 altimeter data records. Each record consists of 44 bytes composed of 4-byte and 2-byte integer fields.

Field	Bytes	Units	Contents
1	1-4	days	Modified Julian date of observation.
2	5-8	seconds	Time from beginning of day.
3	9-12	$10^{-6}$ microseconds	Continuation of time to the microsecond.
4	13-16	$10^{-6}$ microdegrees	Geodetic latitude.
5	17-20	$10^{-6}$ microdegrees	Geodetic east longitude.
6	21-24	millimeters	Sea surface height above ellipsoid.
7	25-26	centimeters	H 1/3, significant wave height.
8	27-28	$10^{-3}$	Surface reflectivity ( $\sigma_0$ )
9	29-30	cm/sec	Wind speed.
10	31-32	$10^{-2}$	Swell coefficient ( $\gamma$ ).
11	33-34	$10^{-3}$ microdegrees	Pointing angle.
12	35-36	$10^{-2}$	Reflectivity coefficient.
13	37-38	--	Index of ice probability.
14	39-40	--	Revolution number of orbit.
15	41-42	--	Unique number.
16	43-44	--	Status bits (1,2,3,...,16).

Data records are organized into passes that consist of a number of observations closely spaced in time. One header record per pass is required to identify the pass, locate it geographically, store the record count, and provide a linked list structure used when reading direct access disk sets. Disk data sets have one additional overall header record which contains pointers to the first pass of the linked list and to the next available record for the addition of new observations. Data may be added to disk sets only, because the linked structure allows for the easy preservation of chronology.

Incoming altimeter observations are read by format specific routines which store groups or passes of data on disk sets. When the disk capacity is reached, the contents are moved to tape by the satellite's unique maintenance program. Whenever possible, a pre-existing tape and the disk are merged onto a second tape in a manner that preserves the time order. By these means the satellite's altimeter data sets are formed.

Table 2.--Seasat altimeter data records. Each record consists of 80 bytes composed of 4-byte and 2-byte integer fields, and 1-byte logical fields.

Field	Bytes	Units	Contents
1	1-4	seconds	Time from beginning of 1978.
2	5-8	microseconds	Continuation of time to the microsecond.
3	9-12	microdegrees	Geodetic nadir latitude.
4	13-16	microdegrees	Geodetic nadir east longitude.
5	17-20	millimeters	Raw altimeter measurement, h.
6	21-24	millimeters	Computed spacecraft height above reference ellipsoid.
7	25-28	millimeters	Surface height above reference ellipsoid, based on altimeter measurement.
8	29-32	millimeters	Calculated geoid height above reference ellipsoid.
9	33-34	millimeters	Barotropic corrections to height measurement.
10	35-36	millimeters	Solid Earth tide correction.
11	37-38	millimeters	Ocean tide height correction.
12	39-40	millimeters	Steric anomaly correction.
13	41-42	millimeters	Ionospheric correction.
14	43-44	millimeters	FNWC wet tropospheric correction.
15	45-46	millimeters	SMMR wet tropospheric correction.
16	47-48	millimeters	Dry tropospheric correction.
17	49-50	--	Spare 2 byte field.
18	51-52	millimeters	Net instrument correction.
19	53-54	millimeters	Residual RMS to straight line fit for compressed 10 per second data.
20	55-56	centimeters	H 1/3, significant wave height.
21	57-58	centimeters	Net instrument correction to H 1/3.
22	59-60	centimeters	H 1/3 sigma of data scatter.
23	61-62	10 <sup>-2</sup> decibels	Backscatter coefficient ( $\sigma_0$ )
24	63-64	cm/sec	Wind speed.
25	65-66	10 <sup>-2</sup> decibels	Automatic gain control (AGC).
26	67-68	10 <sup>-2</sup> decibels	Sigma for AGC.
27	69-70	10 <sup>15</sup> E/m <sup>2</sup>	Electron (E) content of atmosphere.
28	71-72	millibars	Sea surface atmospheric pressure.
29	73-74	millibars	Sea surface atmospheric water vapor pressure.
30	75-76	10 <sup>-2</sup> deg K	Sea surface atmospheric temperature.
31	77-78	--	Orbit revolution number.
32	79	--	8 flags stored in bits 87654321 as follows: Bit 1 0 if sea and 1 if land. Bit 2 Tilt angle, 1 if unavailable and 0 if available. Bit 3 Tilt angle, 1 if out of limits and 0 if not. Bit 4 h blunder, 1 if on and 0 if off. Bit 5 H 1/3 blunder, 1 if on and 0 if off. Bit 6 $\sigma$ AGC, 1 if out of limits and 0 if not. Bit 7 $\sigma$ H 1/3, 1 if out of limits and 0 if not. Bit 8 $\sigma$ h, 1 if out of limits and 0 if not.
33	80	--	Track mode status (frames/average).

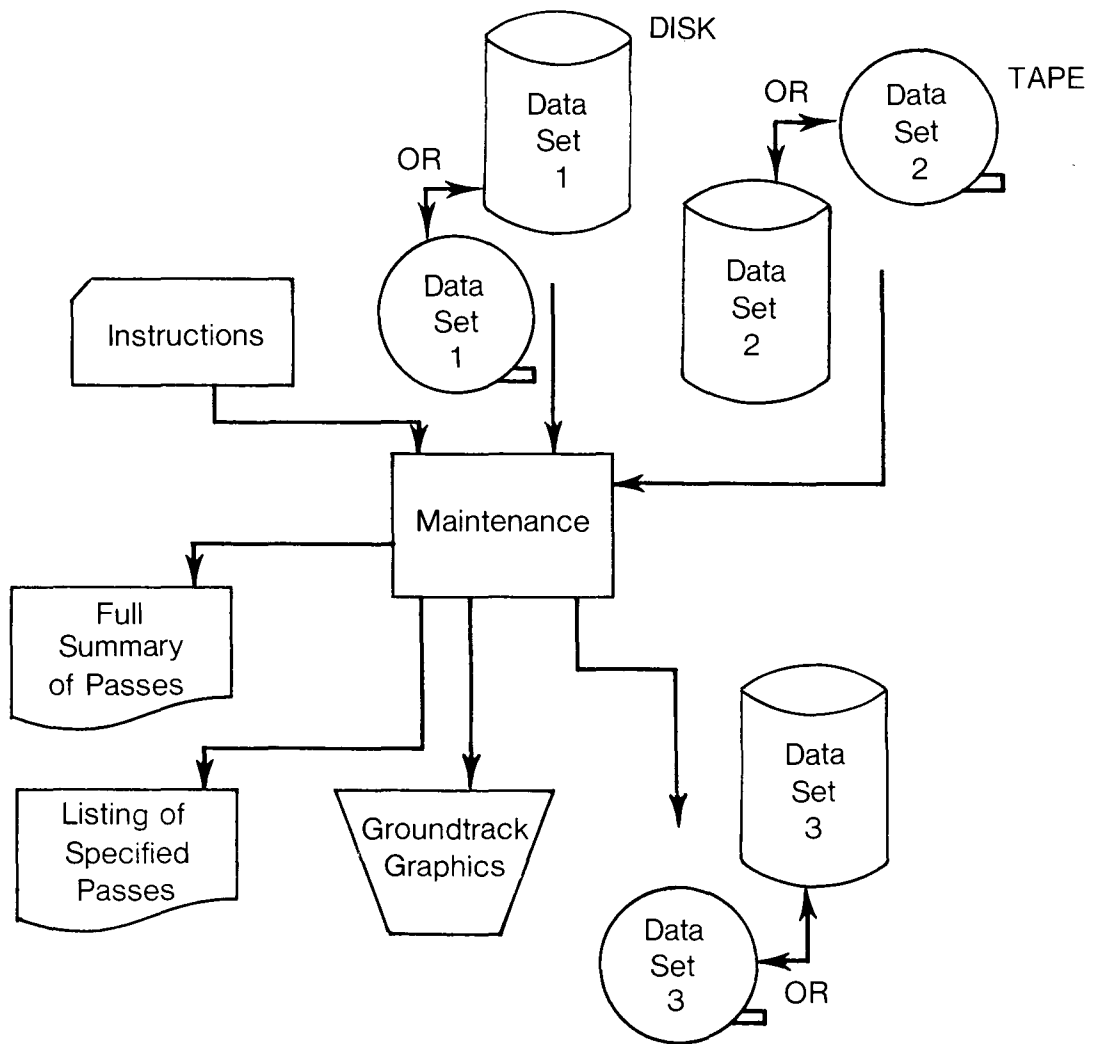


Figure 1.--Maintenance software capability.



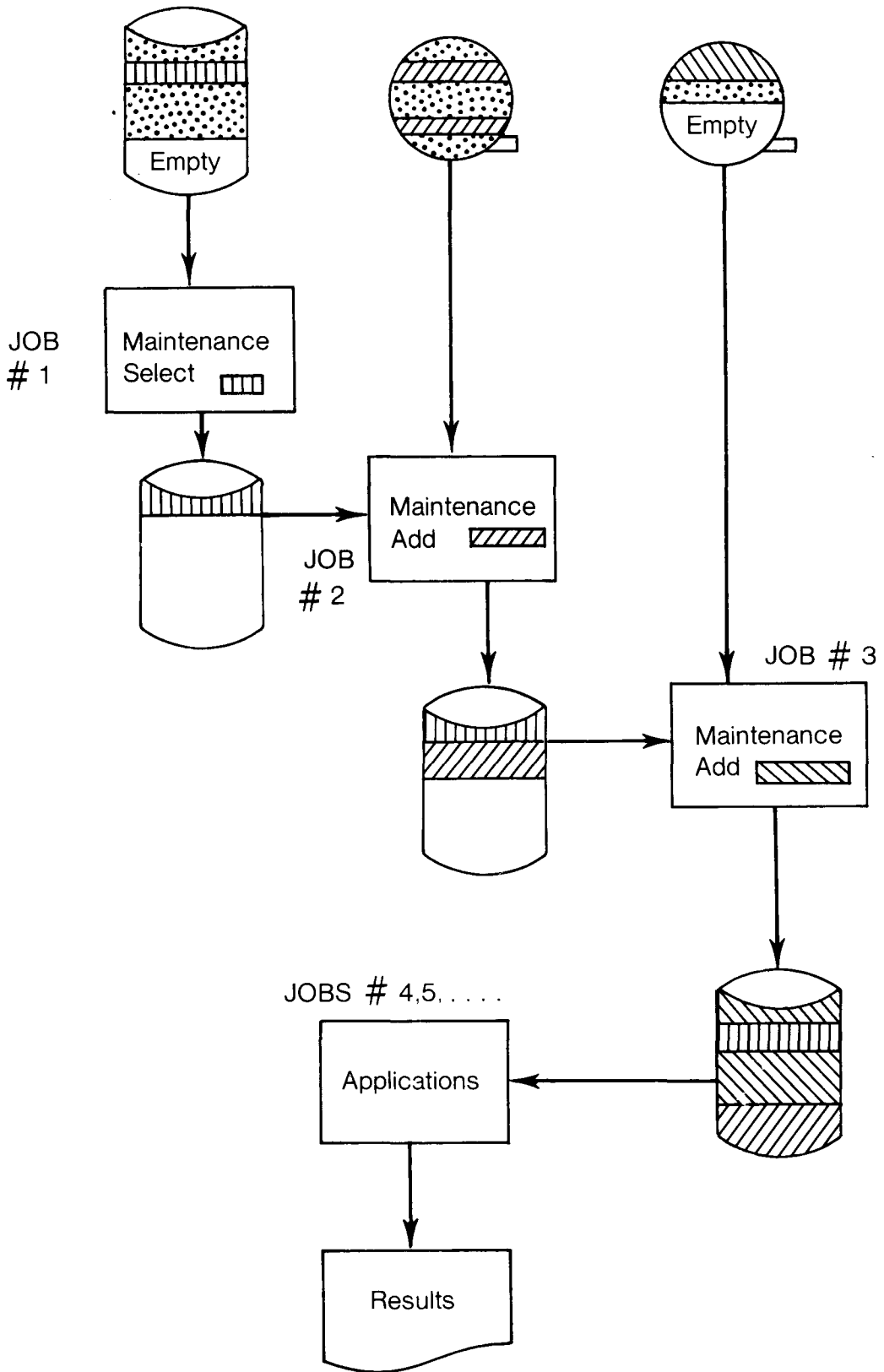


Figure 2.--Selective merging of data.

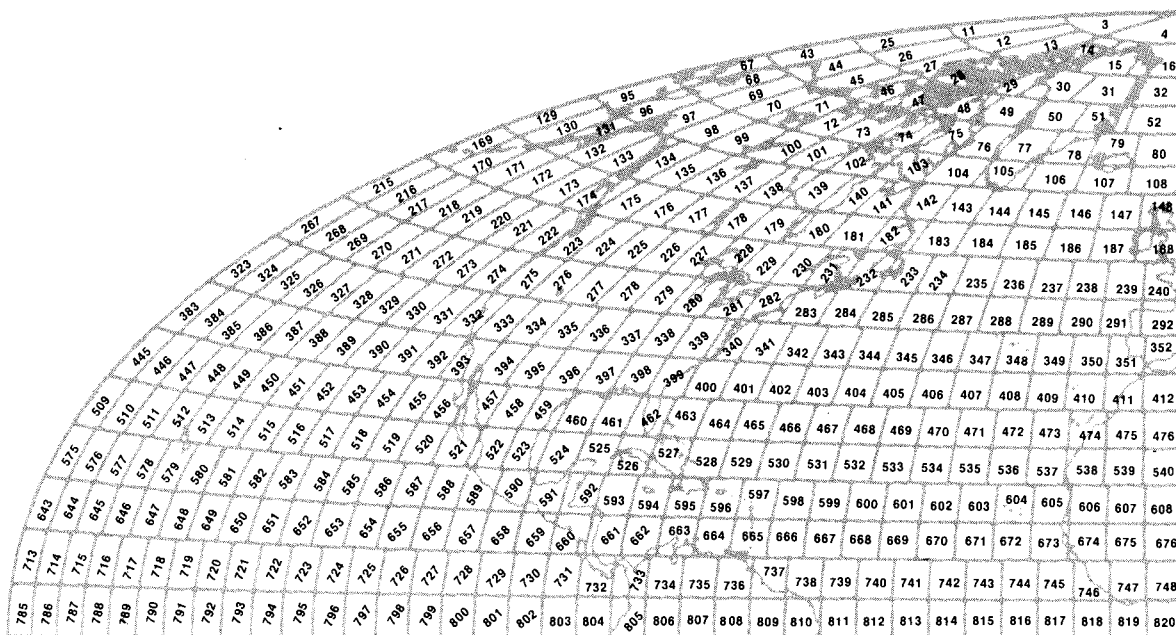


Figure 3a.--Equal-area blocks with index numbers, NW quadrant.

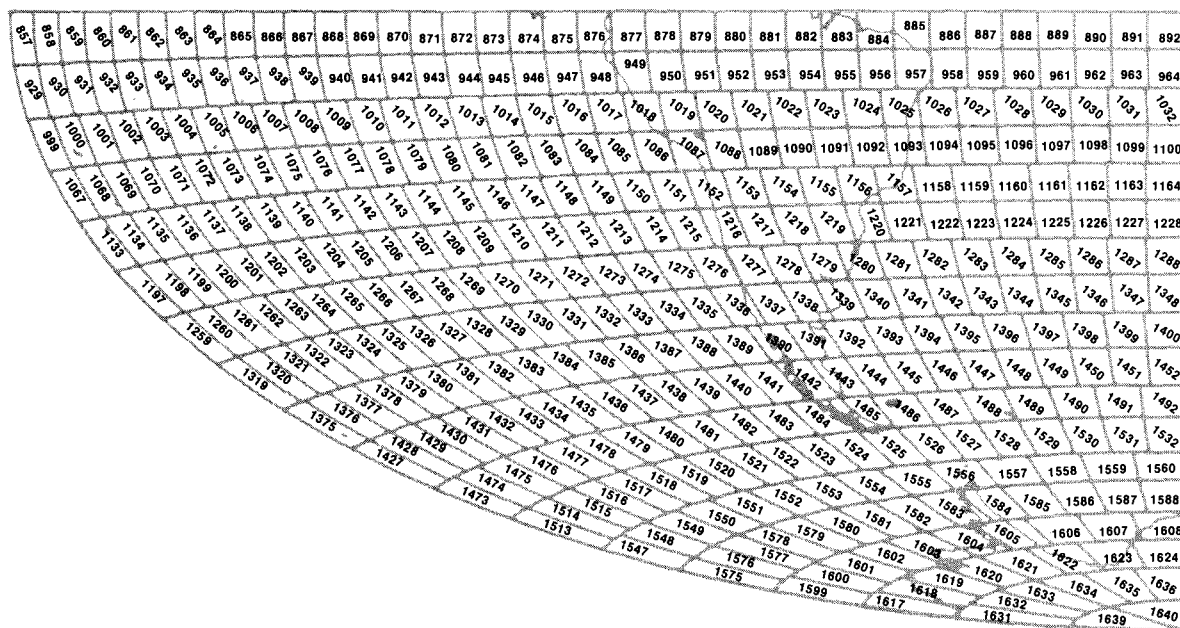


Figure 3b.--Equal-area blocks with index numbers, SW quadrant.

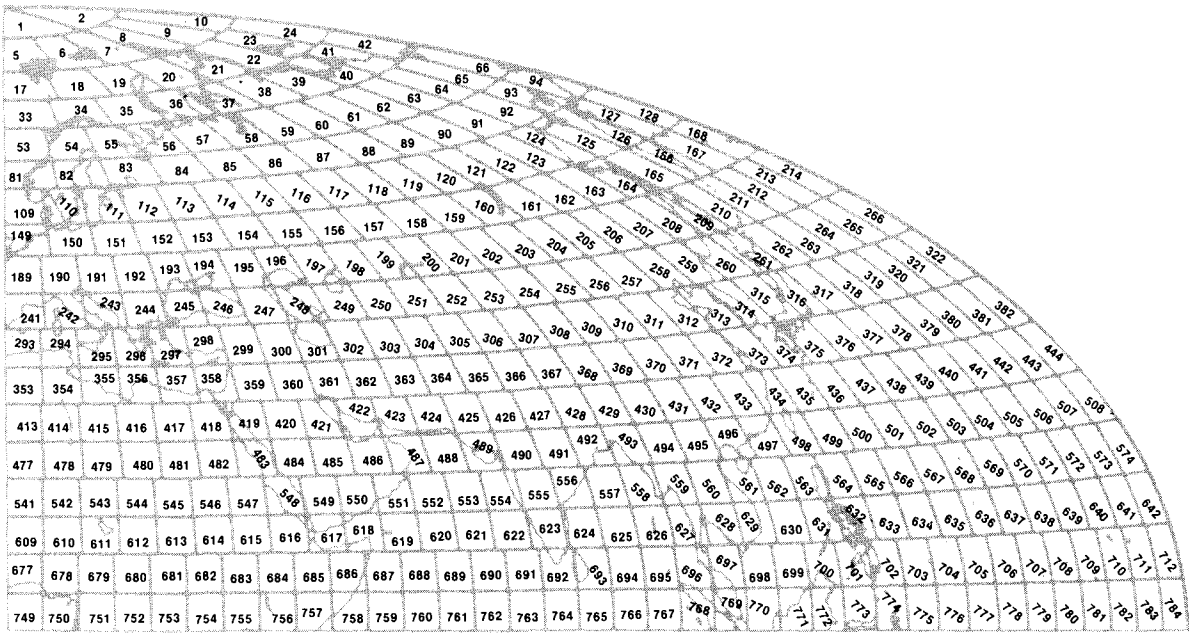


Figure 3c.--Equal-area blocks with index numbers, NE quadrant.

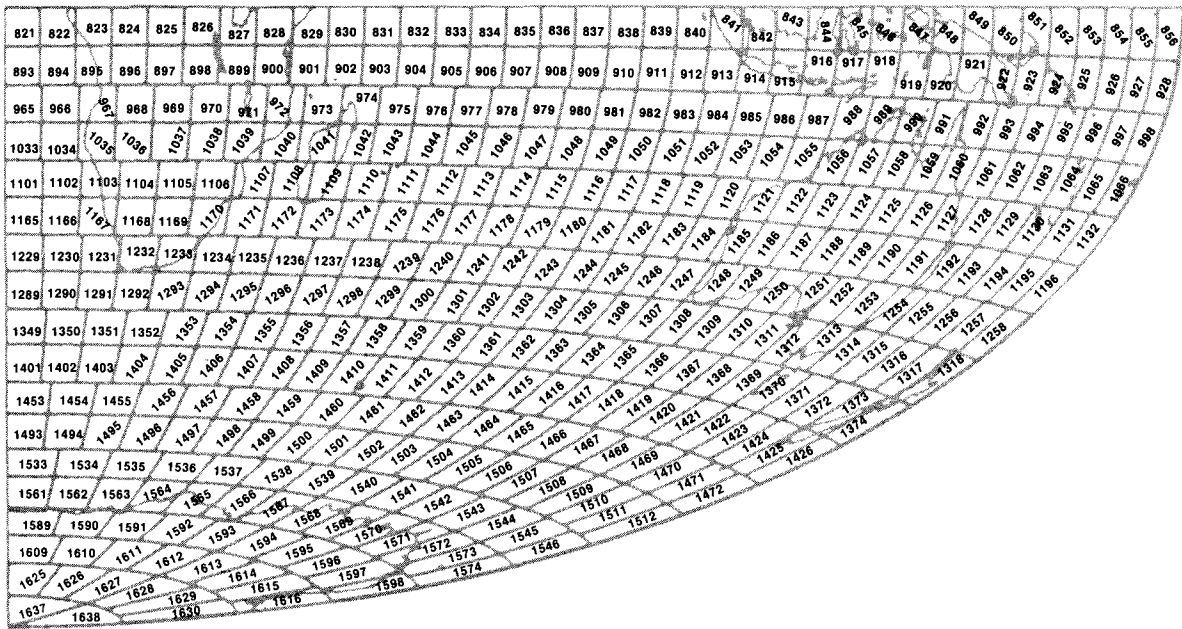


Figure 3d.--Equal-area blocks with index numbers, SE quadrant.

SEASAT DISK SUMMARY

ID	PASS	(FIRST)	DATE & TIME	LAT	E LON	BLOCK	(LAST)	DATE & TIME	LAT	E LON	BLOCK	NO. MEAS.
2081899	61	78 728	433 28.6091	-2.5466	31.6162	827	78 728	639 7.8511	-0.3003	30.7233	827	21
2081914	42	78 728	435 36.5449	4.7455	28.7178	754	78 728	639 14.5568	17.1177	23.6304	545	130
2081949	43	78 728	440 36.1458	21.7241	21.6026	480	78 728	447 48.8865	45.6143	7.9027	190	357
2082002	44	78 728	448 13.4367	46.9216	6.8594	189	78 728	451 34.9838	57.2486	356.0621	148	126
2082027	45	78 728	451 50.5176	58.0030	355.0067	148	78 728	454 4.1963	64.0687	343.8732	107	130
2082044	46	78 728	454 24.2873	64.9211	341.8079	79	78 728	500 10.1466	71.8695	285.4768	48	267
2082088	47	78 728	500 41.9982	71.5072	279.4426	48	78 728	507 19.3100	56.9965	232.2465	134	186
2082137	48	78 728	507 41.3411	55.9066	230.8308	134	78 728	508 0.8621	54.9261	229.6333	174	9
2082143	49	78 728	508 38.5887	53.0163	227.4796	174	78 728	544 29.0222	-64.5419	150.2480	1544	2190
2082392	50	78 728	544 30.0023	-64.5825	150.1468	1572	78 728	545 35.2246	-67.1217	142.7146	1572	84
2082405	51	78 728	546 15.5536	-68.5032	137.3667	1571	78 728	552 38.6547	-69.2200	69.6033	1566	295
2082451	52	78 728	552 57.5697	-68.6418	66.8524	1566	78 728	604 42.8130	-34.2923	20.8016	1232	706
2082516	53	78 728	605 11.9494	-32.6774	19.9109	1232	78 728	605 23.9750	-32.0109	19.5522	1232	8
2082542	54	78 728	605 58.6488	-30.0806	18.5399	1232	78 728	606 21.9939	-28.7793	17.8781	1168	13
2082551	55	78 728	607 23.3450	-25.3448	16.2008	1167	78 728	607 23.3450	-25.3448	16.2008	1167	1
2082556	56	78 728	608 3.6250	-23.0818	15.1430	1103	78 728	608 7.5452	-22.8612	15.0417	1103	3
2082561	57	78 728	608 48.8052	-20.5369	13.9912	1103	78 728	608 49.6873	-20.4871	13.9690	1103	2
2082564	58	78 728	609 14.0905	-19.1099	13.3606	1035	78 728	617 14.1675	8.1544	2.2675	677	442
2082622	59	78 728	617 32.9355	9.2207	1.8358	677	78 728	623 39.0818	29.8704	352.6118	475	211
2082648	60	78 728	624 9.8553	31.5840	351.7189	411	78 728	634 39.4388	63.9869	319.0278	105	619
2082743	61	78 728	635 3.5680	64.9864	316.5518	77	78 728	645 13.6285	64.6755	220.6327	98	345
2082817	62	78 728	645 39.9419	63.5576	218.0280	97	78 728	645 58.3678	62.5544	216.3210	97	7
2082822	63	78 728	646 22.8200	61.4576	214.1867	97	78 728	723 31.2555	-60.3281	133.7784	1507	2223
2083080	64	78 728	723 32.2355	-60.3737	133.7010	1543	78 728	726 9.3864	-66.9963	118.0596	1570	159
2083104	65	78 728	726 54.7790	-68.5549	112.0556	1569	78 728	731 2.5681	-71.8599	67.6856	1592	159
2083136	66	78 728	731 32.0675	-71.5257	62.1002	1592	78 728	807 23.6671	40.1880	321.5982	346	2124
2083385	67	78 728	807 24.6472	40.2414	321.5633	287	78 728	824 5.6203	68.4250	208.2519	346	815
2083305	68	78 728	824 45.7533	67.6401	202.9595	68	78 728	847 23.3661	-5.5210	145.7092	922	1331
2083666	69	78 728	847 52.9446	-7.5097	145.0276	922	78 728	906 58.8930	-66.6964	93.9753	1568	1020
2083798	70	78 728	906 58.0039	-67.3921	91.5980	1568	78 728	1014 30.4576	40.3107	141.7208	261	80
2083818	71	78 728	909 45.7883	-71.6278	64.8383	1592	78 728	910 0.0970	-71.7900	62.1264	1592	6
2083822	72	78 728	910 24.5493	-71.9808	57.4006	1592	78 728	916 18.7390	-63.9201	1.6930	1533	310
2083871	73	78 728	917 29.1555	-60.8031	355.3972	1560	78 728	954 32.8868	60.3462	276.1072	139	2013
2084129	74	78 728	954 33.8468	-60.3917	276.0298	102	78 728	1005 8.4485	67.5767	179.7844	66	531
2084205	75	78 728	1005 27.7865	66.8844	177.3501	66	78 728	1014 30.4576	40.3107	141.7208	261	402
2084269	76	78 728	1014 46.5794	39.4279	141.1499	316	78 728	1014 49.5195	39.2667	141.0472	316	2
2084272	77	78 728	1015 9.5126	38.1682	140.3593	316	78 728	1015 43.6673	36.2842	139.2248	316	10
2084280	78	78 728	1016 18.5080	34.3535	138.1154	376	78 728	1027 16.8559	-2.9914	121.6289	845	623
2084358	79	78 728	1027 36.0159	-4.0870	121.1933	845	78 728	1047 45.1514	-67.7236	65.2963	1566	1218
2084502	80	78 728	1048 20.1882	-68.8719	60.4602	1565	78 728	1048 20.7272	-68.8885	60.3821	1565	2

TOTAL NUMBER OF MEASUREMENTS IS 41183

Figure 4.--Example of Seasat summary output.

SEASAT TAPE DUMP OF THE FIRST 15 RECORDS FOR PASS ID 2082668  
 (8 4-BYTE, 23 2-BYTE, AND 2 1-BYTE FIELDS ON 2 LINES)

17994249	0	855320	31583979	351718856	801167638	801597772	426533	48561	112	154	98	182	0	-36	-169	6
0	-2301	0	6102	818	1031	-34	863	2786	112	154	1014	17	30029	447	17	6
17994253	0	383498	31780115	351614714	801319255	801632440	309415	48776	87	154	98	180	0	-36	-177	10
0	-2302	0	6280	691	1730	-62	844	2773	87	154	1014	18	29972	447	17	10
17994254	0	20553	31815522	351595870	801375089	801638707	259726	48811	1	154	98	180	0	-36	-178	3
0	-2302	0	6403	1	1999	7	592	2519	1	154	1014	18	29962	447	1	3
17994267	0	594223	32569400	351191307	801585774	801772789	183307	49314	7	152	97	171	0	-36	-208	10
0	-2304	0	6251	443	905	-18	33	1968	7	152	1015	21	29747	447	17	10
17994268	0	574265	32623790	351161959	801612179	801782507	166712	49335	25	152	97	170	0	-36	-210	10
0	-2304	0	6161	262	1165	-77	29	1965	25	152	1015	21	29732	447	17	10
17994269	0	527092	32676665	351133319	801633020	801791960	155330	49353	30	152	97	169	0	-36	-212	9
0	-2304	0	6157	189	1828	-43	266	2199	30	152	1015	21	29717	447	1	9
17994270	0	191351	32713523	351113336	801648999	801798553	143712	49365	1	152	97	169	0	-36	-214	3
0	-2304	0	6390	80	1786	-54	285	2218	1	152	1015	21	29707	447	1	3
17994278	0	668768	33183687	350857052	801841397	801882872	37882	49463	1	151	96	161	0	-36	-225	6
0	-2305	0	6154	61	493	-16	1343	3284	1	151	1016	23	29600	447	0	6
17994279	0	648826	33238014	350827272	801851735	801892641	37362	49467	22	151	96	160	0	-36	-225	10
0	-2305	0	6104	52	230	-37	1288	3229	22	151	1016	22	29595	447	0	10
17994280	0	628874	33292335	350797460	801861935	801902413	36978	49469	27	151	96	159	0	-33	-225	10
0	-2305	0	6060	60	157	-49	1283	3223	27	151	1016	22	29589	447	0	10
17994281	0	608928	33346650	350767617	801872267	801912190	36458	49469	25	151	96	158	0	-33	-225	10
0	-2305	0	6025	68	141	-53	1280	3220	25	151	1016	22	29584	447	0	10
17994282	0	586975	33400959	350737742	801882685	801921971	35762	49468	28	151	96	158	0	-33	-224	10
0	-2305	0	6084	70	134	-55	1283	3224	28	151	1016	22	29579	447	0	10
17994283	0	569011	33455262	350707835	801893047	801931755	35231	49466	34	151	96	157	0	-33	-224	10
0	-2305	0	6037	33	123	-58	1276	3216	34	151	1016	22	29573	447	0	10
17994284	0	549071	33509560	350677896	801903412	801941543	34648	49462	30	151	96	156	0	-33	-224	10
0	-2305	0	6042	75	132	-56	1285	3226	30	151	1016	22	29568	447	0	10
17994285	0	529118	33563851	350647924	801913931	801951335	33912	49458	27	150	96	155	0	-33	-224	10
0	-2305	0	6051	51	125	-58	1280	3220	27	150	1016	22	29563	447	0	10

Figure 5.--Dump of Seasat pass, identification no. 2082668

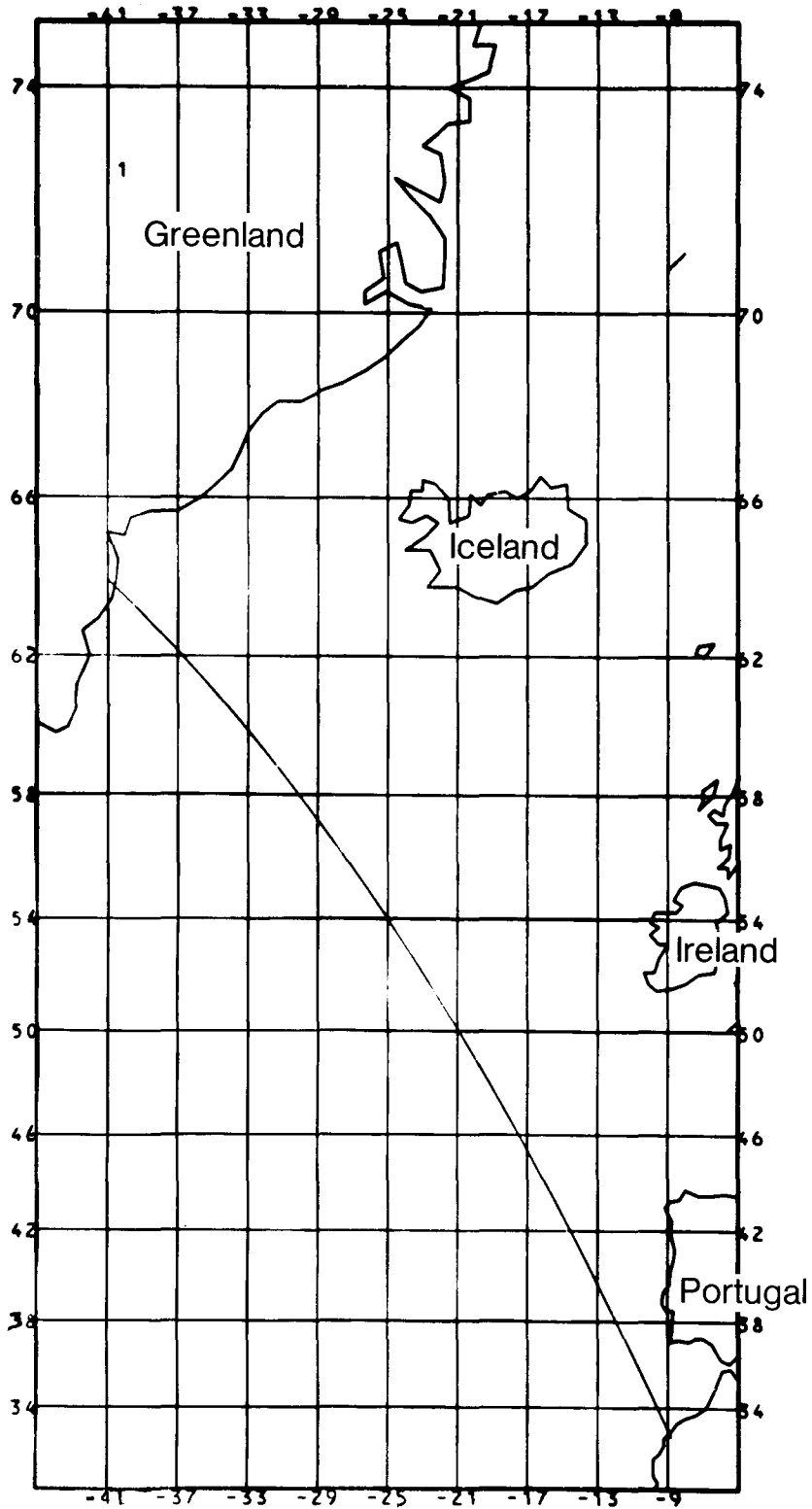


Figure 6.--Plot of Seasat pass, identification no. 2082668.

## DATA ACCESS

The applications user is given two tools for accessing the records of interest. First, the job control language and instructions needed to run the maintenance software on the data sets are provided in order to form the subset of desired passes. Second, a reading routine is supplied for easy access to either tape or disk records. Figure 1 shows the basic options of the maintenance software. To implement the program, input instructions and a tape (or disk set) are necessary; a second input data set is optional. Output may consist of an entire summary by satellite pass, a dump of records for specified passes, a plot of the satellite groundtracks of certain passes against a map of the continents for all or part of the globe, and/or a new data set composed of any subset in data set 1 merged with all of data set 2.

Of the various maintenance options, selective merging is the most important and hardest to envision. Figure 2 shows how several shaded data passes of interest could be gathered into one set for convenient applicational access. The indicated altimeter passes may be defined by: (1) the order in which they appear on the set, (2) quantity of data, (3) traversal of equal-area 5° square blocks (Morrison 1977) (fig. 3), or (4) traversal of user-defined blocks. The first three methods are equally fast; the fourth is slower because individual data records are interrogated.

Figures 4, 5, and 6 show examples of the summary, dump, and plot outputs. Table 1 must be used with the dump example to interpret the field contents. Plotting is a slow option because each record of all selected passes must be examined to see if it can or cannot be plotted within the confines of the graph. Users may obtain complete instructions for both the maintenance and reading programs from the Geodetic Research and Development Laboratory. They are not provided here because these features are subject to changes as requested by the users.

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