NOAA Technical Memorandum NOS NGS-49

THE NOAA GEOSAT GEOPHYSICAL DATA RECORDS:

SUMMARY OF THE SECOND YEAR OF THE EXACT REPEAT MISSION

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U.S. DEPARTMENT OF COMMERCE / National Oceanic and Atmospheric Administration / National Ocean Service / Office of Charting and Geodetic Services

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For sale by the National Geodetic Survey, NOAA,
Rockville, MD 20852

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National Ocean Service, NOAA
Rockville, MD 20852

ABSTRACT. The GEOSAT radar altimeter has provided more than 4 years of global observations of sea level, wind speed, and significant wave height since its launch in March 1985. Although sea level observations made by GEOSAT during the first 18 months of the mission are classified, data collected after November 8, 1986, are publicly available through NOAA. This portion of the GEOSAT mission is known as the Exact Repeat Mission (ERM) because the ground track repeats within approximately 1 km every 17 days.

The National Ocean Service of NOAA, in cooperation with the U.S. Navy and the Johns Hopkins University Applied Physics Laboratory (JHU APL), produces the GEOSAT Geophysical Data Records (GDRs). For background or ordering information, see the "GEOSAT Altimeter Geophysical Data Record User Handbook" (Cheney et al., 1987), which describes the data flow and NOAA processing. In this report we summarize GEOSAT ocean data collected during the second year of the ERM, November 1987-88. (A secondary set of ice/land GDRs is also produced, but will not be discussed in this summary.)

GLOBAL DATA DISTRIBUTION

Geophysical Data Records are produced by the Geodetic Research and Development Laboratory in Rockville, Maryland, by combining Sensor Data Records (SDRs), the satellite ephemeris, corrections for solid and fluid tides, and path length effects due to the troposphere and ionosphere. Figure 1 shows the total number of 1-second GDR records for each day of the second year of the ERM. No data were collected during a 1-week period in November 1987 (days 323 to 329) due to satellite attitude excursions associated with operation of the onboard momentum wheels. A second period of extreme data loss occurred during 8 days in August 1988 (days 231 to 238) when one of GEOSAT's batteries was reconditioned. Otherwise, the nominal number of records per day was approximately 50,000 during the first half of the year, declining to 45,000 or less during the latter half. As during the previous year, there is a tendency for the number of observations to be high in boreal winter and low in summer. However, superimposed on the seasonal variation is a low-frequency trend of data loss that may be related to increased drag and solar radiation pressure as the 1990 solar maximum approaches.

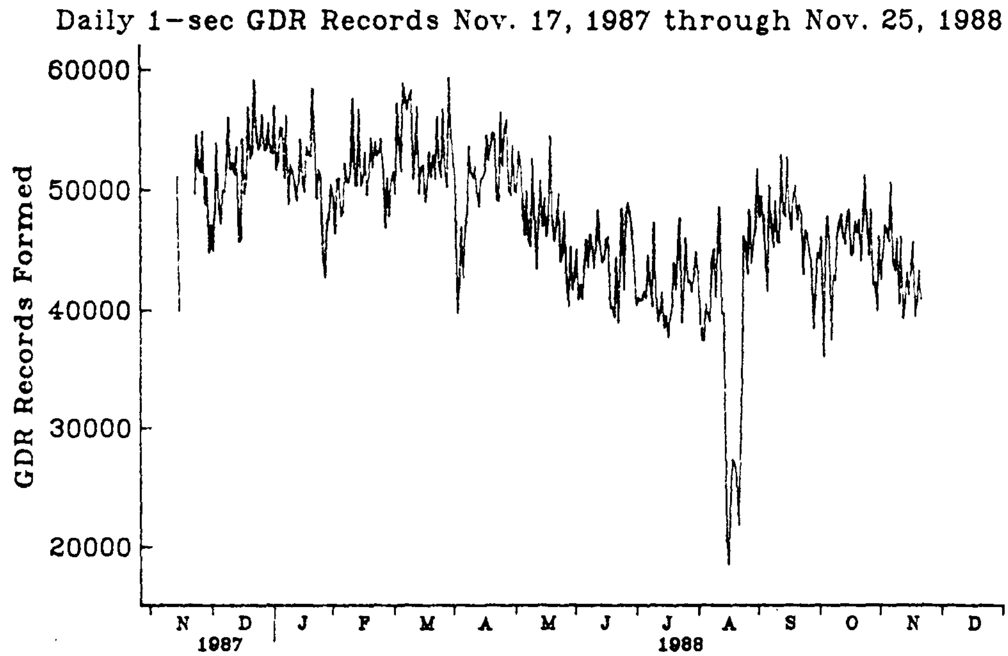

Figure 1.--Number of 1-second GDR records for each day of the ERM second year.

The sequence of global groundtrack plots for each 17-day repeat cycle in the second year (see appendix) shows the changing areal coverage during the second year. In addition to the aforementioned gaps in global data, migratory regional gaps occur similar to those during the first year.

GEOSAT BURN HISTORY

To maintain groundtrack colinearity, GEOSAT Mission Operations at JHU APL fired the thrusters onboard GEOSAT during the times listed in table 1. All times are Universal Time Coordinated (UTC). The thruster vector identification (TV ID) is in relation to the direction of flight. A "+" burn is an increase in velocity in the same direction as the flight path vector. Burns are paired to reduce attitude disturbances caused by thruster misalignment with respect to the spacecraft center of mass. The offset is less than 1 cm.

Table 1--Times at which GEOSAT thrusters were fired

Thruster ID Vector	Time on	Time off	Duration (seconds)
+	86-341/20:18:07	86-341/20:18:57	50
+	86-341/20:48:20	86-341/20:49:07	47
+	87-007/22:40:51	87-007/22:41:48	57
+	87-007/23:11:00	87-007/23:11:57	57
+	87-051/10:21:18	87-051/10:21:59	41
+	87-051/10:51:20	87-051/10:52:10	50
+	87-123/17:13:22	87-123/17:14:36	74
+	87-123/17:43:41	87-123/17:44:46	64
+	87-156/18:29:56	87-156/18:31:10	74
+	87-156/19:00:13	87-156/19:01:19	66
-	87-173/19:10:00	87-173/19:10:08	8
-	87-173/19:40:00	87-173/19:40:16	16
+	87-207/12:30:01	87-207/12:30:59	58
+	87-207/13:00:29	87-207/13:01:59	50
+	87-237/15:17:08	87-237/15:17:33	25
+	87-237/15:47:1[illegible]	87-237/15:47:41	25
+	87-267/16:14:01	87-267/16:14:44	41
+	87-267/16:43:59	87-267/16:44:40	41
+	87-297/19:08:33	87-297/19:09:55	82
+	87-297/19:39:24	87-297/19:40:46	82
+	87-325/21:27:25	87-325/21:29:37	132
+	87-325/21:56:40	87-325/21:58:52	132
+	87-356/23:37:20	87-356/23:38:33	73
+	87-357/00:08:03	87-357/00:09:16	73
+	88-027/11:15:00	88-027/11:16:38	98
+	88-027/11:45:00	88-027/11:46:30	90
+	88-084/16:54:00	88-084/16:55:46	106
+	88-084/17:24:00	88-084/17:25:46	106
+	88-105/17:41:00	88-105/17:43:19	139
+	88-105/18:11:00	88-105/18:13:11	131
+	88-135/18:50:00	88-135/18:52:19	139
+	88-135/19:20:00	88-135/19:22:27	147

-	88-146/19:50:01	88-146/19:50:25	25
-	88-146/20:20:03	88-146/20:20:28	25
+	88-170/12:45:00	88-170/12:47:27	147
+	88-170/13:15:00	88-170/13:17:19	139
+	88-216/15:40:00	88-216/15:42:03	123
+	88-216/16:10:00	88-216/16:12:03	123
+	88-250/18:00:00	88-250/18:02:27	147
+	88-250/18:30:00	88-250/18:32:27	147
+	88-270/19:20:16	88-270/19:23:00	164
+	88-270/19:50:19	88-270/19:53:03	164
+	88-279/19:45:00	88-279/19:47:27	147
+	88-279/20:15:00	88-279/20:17:27	147
+	88-288/20:10:00	88-279/20:12:44	164
+	88-288/20:40:00	88-288/20:42:36	156
+	88-300/22:00:00	88-300/22:03:17	197
+	88-300/22:30:00	88-300/22:33:17	197
+	88-316/22:00:00	88-316/22:03:49	229
+	88-316/22:30:00	88-316/22:33:49	229

Figure 2 shows crosstrack deviations from the nominal 17-day track. Positive values imply eastward deviations. Atmospheric drag during the first year of the ERM was relatively low, and orbit adjustments were performed at approximately monthly intervals. Maximum deviations were 1 km from the central track, and the standard deviation was 0.32 km based on daily values. Increased drag due to larger solar flux values during 1988 (see next section) required more frequent burns, and the standard deviation for the second year of the ERM increased to 0.66 km with maximum deviations increasing correspondingly to approximately 1.5 km. (Drag has continued to increase during the third year of the ERM, and in January 1989 burns were required at approximately 1-week intervals.)

IONOSPHERIC CORRECTION

GEOSAT was launched near solar minimum, and path delay due to the ionosphere had not been a serious concern because of its small amplitude and large geographic scale. Unfortunately, figure 3 shows increasingly enormous escalations and variations in daily solar flux values beginning in late 1987. Ionosphere corrections reached a maximum value of 10 cm at the end of the second ERM year. This situation will continue to worsen until solar maximum is reached in 1990.

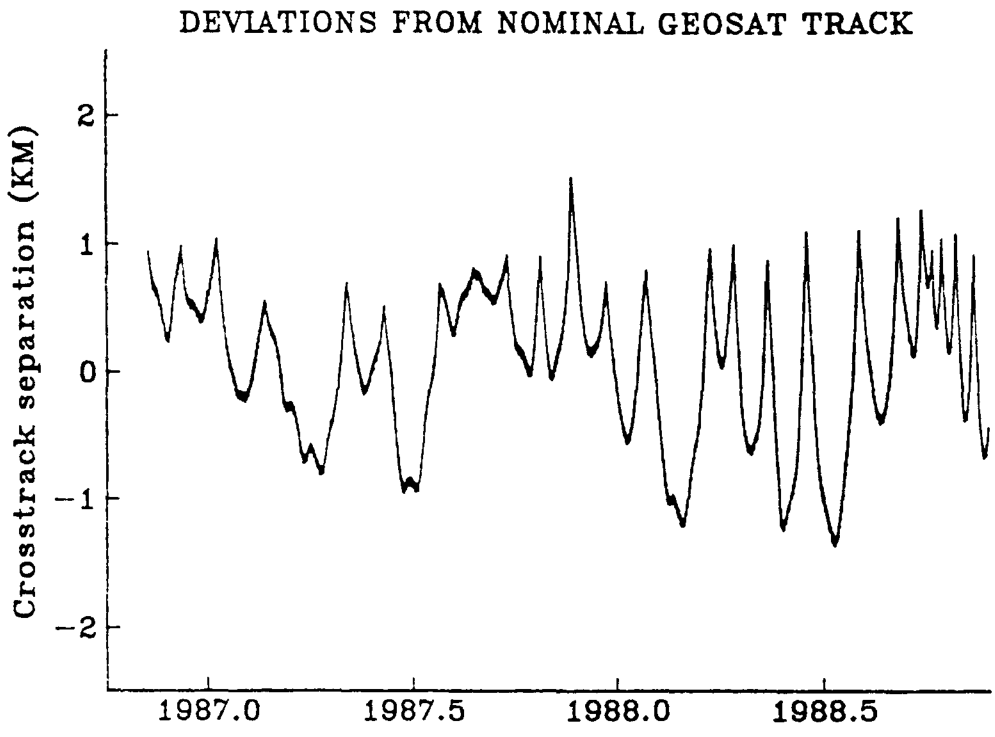

Figure 2.--Daily crosstrack deviations from the nominal 17-day GEOSAT groundtrack.

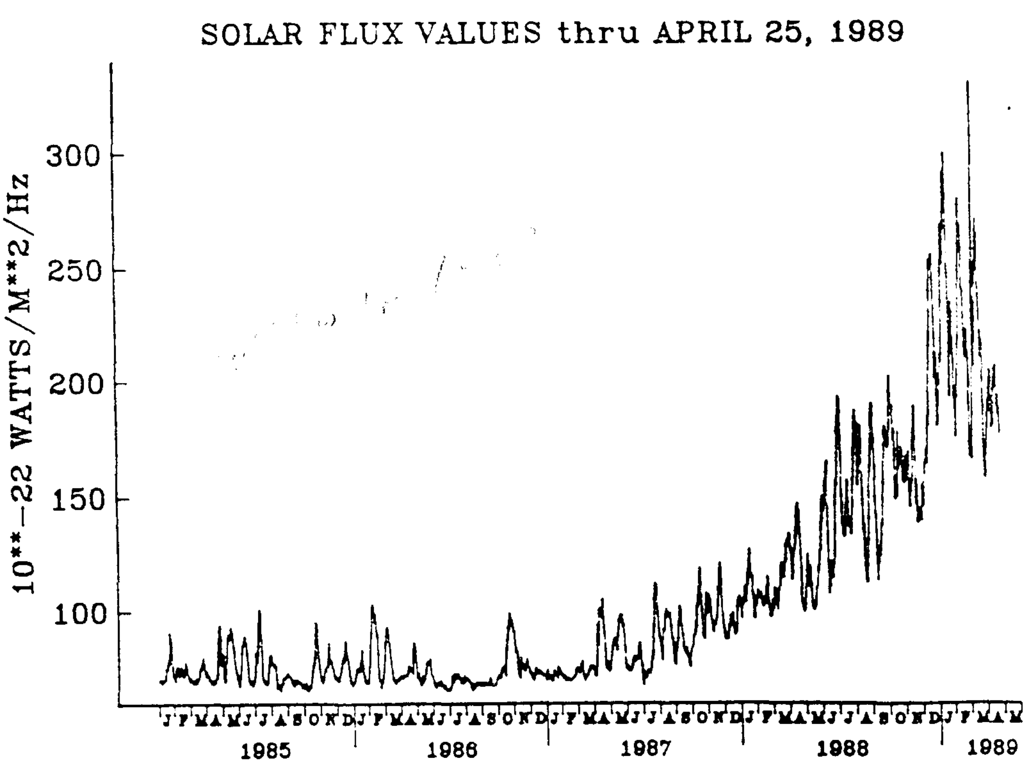

Figure 3.--Daily values of solar flux, 1985-89.

TIDAL CORRECTION

Based on suggestions made by P.L. Woodworth of Proudman Oceanographic Laboratory (POL), two modifications were made to the tidal correction program, affecting all GDRs from October 23, 1988 (day 297) onward. First, the Q1 model constituent was changed to include a term for the mean longitude of lunar perigee, P_0. This term was accidentally omitted from table 1 of Schwiderski and Szeto (1981). Second, nodal variation terms were added to all 11 model constituents. In order to gauge the overall effect of these changes on the GDR tidal corrections, a before/after comparison was made with respect to the POL implementation of the Schwiderski tide model. Before making these changes, the GDR and POL tide programs differed by approximately 1.8 cm rms over the open ocean. Afterwards, the two differed by approximately 0.3 cm rms.

GEOID MODEL

Geoid heights interpolated from a 1-degree global model are included in the GDR records. In the summary of the first year of the ERM (Cheney et al., 1988), we pointed out ripples erroneously introduced in the geoid profiles by our interpolation scheme. Although most GEOSAT users employ geoid-independent methods (e.g., collinear differences), we have corrected this error by employing a different (bilinear) form of interpolation. This modification was implemented beginning with 1988 day 203 (cycle 37). Figure 4 shows geoid profiles along the same groundtrack before and after the change, indicating that the ripples are no longer present. Plotted on the same scale are sea heights from the GEOSAT altimeter, which differ from the geoid profile primarily because of uncertainty in the radial position of the satellite.

Investigators who use the geoid height value in their sea level variability analyses should carefully examine the effect of this modification on their results. The new geoid values differ by several decimeters from those previously provided in the GDRs. If the geoid model is used only for gross error checking, the impact will be negligible. However, in analyses where the geoid height is applied as a correction, use of the modified geoid values for passes after 1988 day 203 will cause fictitious changes in sea level when compared to previous collinear profiles. Users affected by this modification may wish to obtain the gridded geoid model together with the old and new interpolation routines. These are available on request from the NOAA Geosat Project, N/CG112, National Ocean Service, NOAA, Rockville, MD 20852, tel. (301) 443-8556, telemail NOAA.GEOSAT (Omnet).

TROPOSPHERIC CORRECTION

The wet and dry tropospheric corrections in the GDRs are interpolated from global 12-hour interval grids provided by the Fleet Numerical Oceanographic Center. Table 2 shows times at which interpolation over longer intervals was performed due to grids being unavailable.

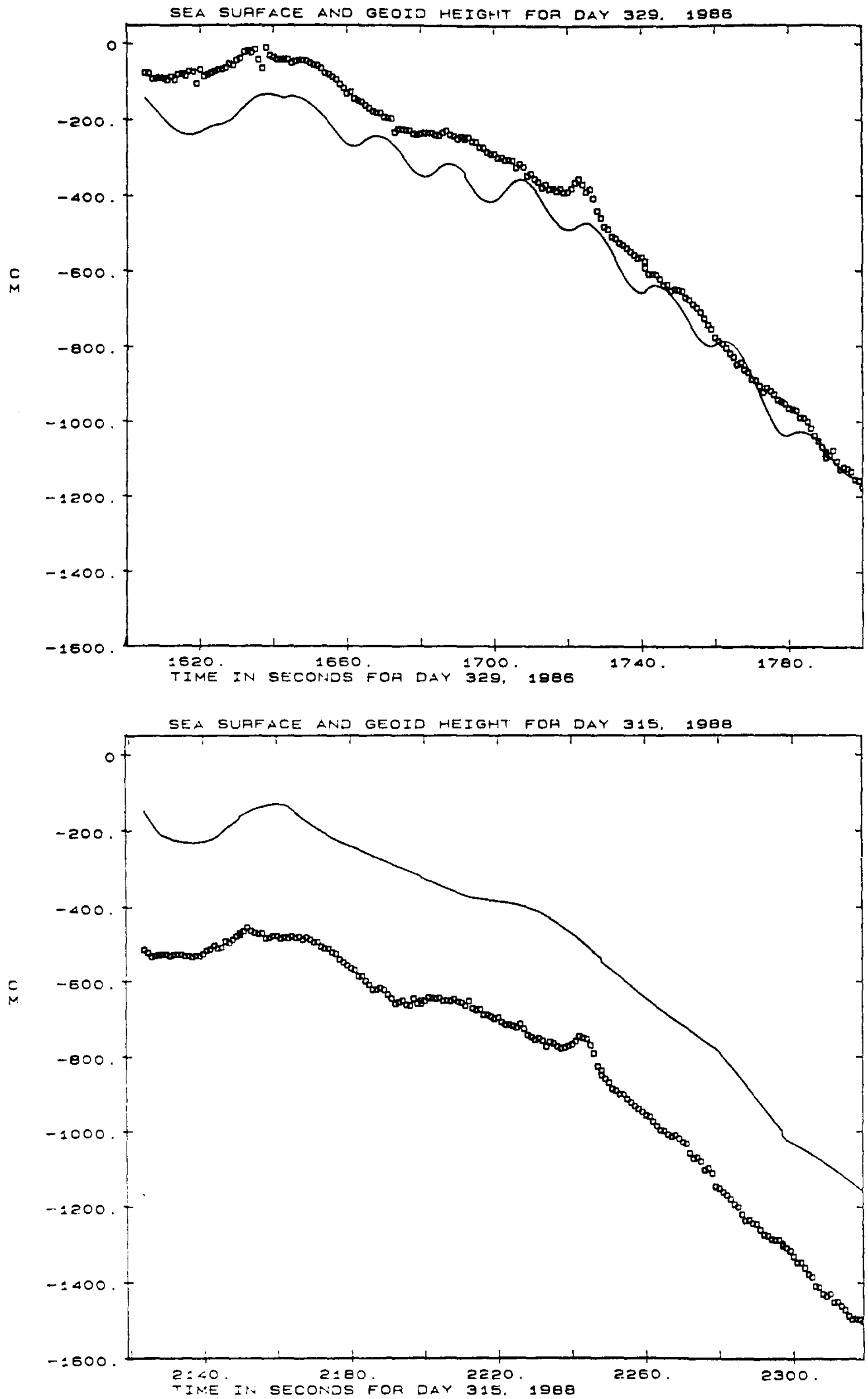

Figure 4.--Comparison of 1-second GEOSAT sea heights (squares) and GDR geoid model height (smooth curve) for the same segment in the North Pacific at two different times. The lower figure shows that the bilinear interpolation scheme has removed the erroneous geoid ripples seen in the upper figure.

Table 2.--Time periods when gaps exist in the series of 12-hour global grids of tropospheric data provided by Fleet Numerical Oceanographic Center

1986	Day 336 (0000z) to Day 340 (0000 Z) = 4.0 day gap
	Day 348 (1200z) to Day 349 (1200 Z) = 1.0
1987	Day 15 (1200z) to Day 16 (1200 Z) = 1.0
	Day 31 (0000z) to Day 35 (1200 Z) = 4.5
	Day 37 (0000z) to Day 41 (0000 Z) = 4.0
	Day 91 (1200z) to Day 92 (1200 Z) = 1.0
	Day 103 (1200z) to Day 104 (1200 Z) = 1.0
	Day 277 (1200z) to Day 282 (0000 Z) = 4.5
	Day 333 (0000z) to Day 334 (0000 Z) = 1.0
	Day 354 (0000z) to Day 355 (0000 Z) = 1.0
1988	Day 18 (0000z) to Day 20 (0000 Z) = 2.0
	Day 232 (0000z) to Day 233 (0000 Z) = 1.0
	Day 261 (0000z) to Day 263 (0000 Z) = 1.5
	Day 266 (0000z) to Day 268 (0000 Z) = 1.5

LEAP SECOND CORRECTION

Addition of a leap second was required at the end of 1987. Leap seconds present difficulties in altimeter data sets because the satellite is technically at two different locations at the same time on one particular arc. We have chosen to simply delete a short segment of data so that the leap second occurs between two different orbital arcs. Accordingly, the GDR for 1987 day 365 was truncated on an ascending arc 1 second before the end of the day. The GDR for 1988 day 1 begins 2425 seconds into the day on a descending arc.

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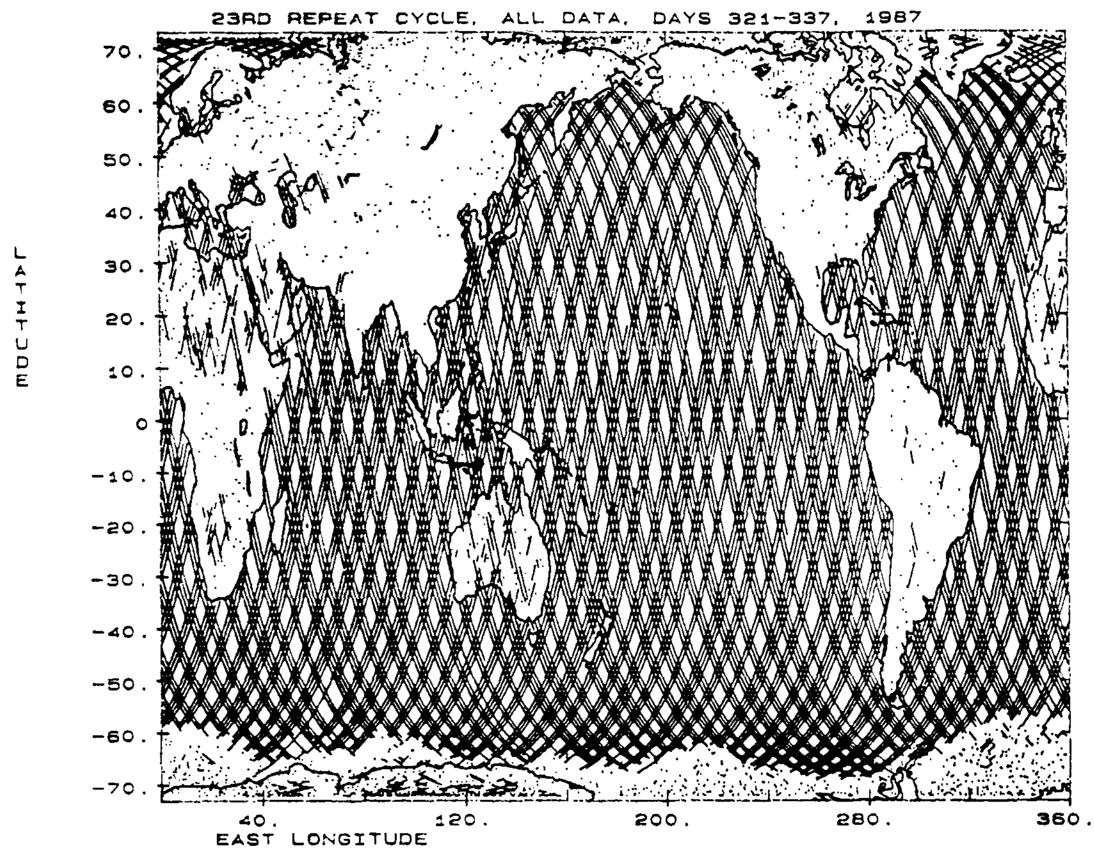
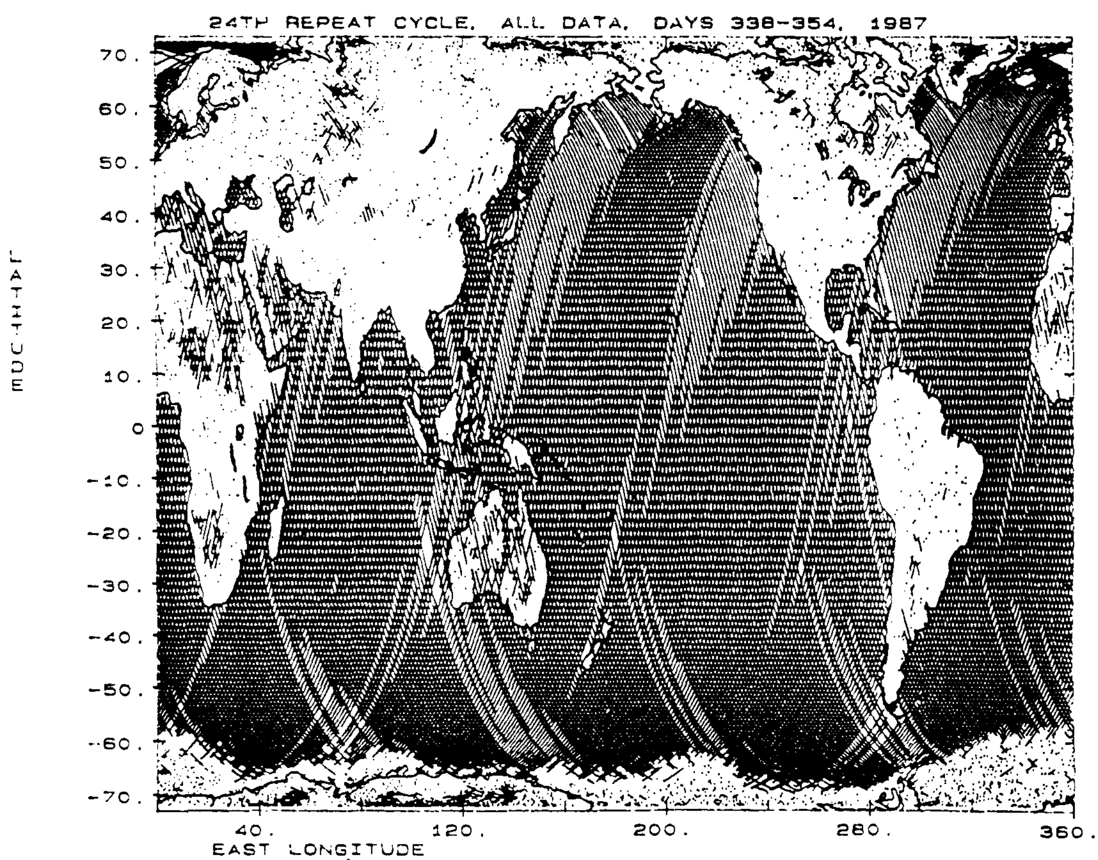
Cheney, R.E., Douglas, B.C., Agreen, R.W., Miller, L., and Doyle, N.S., 1988: The NOAA GEOSAT Geophysical Data Records: Summary of the first year of the Exact Repeat Mission. NOAA Technical Memorandum NOS NGS-48, 20 pp., National Geodetic Survey, N/CG112, NOAA, Rockville, MD 20852.

Cheney, R.E., Douglas, B.C., Agreen, R.W., Miller, L., Porter, D.L., and Doyle, N.S., 1987: GEOSAT altimeter geophysical data record user handbook. NOAA Technical Memorandum NOS NGS-46, 32 pp., National Geodetic Survey, N/CG112, NOAA, Rockville, MD 20852.

Schwiderski, E.W. and Szeto, L. T., 1981: The NSWC global ocean tide data tape (GOTD), its features and application, random-point program. NSWC Technical Report 81-254, Naval Surface Weapons Center, Dahlgren, VA 22448.

APPENDIX.--GEOSAT GEOPHYSICAL DATA RECORDS


23RD REPEAT CYCLE, ALL DATA, DAYS 321-337, 1987
70.
60.
50.
40.
30.
20.
10.
0
-10.
-20.
-30.
-40.
-50.
-60.
-70.
LATITUDE
40.
120.
200.
280.
360.
EAST LONGITUDE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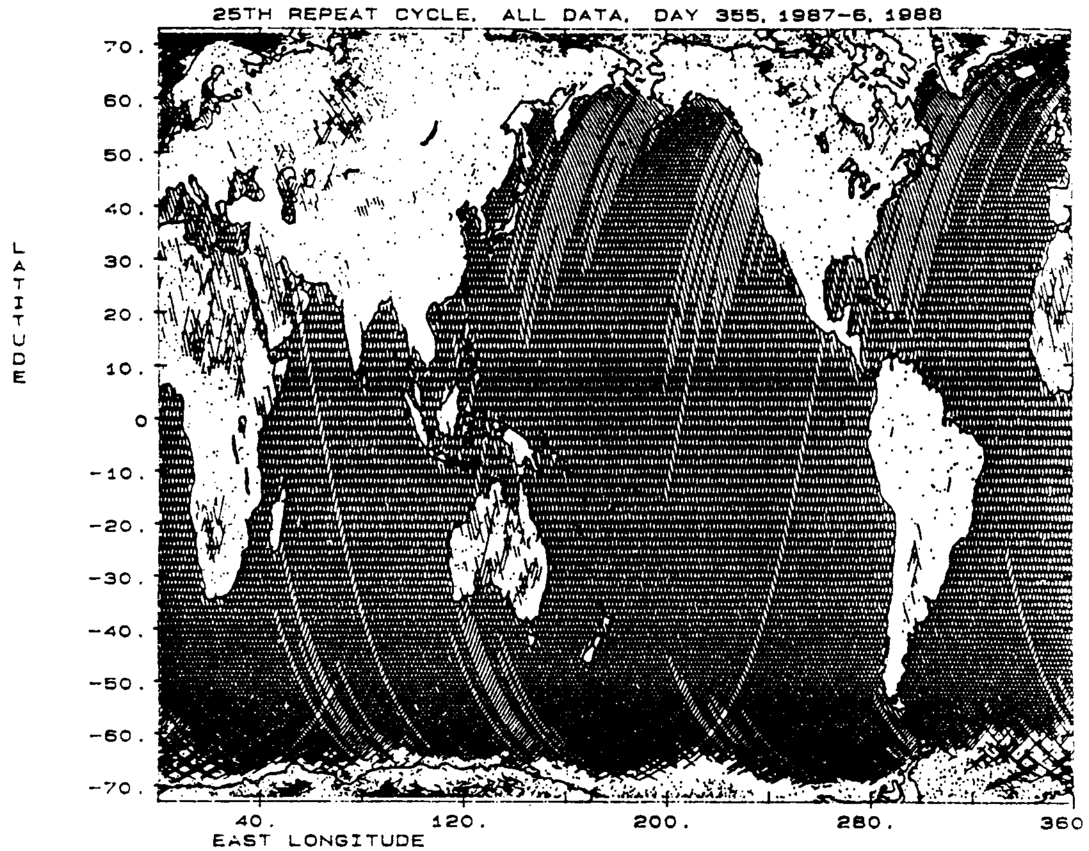
60.
50.
40.
30.
20.
10.
0
-10.
-20.
-30.
-40.
-50.
-60.
-70.
LATITUDE
40.
120.
200.
280.
360.
EAST LONGITUDE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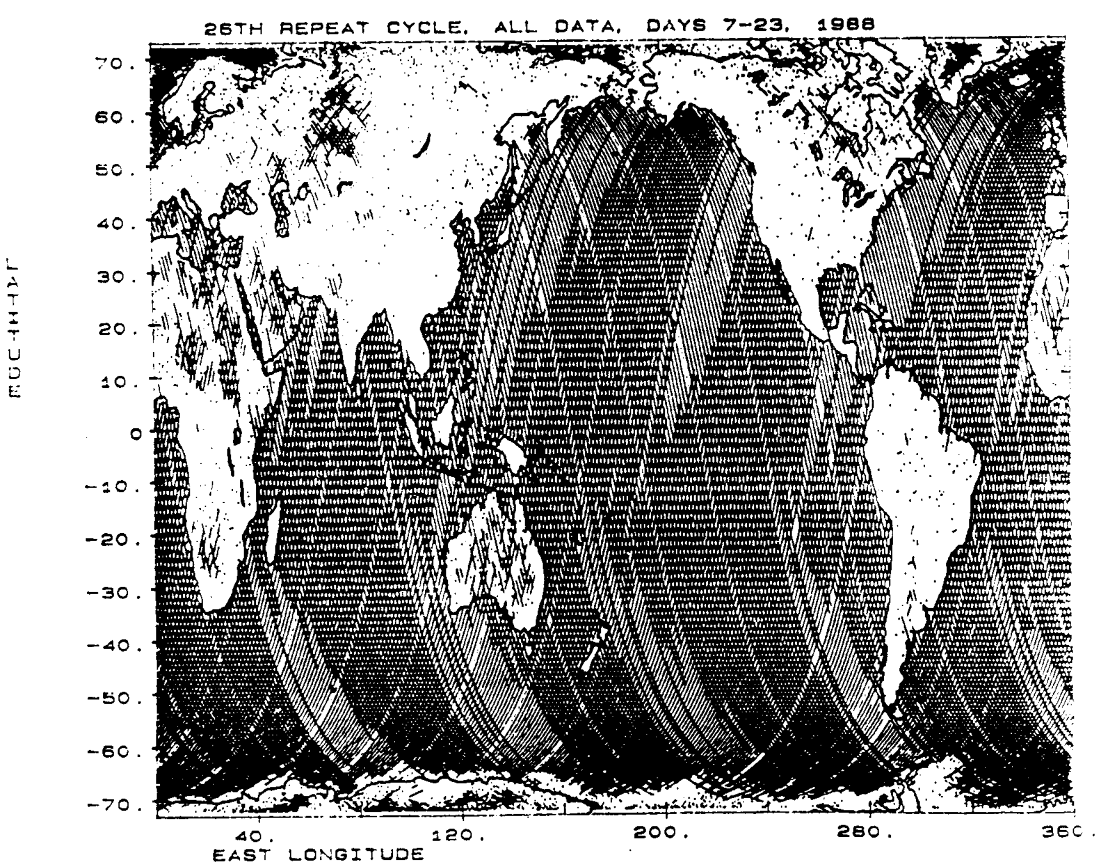
60.
50.
40.
30.
20.
10.
0
-10.
-20.
-30.
-40.
-50.
-60.
-70.
40.
120.
200.
280.
360.
EAST LONGITUDE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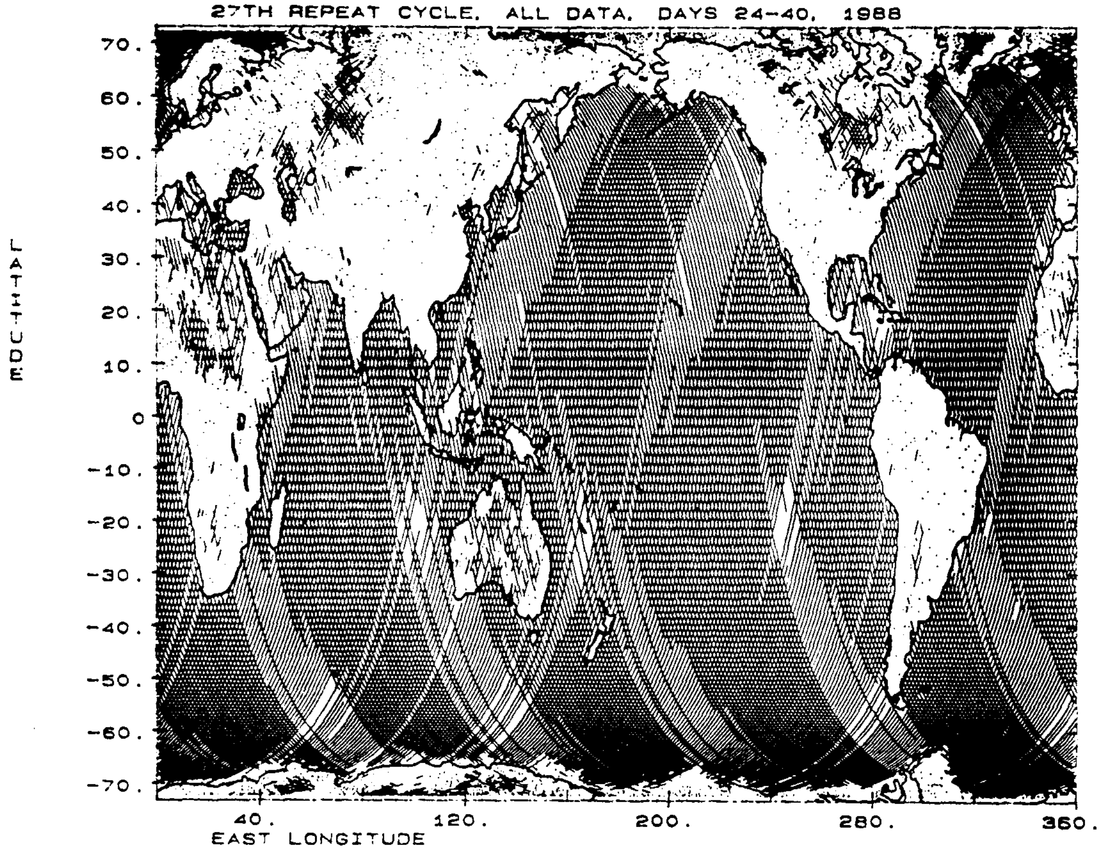
50.
40.
30.
20.
10.
0
-10.
-20.
-30.
-40.
-50.
-60.
-70.
40.
120.
200.
280.
360.
EAST LONGITUDE


27TH REPEAT CYCLE. ALL DATA. DAYS 24-40. 1988
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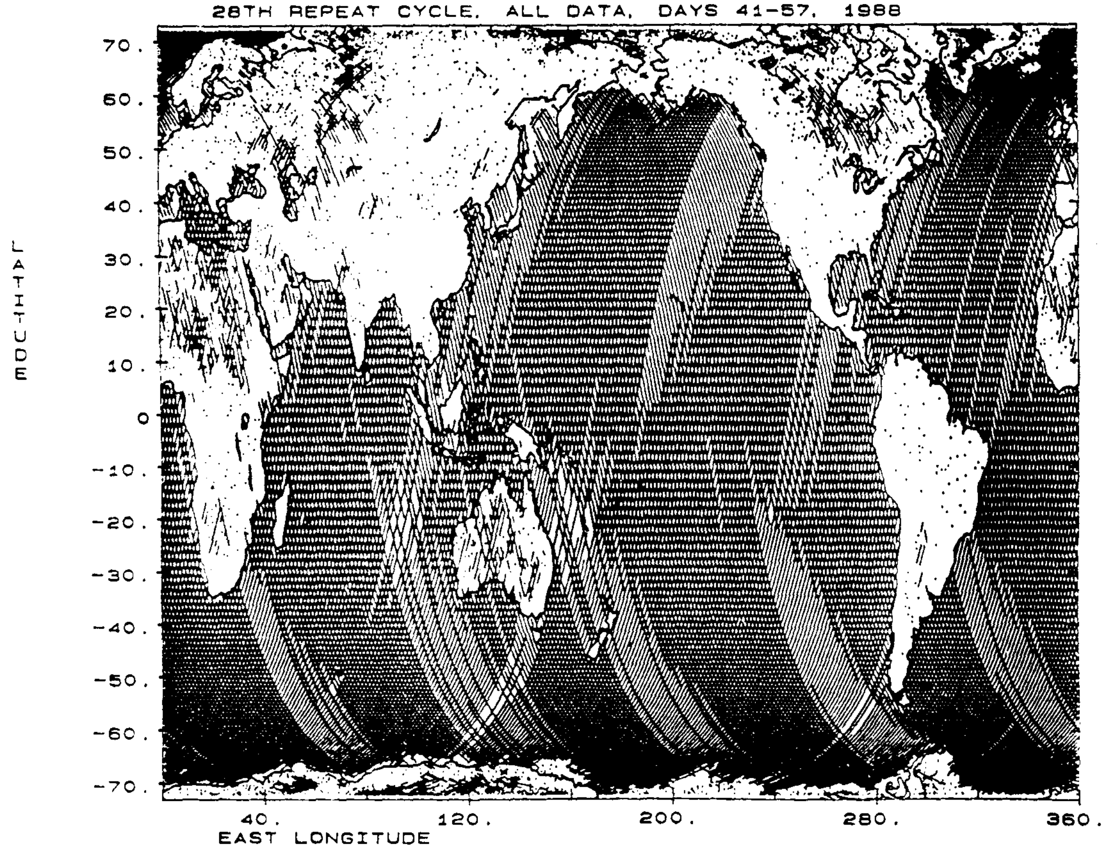
60.
50.
40.
30.
20.
10.
0
-10.
-20.
-30.
-40.
-50.
-60.
-70.
40.
120.
200.
280.
360.
EAST LONGITUDE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60.
50.
40.
30.
20.
10.
0
-10.
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-40.
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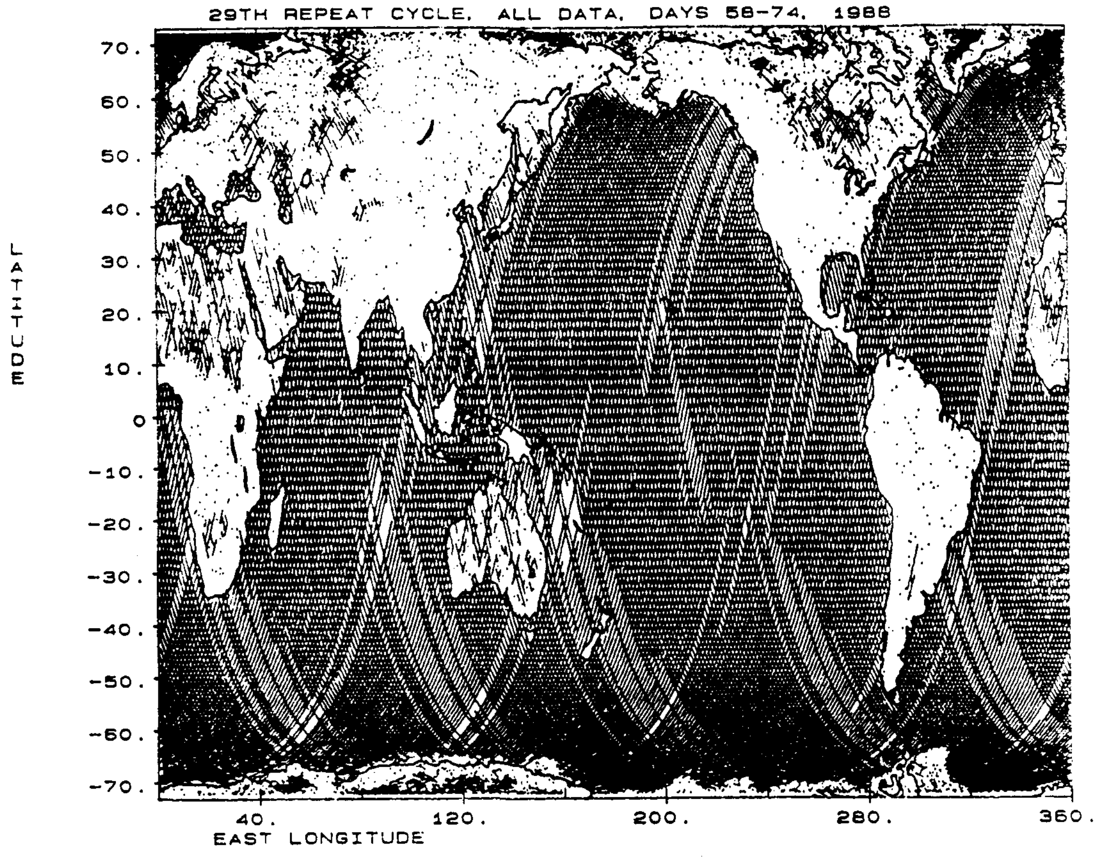
-60.
-70.
40.
120.
200.
280.
360.
EAST LONGITUDE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30.
20.
10.
0
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-40.
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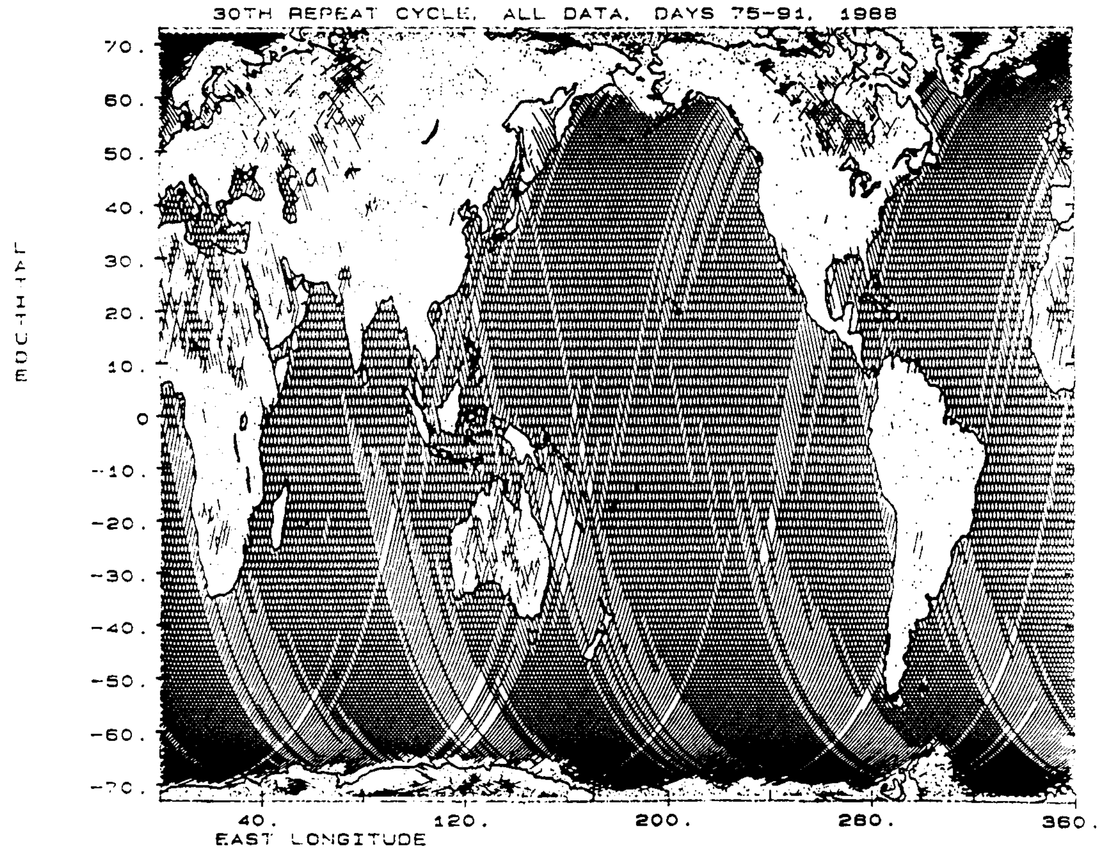
120.
200.
280.
360.
EAST LONGITUDE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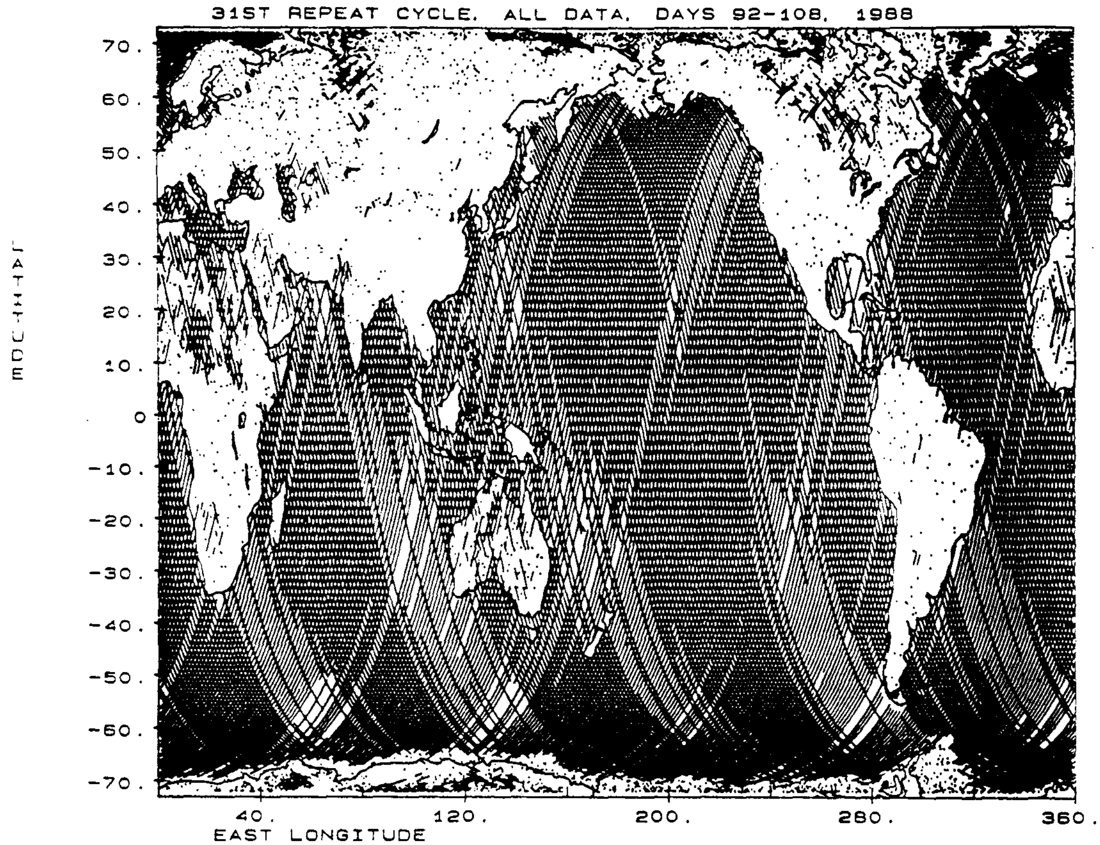
40.
120.
200.
280.
360.
EAST LONGITUDE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0
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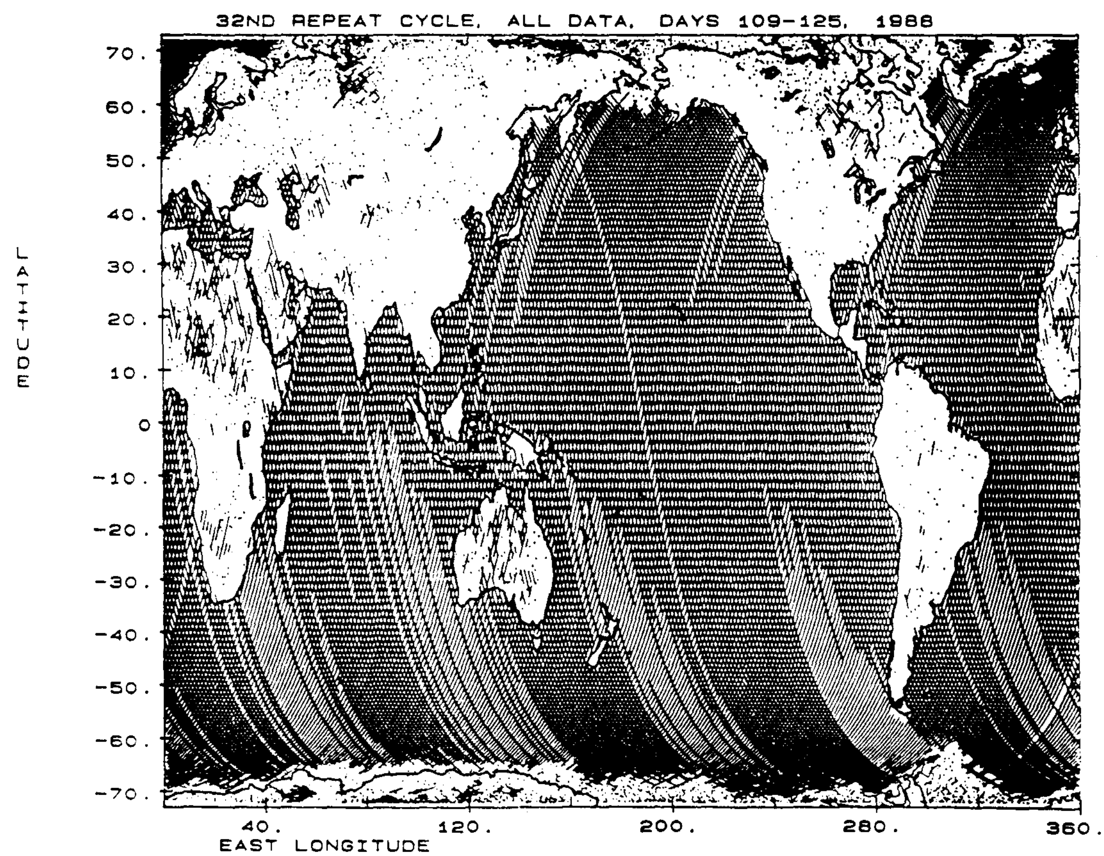
200.
280.
360.
EAST LONGITUDE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30.
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10.
0
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40.
120.
200.
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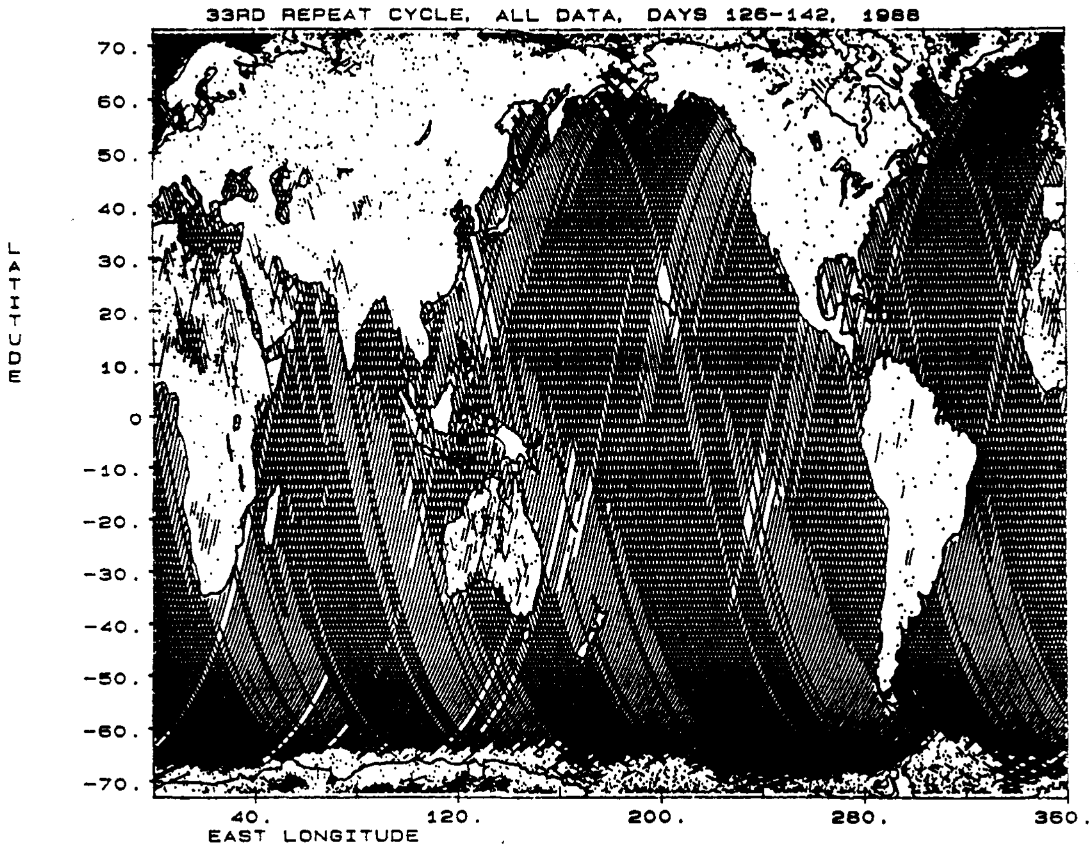
360.
EAST LONGITUDE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50.
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30.
20.
10.
0
-10.
-20.
-30.
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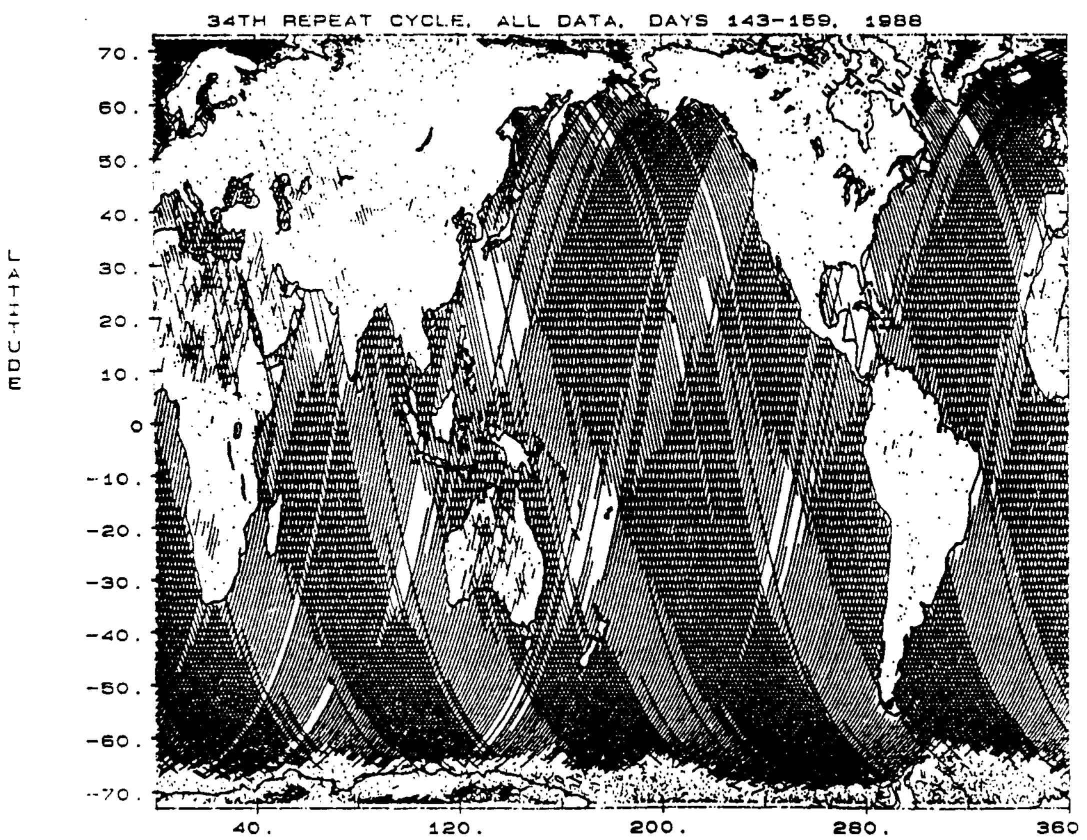
-50.
-60.
-70.
LATITUDE
40.
120.
200.
280.
360.
EAST LONGITUDE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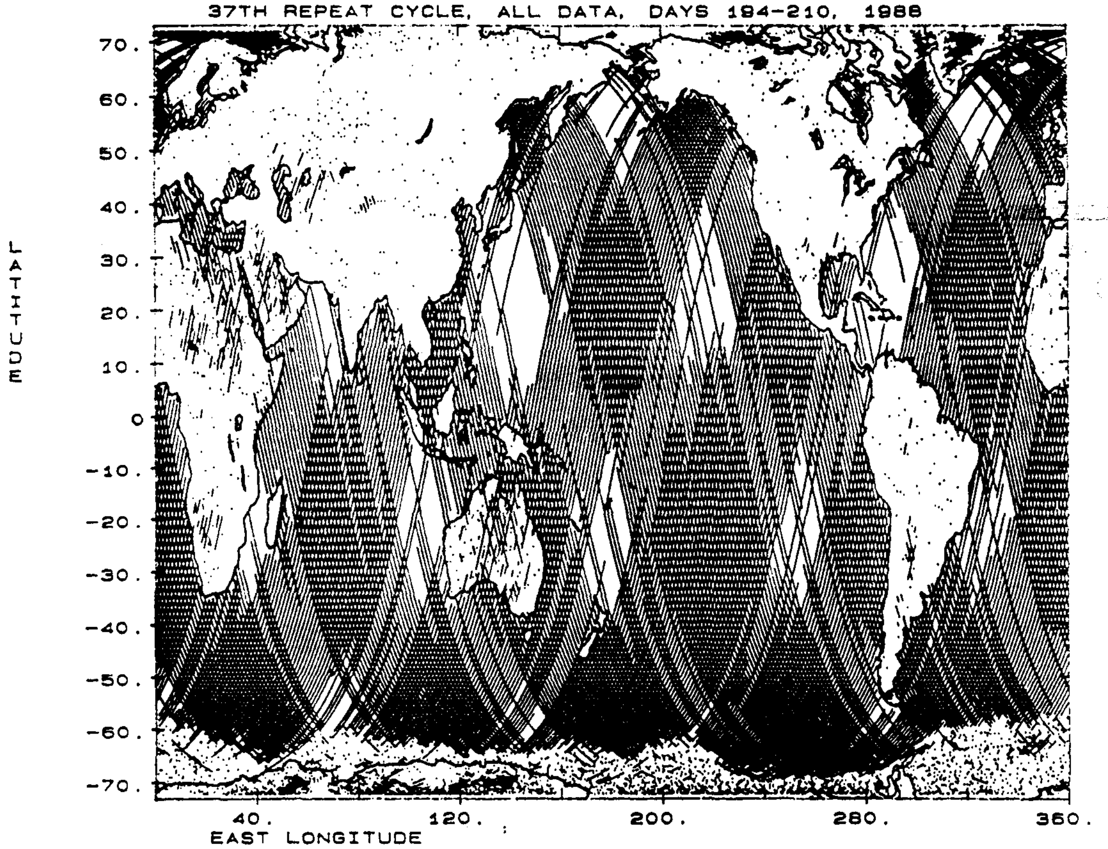
50.
40.
30.
20.
10.
0
-10.
-20.
-30.
-40.
-50.
-60.
-70.
LATITUDE
40.
120.
200.
280.
360.
EAST LONGITUDE



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50.
40.
30.
20.
10.
0
-10.
-20.
-30.
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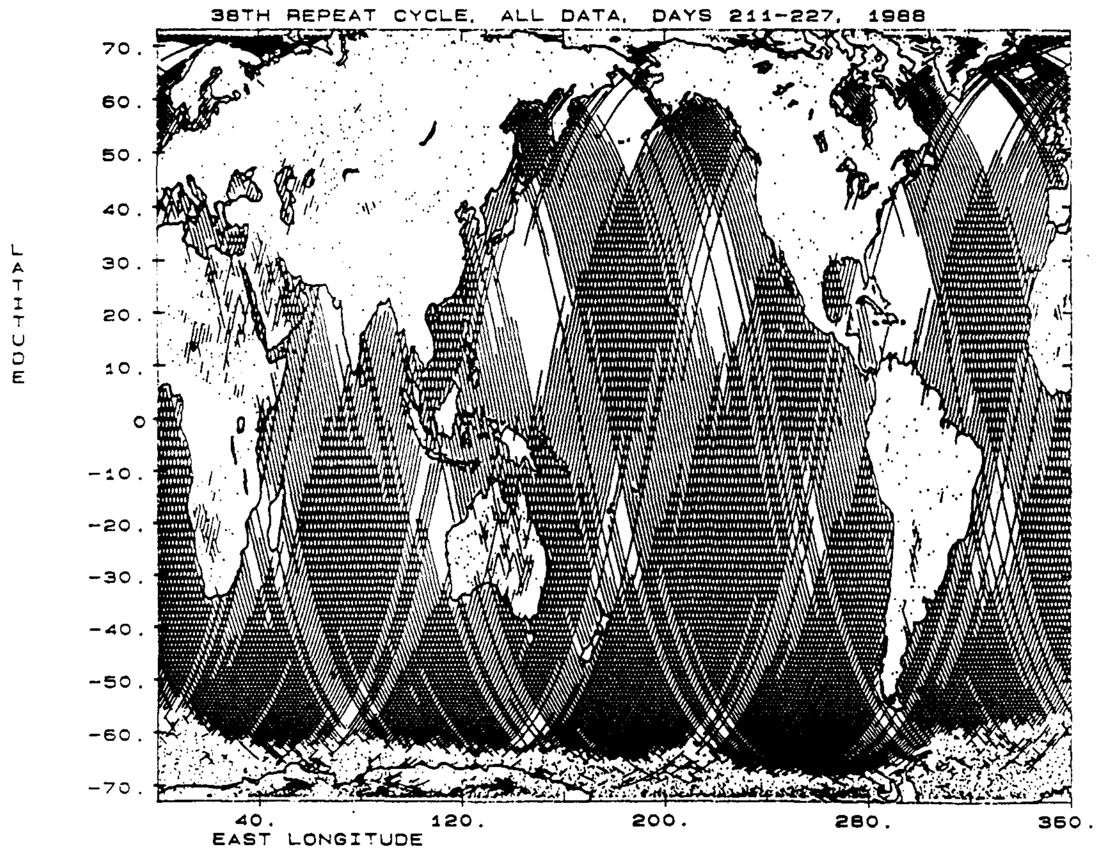
40.
120.
200.
280.
360.
EAST LONGITUDE



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50.
40.
30.
20.
10.
0
-10.
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-60.
-70.
40.
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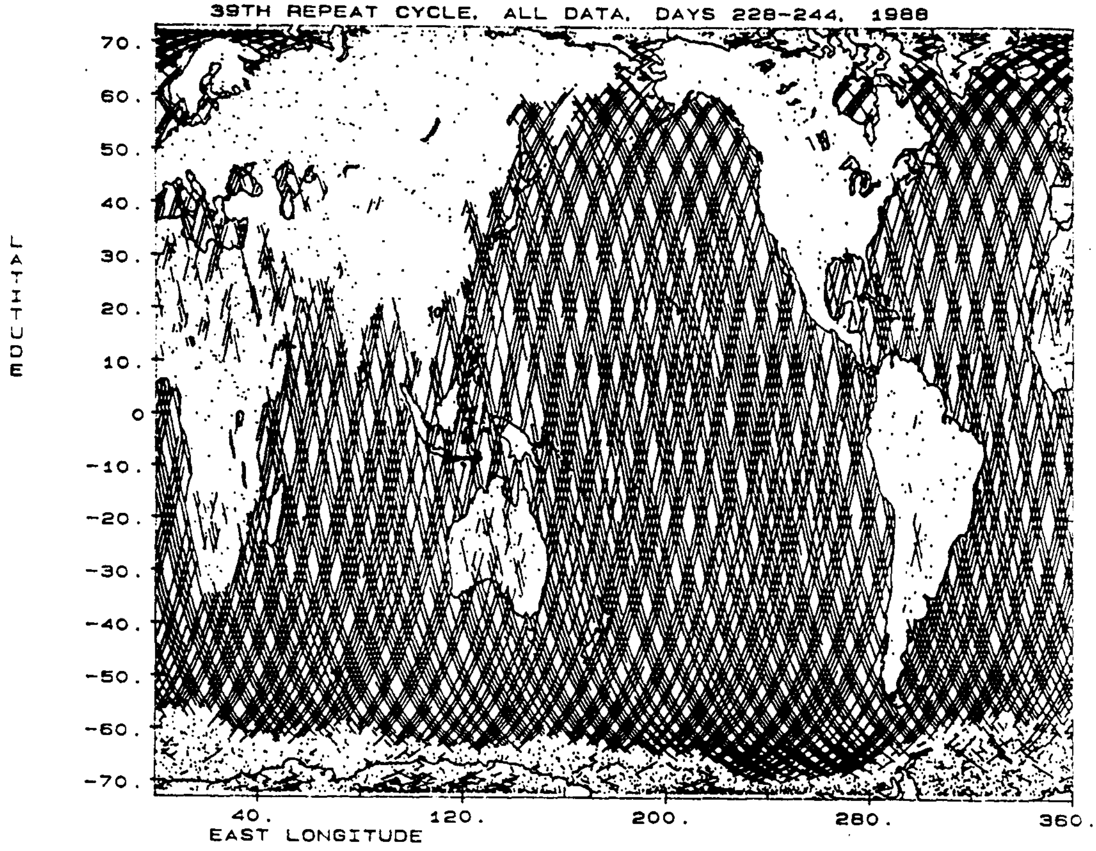
200.
280.
360.
EAST LONGITUDE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50.
40.
30.
20.
10.
0
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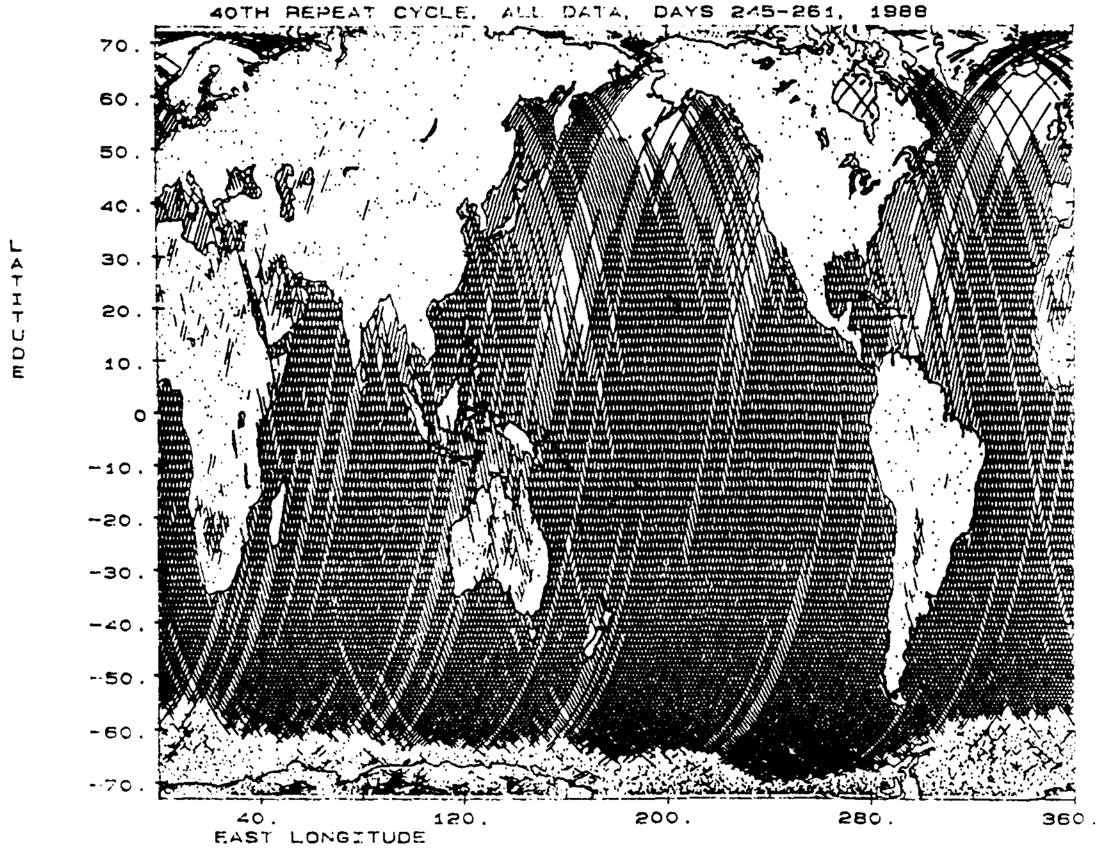
-50.
-60.
-70.
40.
120.
200.
280.
360.
EAST LONGITUDE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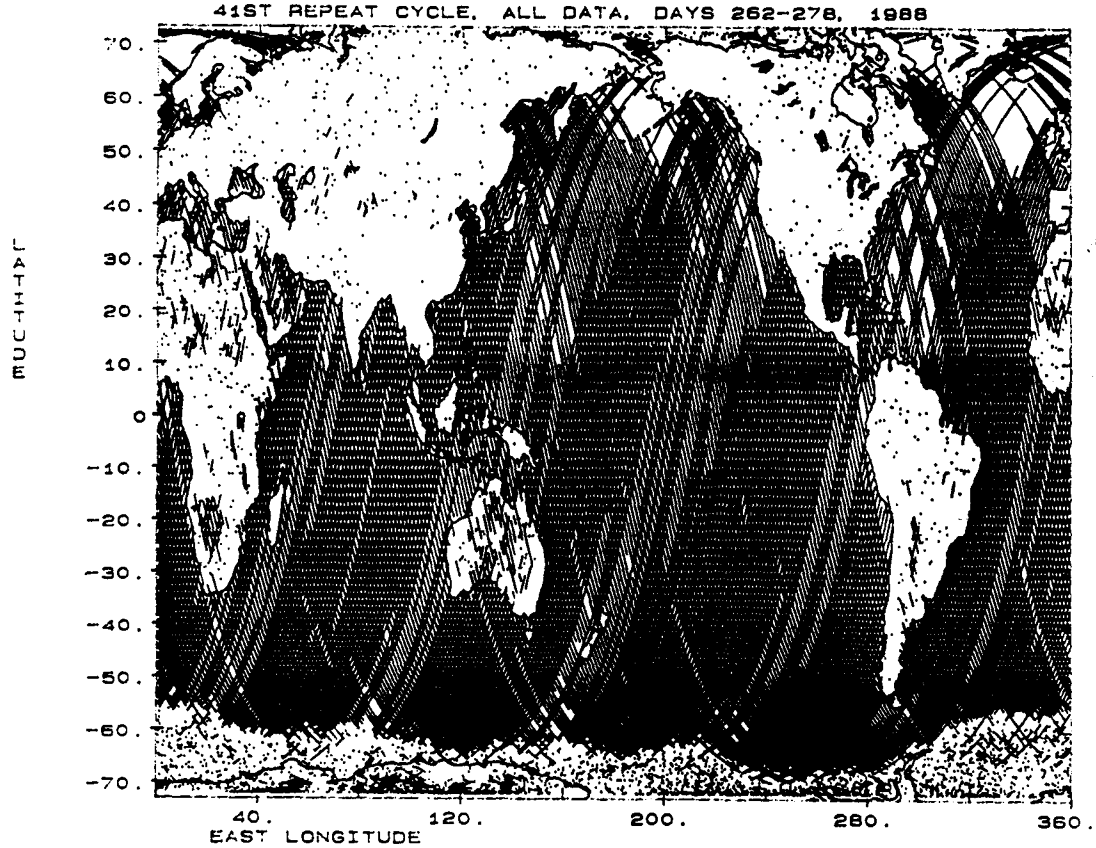
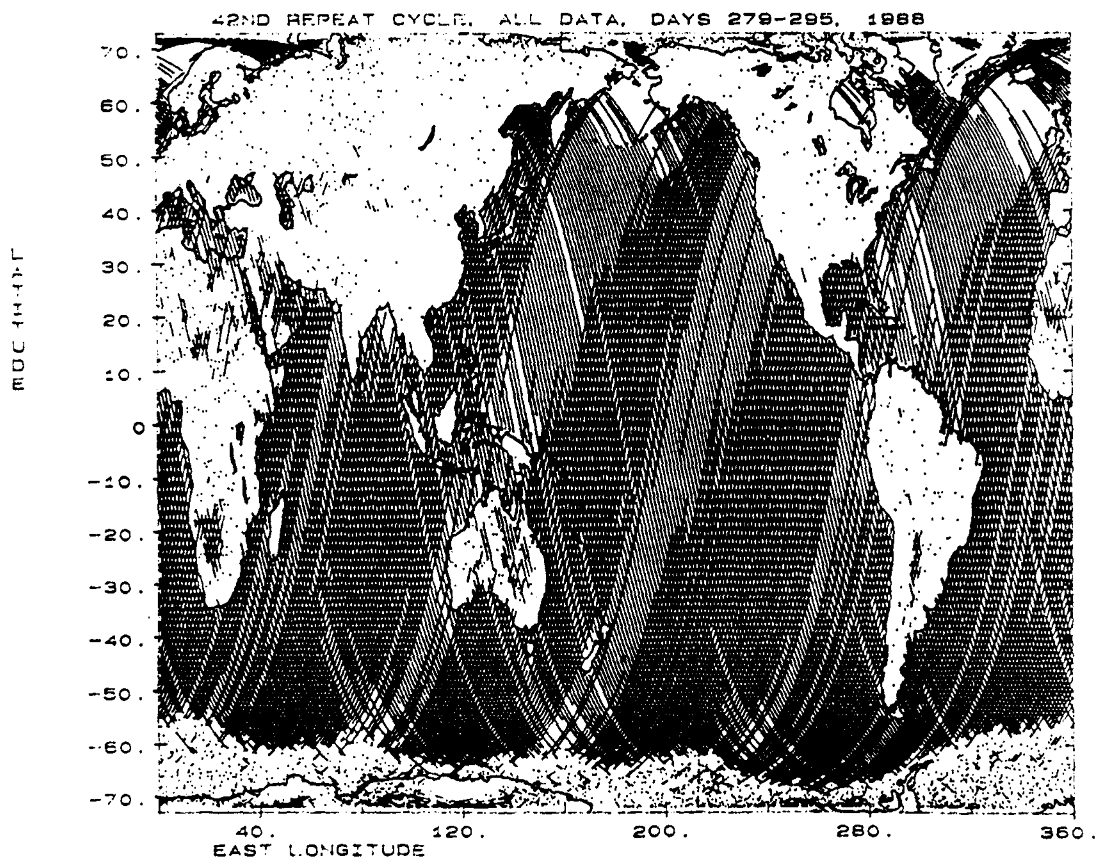
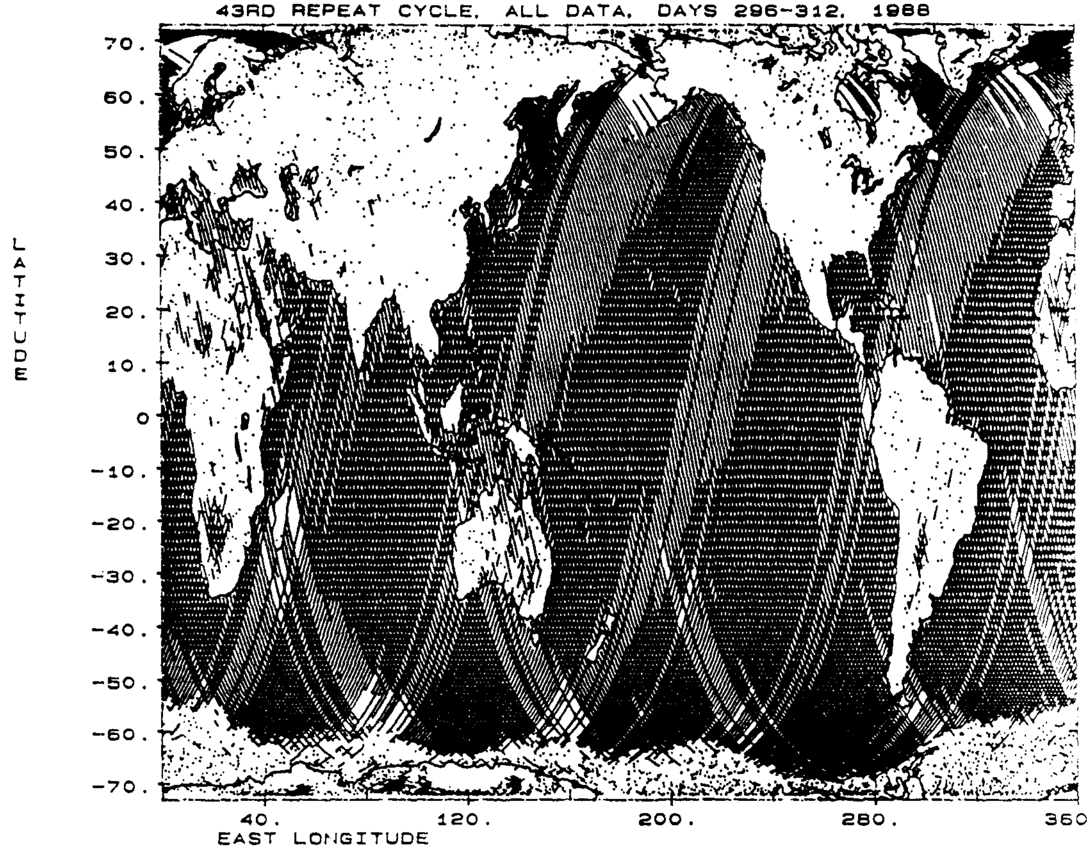
60.
50.
40.
30.
20.
10.
0
-10.
-20.
-30.
-40.
-50.
-60.
-70.
40.
120.
200.
280.
360.
EAST LONGITUDE


41ST REPEAT CYCLE. ALL DATA. DAYS 262-278. 1988
LATITUDE
70.
60.
50.
40.
30.
20.
10.
0
-10.
-20.
-30.
-40.
-50.
-60.
-70.
40.
120.
200.
280.
360.
EAST LONGITUDE


42ND REPEAT CYCLE. ALL DATA. DAYS 279-295. 1988
LATITUDE
70.
60.
50.
40.
30.
20.
10.
0
-10.
-20.
-30.
-40.
-50.
-60.
-70.
40.
120.
200.
280.
360.
EAST LONGITUDE

43RD REPEAT CYCLE, ALL DATA, DAYS 296-312, 1988



44TH REPEAT CYCLE, ALL DATA, DAYS 313-329, 1988