NASA/TM-2003-212236/Vol.12

Topography Experiment (TOPEX) Software Document Series

Volume 12

TOPEX Radar Altimeter Engineering Assessment Report Update - From Launch to Turn-Off of Side A on February 10, 1999

August 1999

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About the Series

The TOPEX Radar Altimeter Technical Memorandum Series is a collection of performance assessment documents produced by the NASA Goddard Space Flight Wallops Flight Facility over a period starting before the TOPEX launch in 1992 and continuing over greater than 10 year TOPEX lifetime. Because of the mission's success over this long period and because the data are being used internationally to redefine many aspects of ocean knowledge, it is important to make a permanent record of the TOPEX radar altimeter performance assessments which were originally provided to the TOPEX project in a series of internal reports over the life of the mission. The original reports are being printed in this series without change in order to make the information more publicly available as the original investigators become less available to explain the altimeter operation and details of the various data anomalies that have been resolved.

Foreword

The Engineering Assessment of the TOPEX Radar Altimeter is performed on a continuing basis by the TOPEX Altimeter Team at NASA / GSFC Wallops Flight Facility. The Assessment Team members are:

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For the latest updates on the performance of the TOPEX Radar Altimeter, and for accessing many of our reports, readers are encouraged to contact our WFF / TOPEX Home Page at http: / / topex.wff.nasa.gov.

For additional information on this topic, please contact the Team Leader, David W. Hancock III. He may be reached at 757-824-1238 (Voice), 757-824-1036 (FAX), or by e-mail at hancock@osb.wff.nasa.gov.

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Section 1
Introduction

1.1 Identification of Document

The initial TOPEX Mission Radar Altimeter Engineering Assessment Report, in February 1994, presented performance results for the NASA Radar Altimeter on the TOPEX/POSEIDON spacecraft, from the time of its launch in August 1992 to February 1994. Since that time, there have been four interim supplemental Engineering Assessment Reports, issued in March 1995, May 1996, March 1997, and again in June 1998 which updated the performance results to the end of calendar years 1994, 1995, 1996, and 1997, respectively.

All the assessment reports have presented results of the Side-A altimeter on the spacecraft. Due to indications of an evolving change in the altimeter's point target response, Side-A was turned off on February 10, 1999. [Side-A could be turned back on if dictated by future events.] Side-B was turned on to Track mode the next day, on February 11, 1999.

This fifth supplement updates the altimeter performance to the turnoff date of Side-A, and describes significant events that occurred since the beginning of 1998.

As the performance data base has expanded, and as analysis tools and techniques continue to evolve, the longer-term trends of the altimeter data have become more apparent. The updated findings are presented here.

Section 2
On-Orbit Instrument Performance

From the time of the initial turn-on of Side A after launch to the time of its being turned off on February 10, 1999, the NASA Radar Altimeter was in TRACK mode for a total of approximately 50,200 hours. The altimeter had been in IDLE mode for an additional 6,100 hours since launch, generally due to the French Altimeter's being turned on. The altimeter had been in OFF mode for a total of 394 hours, due primarily to a 230-hour spacecraft-level Safehold which began on November 26, 1995, and to a 68-hour spacecraft-level Safehold which began on January 20, 1996.

Due to a change in its point target response (PTR), which will be described in Section 3.3 of this document, Altimeter Side A was turned off on February 10, 1999. On that date, Side B was turned on and is performing well. Side A was still operational at the time of its turnoff, and could be turned back on if there were to be a problem with Side B. The Side A C-Band frequency remained at 320 MHz since turn-on, except for a very brief period shortly after launch when the bandwidth was switched to 100 MHz, to affirm the 100MHz operability.

The parameter file C35028SL, described in Table 5.8.4 of the February 1994 Engineering Assessment Report, was in use until day 40 of 1995. On that day, at 1920 UTC, a new parameter set, C3502840, was implemented. The only difference between the two parameter sets is that the initial AGC acquisition value prior to the first cal mode is 40 dB instead of the previous 60 dB. The rationale for this change is discussed in Section 2.2.8 (page 27) of the March 1995 Engineering Assessment supplement. Parameter file C3502840 was still in use at the time of the Side A turn-off, and is now being used for Side B.

The succeeding sub-sections discuss:

- launch-to-turnoff internal calibration results
- launch-to-turnoff cycle summary results
- launch-to-turnoff key events

2.1 Launch-to-Date Internal Calibrations

Internal altimeter calibrations are scheduled twice-per-day, over land areas, at approximately 0000 UTC and 1200 UTC. Internal calibrations are also performed whenever the NASA altimeter is commanded from TRACK to IDLE for a period of tracking by the French altimeter, or from IDLE back to TRACK when tracking resumes for the NASA altimeter. The WFF Side A database presently contains approximately 4700 internal calibration sets. The calibrations prior to and after the French altimeter operations are not constrained to land areas, and usually occur over open ocean.

2.1.1 Range Calibrations

Our processing of the calibration mode data was modified in 1994, to remove the effect of the 7.3 mm quantization; the revised method is discussed in Section 2.1.1 (page 2) of the March 1995 supplement. All the calibration data since launch have been reprocessed using the revised method. The change in Ku-Band range, from day 239 of 1992 to Side A turn-off, is plotted in Figure 2-1 "Ku-Band Range CAL-1 Results" on page 2-3. CAL-1 steps 4 through 7 are shown in the Figure. Step 5 best represents typical AGC levels for normal ocean fine-track operation, and has been used for the range trend analysis presented in Section 3.1.

The delta range shown in Figure 2-1 (and in the succeeding calibration plots) is calculated based on the measurement minus a reference. This calibration range plot suggests that the Ku-Band delta range rate changed from a generally negative slope to a positive slope shortly after the beginning of 1996, and the ending delta range is approximately 6 mm higher than its 1992 level. In the Figure, the year 1996 begins on elapsed day 1222.

The change in C-Band calibration range is depicted in Figure 2-2 "C-Band Range CAL-1 Results" on page 2-4. This plot indicates that, early in the mission, the C-Band range was negatively changing at the rate of several millimeters per year. Beginning in the latter part of 1994 and continuing through 1995, the C-Band range generally stabilized, although there was more frequent toggling of the 7.3 mm quantization step. Shortly after the beginning of 1996, and continuing through to the Side A turn-off, the range change has had a positive slope, and at turn-off was10 mm more positive than in 1992.

Range calibrations and their correction values are discussed in more detail in Section 3.1

2.1.2 AGC Calibrations

2.1.2.1 CAL-1 and CAL-2

The change in Ku-Band AGC since launch is shown in Figure 2-3 "Ku-Band AGC CAL-1 and CAL-2 Results" on page 2-5. CAL-1 steps 4 through 6, plus CAL-2, are depicted in the Figure. As for the earlier range calibration, Step 5 of the CAL-1 AGC steps is considered to be the most typical for normal ocean operations. From launch to the end of 1994 (day 855 in the Figure), the Ku-Band CAL-1 AGC had been decreasing at a rate approximating 0.3 dB per year. During 1995, CAL-1 AGC decreased about 0.4 dB. From the beginning of 1996 (day 1222) and continuing to turn-off, there has been an accelerated linear AGC decrease of about 0.8 dB per year. Since launch, there had been an approximate 3.7 dB total decrease in CAL-1 AGC. The Ku-Band CAL-2 shows a slight increase of about 0.1 dB since the beginning of 1998 (day 1952 in the Figure), and a total decrease since launch of about 0.6 dB.

The change in C-Band AGC since launch is shown in Figure 2-4 "C-Band AGC CAL-1 and CAL-2 Results" on page 2-6. Similar to the Ku-Band, the C-Band AGC exhibits an accelerated rate of decrease since the beginning of 1996. Prior to 1996, the total decrease since launch was about 0.7 dB; since then, there was a linear decrease of an

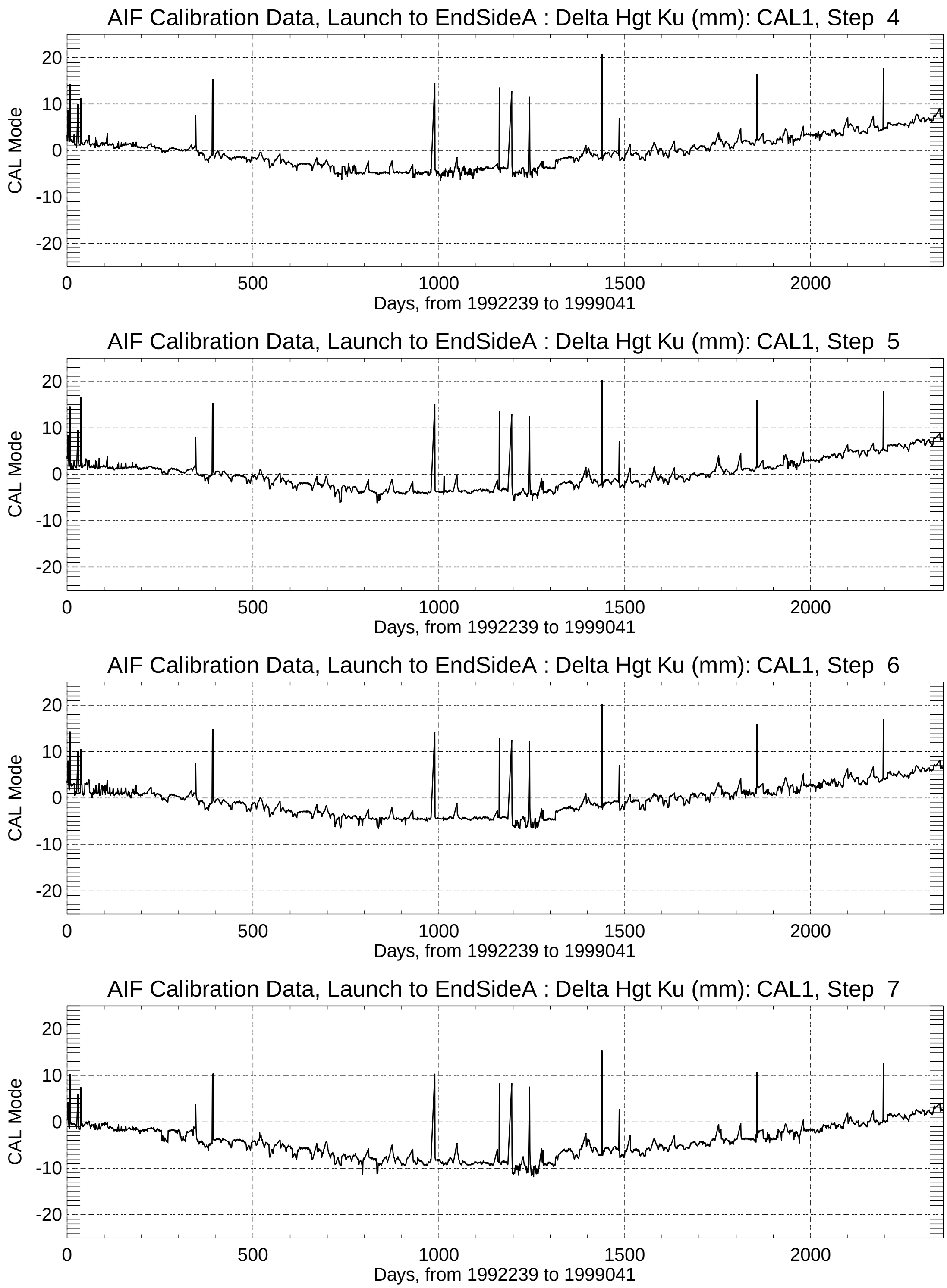

Figure 2-1 Ku-Band Range CAL-1 Results

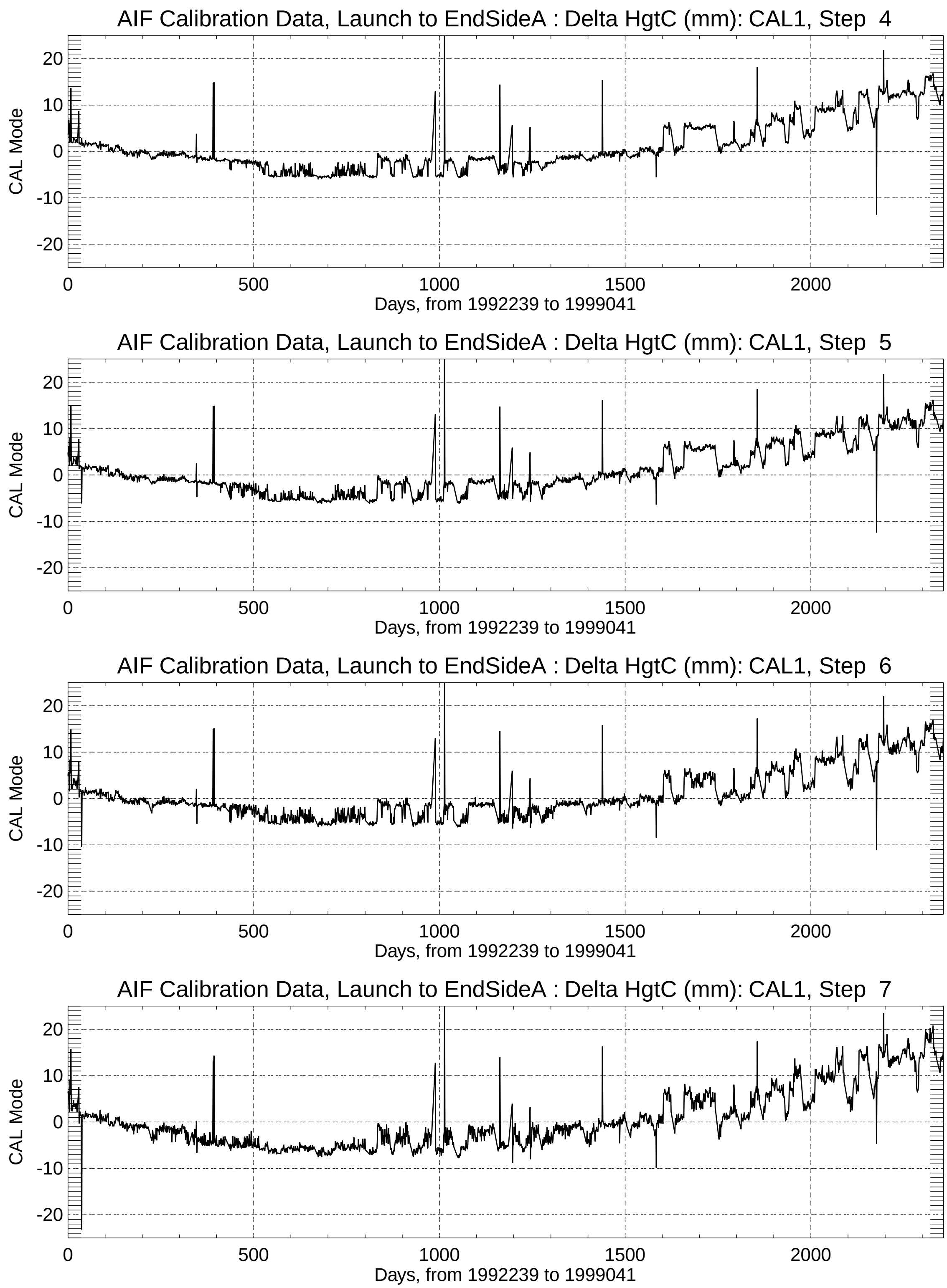

Figure 2-2 C-Band Range CAL-1 Results

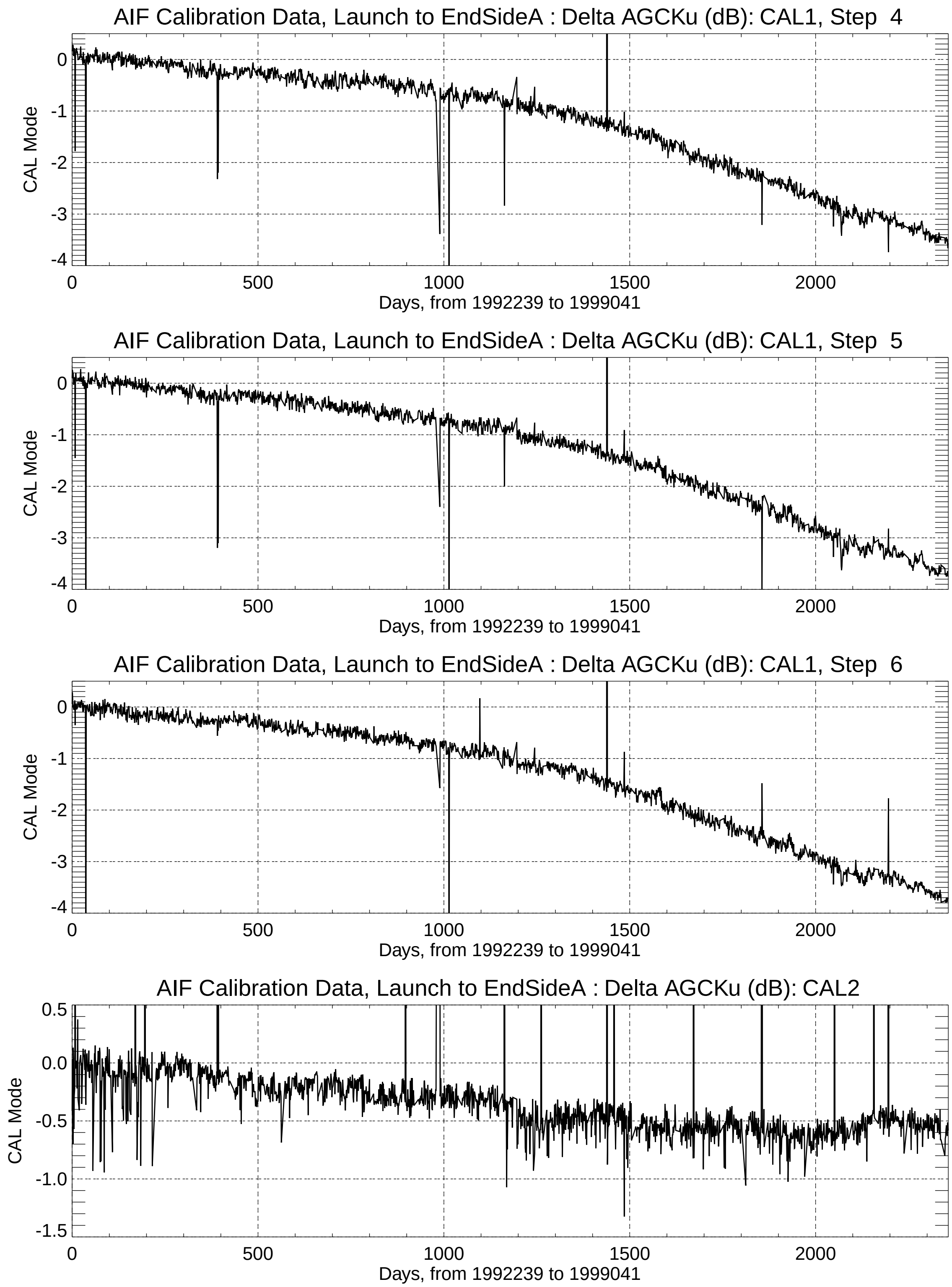

Figure 2-3 Ku-Band AGC CAL-1 and CAL-2 Results

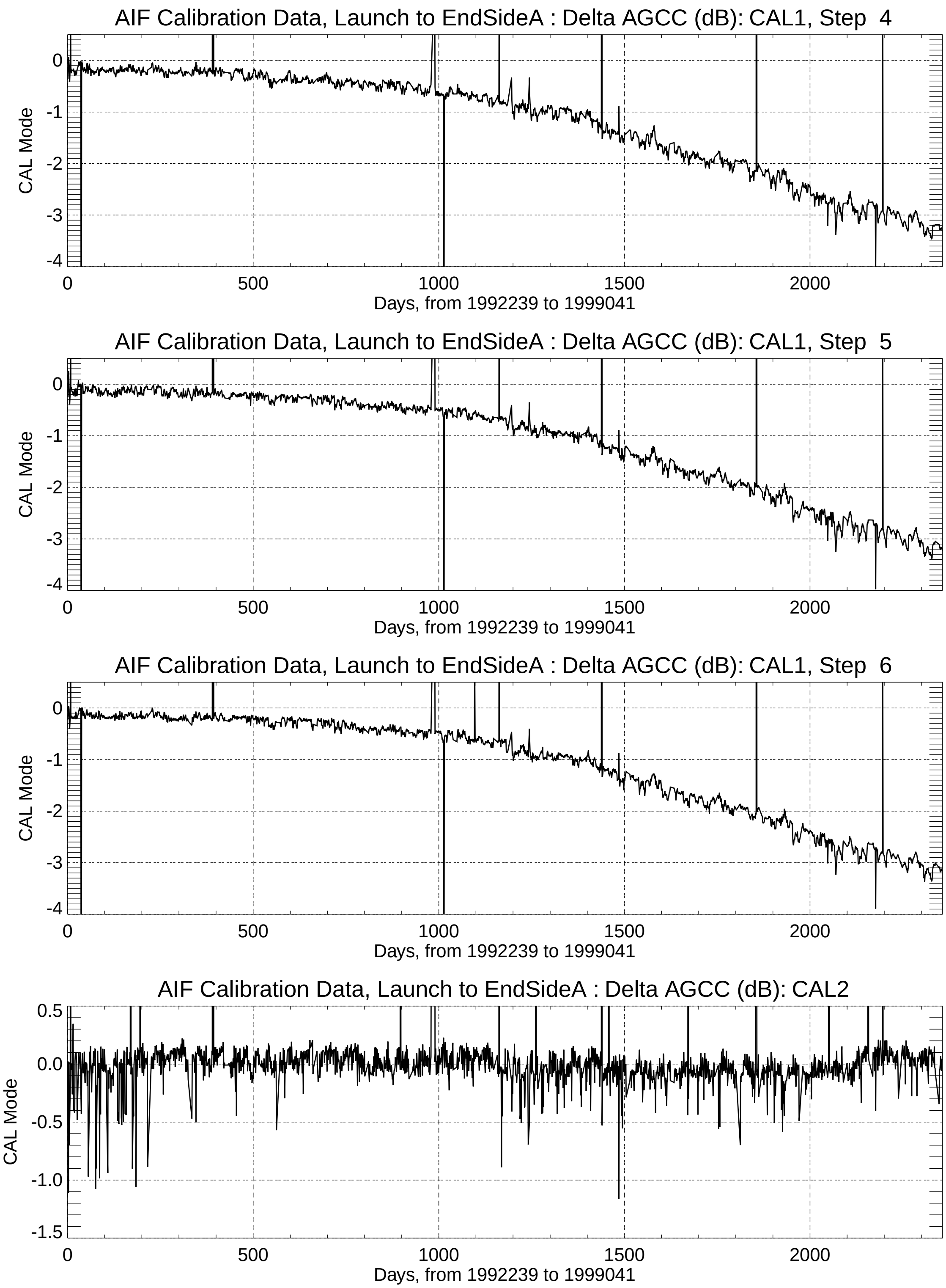

Figure 2-4 C-Band AGC CAL-1 and CAL-2 Results

additional 2.3 dB. Similar to Ku-Band, the C-Band CAL-2 exhibited a 0.1 dB positive change since the end of 1997.

These AGC changes are believed to be the result of normal component aging. A more thorough analysis of the AGC calibrations is presented in Section 3.2.

2.1.2.2 CAL-2 Differences over Water and Land

In the CAL-2 plots, for both Ku- and C-Band, there are occasional AGC decreases of approximately 0.9 dB. These decreases are more prevalent early in the mission. An examination of the early-mission CAL-2 calibrations with decreased signal levels uncovered the fact that they generally occurred over open ocean. Whenever the calibrations were over land areas, the AGC levels were normal.

The conclusion was that the decreases in power during CAL-2 are directly attributable to the type of surface directly below the altimeter. In CAL-2, the receive path is through the antenna, and higher passive emissions occur over land areas. Based on standard radiometric equations, the nominal emission difference between land and water is 0.83 dB, very close to the observed power difference. This CAL-2 study is documented in the TOPEX/Poseidon Research News (Hancock, et al, 1995)

2.2 Launch-to-Date Cycle Summaries

The data in the launch-to-date cycle summary plots which follow are extracted from the Geophysical Data Record (GDR) database at WFF. The criteria for TOPEX GDR measurements to be accepted for the WFF database are: 1) the data are classified as Deep Water, 2) the data are in normal Track Mode, and 3) selected data quality flags are not set.

For each measurement type, the plots contain one averaged measurement per cycle. The cycle average value is itself the mean of one-minute along-track boxcar averages, after editing. Data are excluded from the averaging process whenever the one-minute-averaged off-nadir angle exceeds 0.12 degree or the averaged Ku-Band sigma-naught exceeds 16 dB or whenever the number of non-flagged frames within the one-minute interval is fewer than 45. These edit criteria primarily have to do with eliminating the effects of sigma-naught blooms, which are briefly discussed in Section 3.3.2. As a result of this edit, approximately 15% of the database measurements are excluded from the averaging process. This tight editing is part of our effort to ensure that anomalous data are excluded from the performance assessment process.

Investigators should use the NASA radar altimeter (ALT) data products for data cycles 1-8 with great care. The reasons for this statement are described in Section 2.2 of the May 1996 Engineering Assessment Report.

2.2.1 Sea Surface Height

The sea surface heights (ssh) contained in the GDR files are based on combined heights. Cycle-average ssh are shown in Figure 2-5 "Cycle-Average Sea Surface Heights in Meters" on page 2-8. It is not possible to discern range drifts at the millimeter level from these data, but seasonal variations of sea level are observable.

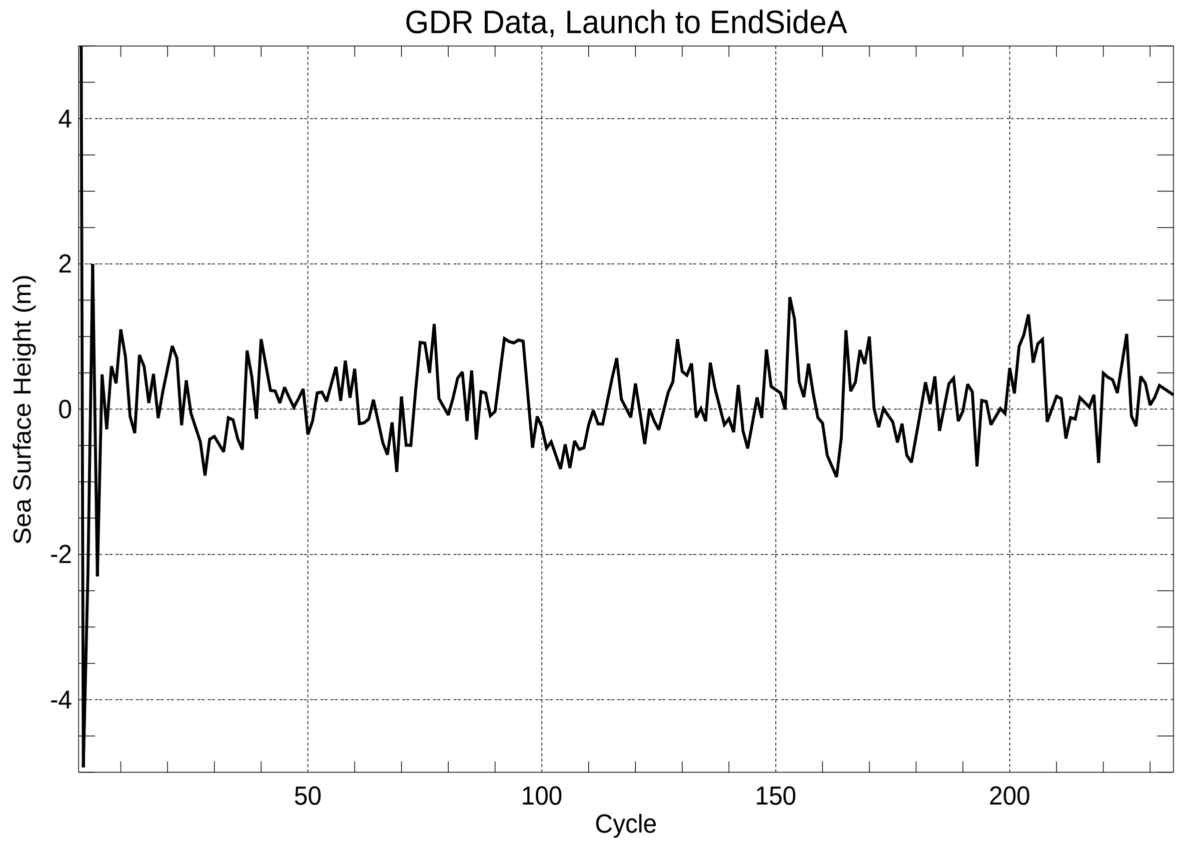

Figure 2-5 Cycle-Average Sea Surface Heights in Meters

Beginning with cycle 17, ssh has a 37-cycle periodicity. For example, lower ssh levels during cycles 25 through 35 are echoed during cycles 62 through 72, again during cycles 99 through 109, during cycles 136 through 146, during cycles 173 through 183, and again during cycles 210 through 220. Higher ssh levels are observed during cycles 37 through 43, during cycles 74 through 80, during cycles 111 through 117, during cycles 148 through 154, cycles 185 through 191, and again during cycles 222 through 228. [It is noted that a recent set of higher ssh cycles (185-191) are not as high as the earlier ones. It is postulated that this is the result of a redistribution of sea heights due to El Nino.] A 37-cycle repeatability is anticipated because, with each cycle lasting 9.916 days, there are approximately 37 (36.83) cycles per annum. Repeatability is not expected before cycle 17 because, prior to this, the NASA altimeter was not in TRACK mode for full cycles. This expected periodicity lends credence that the altimeter data remain internally consistent.

The only calibration correction applied to date to Side A range is the +100 mm added to C-Band range shortly after launch. This correction was described in Section 5.1.2 of the February 1994 Engineering Assessment Report.

2.2.2 Sigma-Naught

The sigma-naught cycle-averages, after adding the non-temperature-corrected sigma-naught corrections, are plotted in Figure 2-6 "Cycle-Average Ku-Band Sigma-naught in dB" on page 2-9 and Figure 2-7 "Cycle-Average C-Band Sigma-naught in dB" on page 2-10, for Ku-Band and C-Band, respectively.

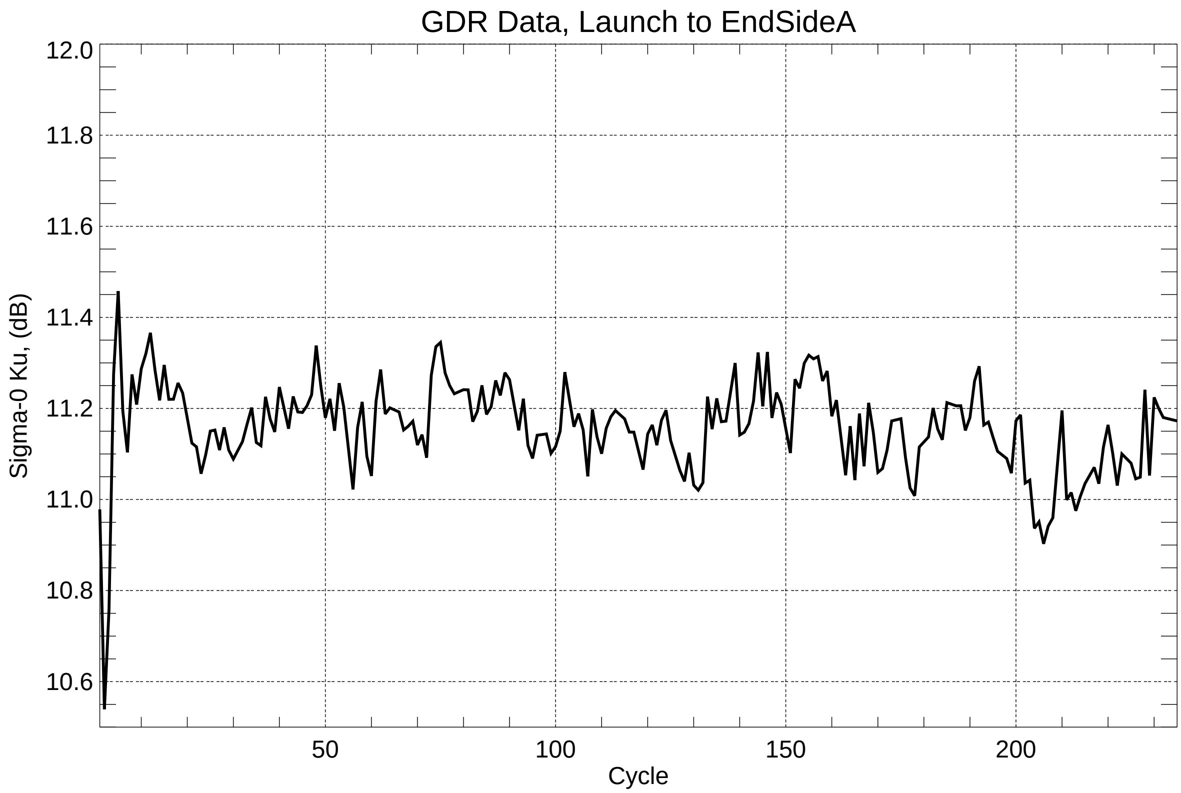

Figure 2-6 Cycle-Average Ku-Band Sigma-naught in dB

From cycle 17 to the present, Ku-Band sigma-naught cycle-averages, after correction, have generally remained within a window of 11.10±0.20 dB, and C-Band sigma-naught cycle-averages have generally remained at 14.70±0.20 dB. There are apparent annual cycles in the sigma-naught averages, particularly in the Ku-Band (low values occur at cycles 22, 59, 96, 132, 169 and 206). Even with the annual effects, the sigma-naughts have remained within the pre-launch design goal for sigma-naught accuracy of ±0.25 dB

2.2.3 Significant Wave Height

Ku-Band cycle-averages for significant wave height (swh) are shown in Figure 2-8 "Cycle-Average Ku-Band Significant Wave Height in Meters" on page 2-11. Subsequent to cycle 8, and prior to cycle 190, the cycle-average swh's remained in the range of 2.8+0.3 m, with no obvious long-term drift. However, beginning with cycle 190, the swh are observed to be anomalously high.

Upon the appearance of the anomalously high swh's, we consulted members of the TOPEX Science Team to discern whether the observed values might be real or might be due to an instrument effect. After a study, the cause was attributed to an instru-

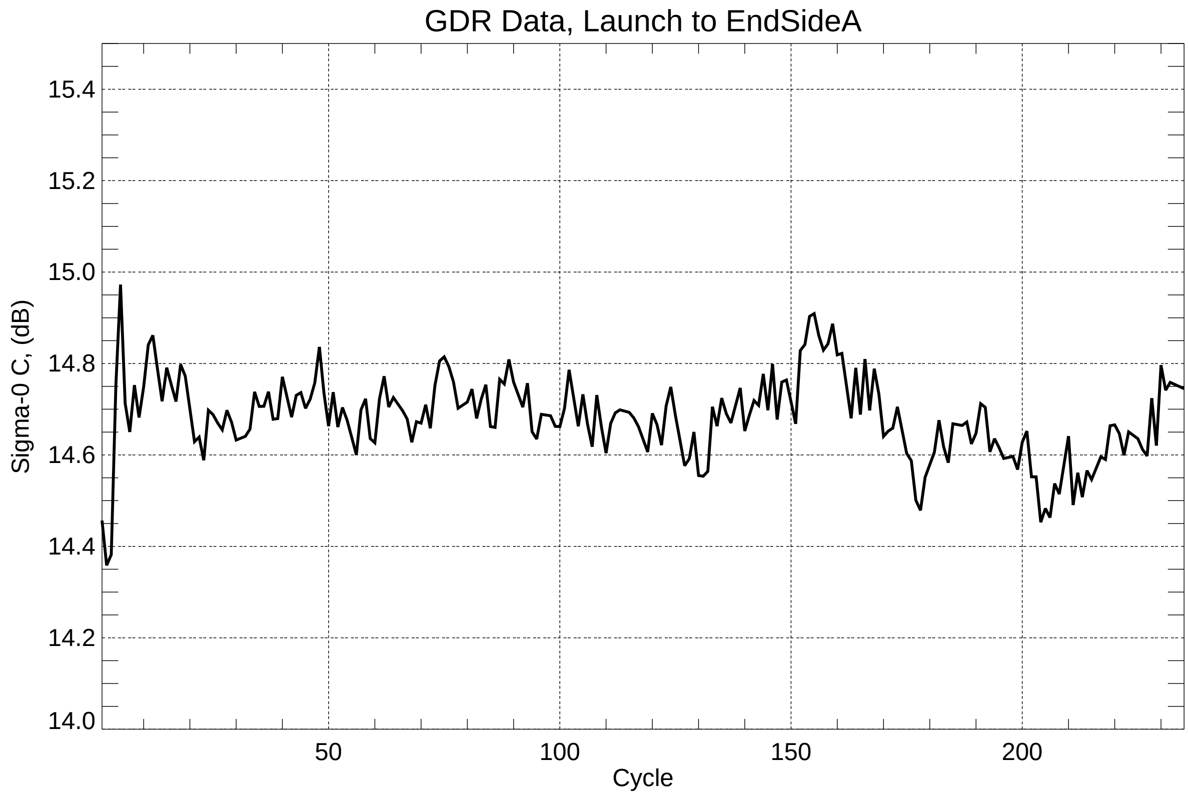

Figure 2-7 Cycle-Average C-Band Sigma-naught in dB

ment effect; this finding led to the decision to switch the Altimeter from Side A to Side B in February 1999. These high values are attributed to a change in the altimeter's Point Target Response (PTR); these effects are discussed further in Section 3.3.

Prior to Cycle 190, when the swh anomaly appeared, there is an annual cycle in the data, with particularly low swh's (2.5-2.6 m) centered around cycles 11, 48, 85, 122, and 159, gradually building up to 3.0-3.1 m swh centered around cycles 23, 60, 97, 134, and 171. Cycles 11, 48, 85, 122, and 159 occurred in early January 1993, January 1994, January 1995, January 1996 and January 1997, respectively, corresponding to summer in the southern hemisphere. Cycles 23, 60, 97, 134, and 171were in early May 1993, May 1994, May 1995, May 1996, and May 1997 respectively, corresponding with early fall in the southern hemisphere. The southern hemisphere is referred to here because there is a considerably higher percentage of the total ocean area south of the equator. Section 3.3.1 contains additional swh trend discussion.

2.2.4 Range RMS

The calculated Ku-Band range rms values depicted in Figure 2-9 "Cycle-Average Ku-Band Range RMS in Millimeters" on page 2-12 are based on the rms derivation described in Section 5.1.1 of the February 1994 Engineering Assessment Report. Subsequent to cycle 17, and prior to cycle 165 (March 1997), the rms values remained in a narrow band of 18.5±0.9 mm, and are observed to be directly correlated with the

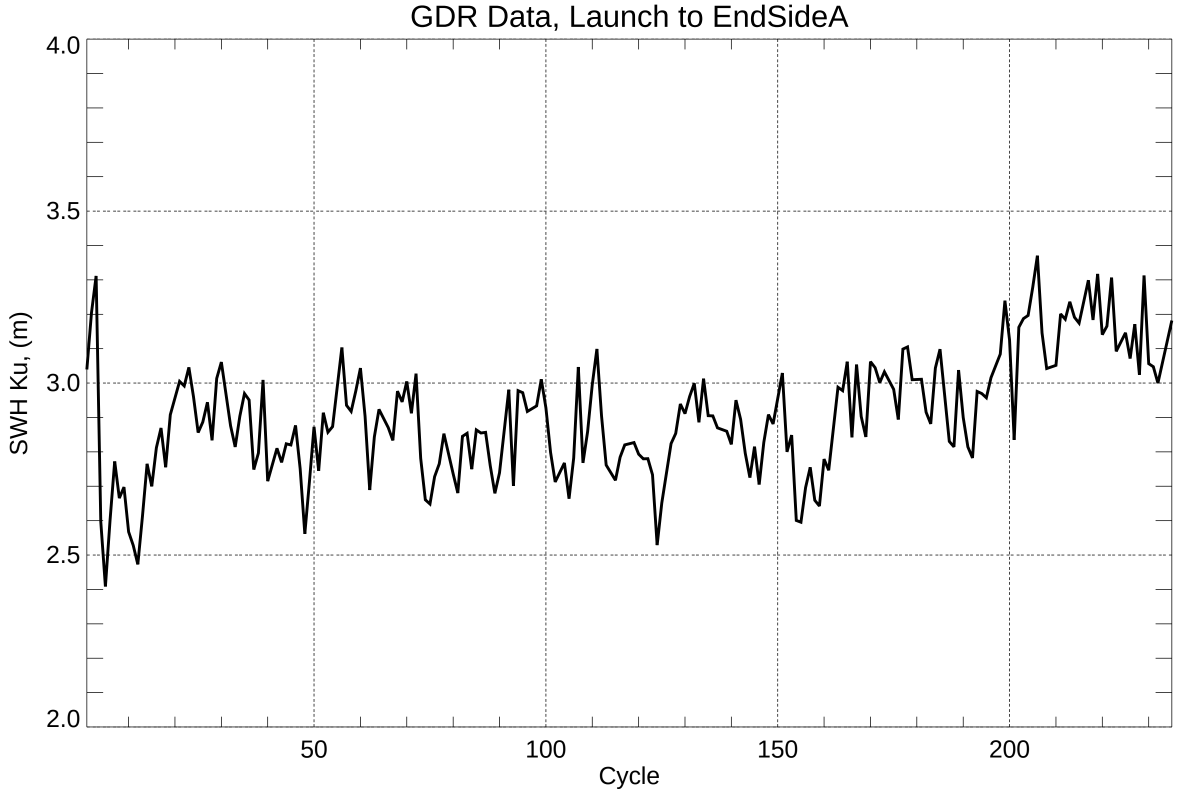

Figure 2-8 Cycle-Average Ku-Band Significant Wave Height in Meters

swh's in Figure 2-8; the higher the SWH, the higher the rms. Beginning with cycle 165 and continuing until Side A turnoff, the average range rms increased to 20.7 mm, generally following the trend of the false (instrument-related) swh increases.

2.2.5 Waveform Monitoring

Selected telemetered waveform gates during CAL-2 and STANDBY modes are monitored daily, to discern waveform changes throughout the mission. CAL-2 waveform sets are generally available twice per day, during calibrations. STANDBY waveforms are generally available four times per day, since the altimeter passes through STANDBY mode just prior to and immediately after each CALIBRATE mode. The relationship of telemetered waveform sample numbers to the onboard waveform sample numbers is listed in Table 6.2.1 of the February 1994 Engineering Assessment Report.

For both Ku-Band and C-Band, the monitored waveform samples are as follows: CAL-2 gates 23, 29, 48, and 93; and STANDBY gates 38, 39, 68, and 69. The Ku-Band waveform sample history is shown in Figure 2-10 "Ku-Band CAL-2 Waveform Sample History" on page 2-13 and Figure 2-11 "Ku-Band STANDBY Sample History" on page 2-14 for CAL-2 and STANDBY, respectively. The C-Band waveform history is depicted in Figure 2-12 "C-Band CAL-2 Waveform Samples" on page 2-15 and Figure

2-13 "C-Band STANDBY Waveform Samples" on page 2-16, respectively, for CAL-2 and STANDBY.

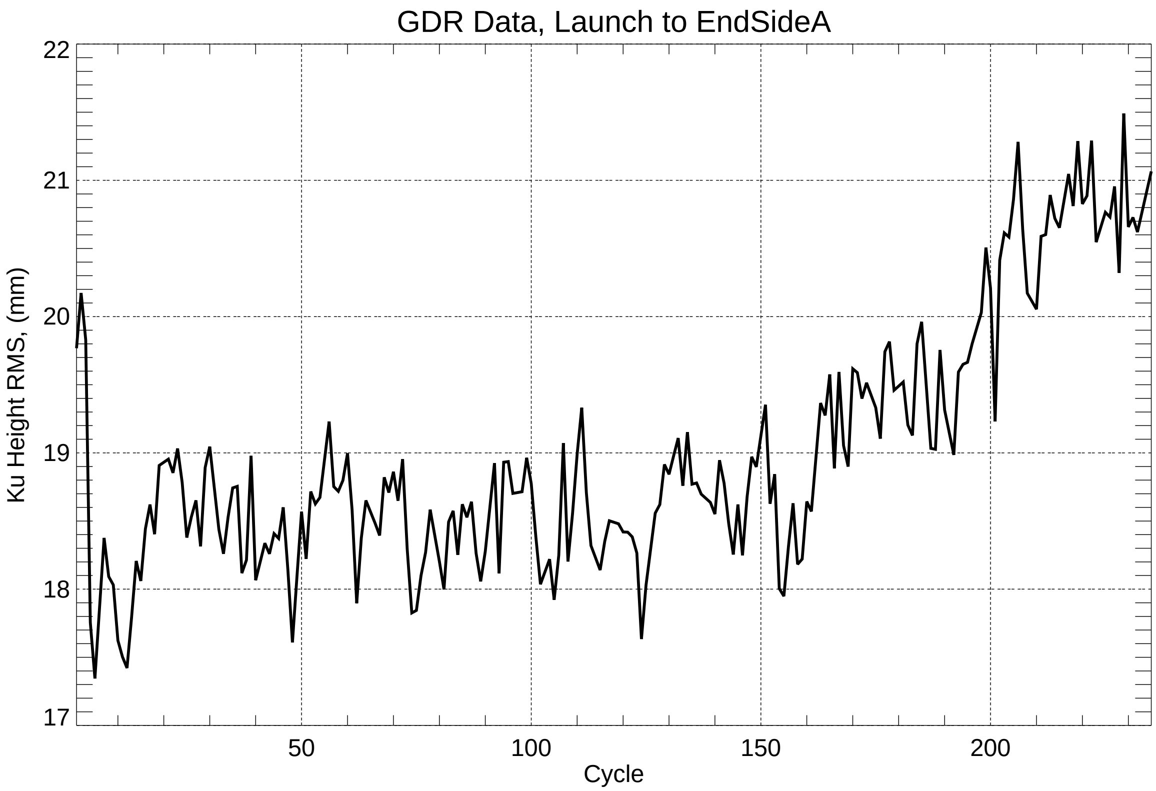

Figure 2-9 Cycle-Average Ku-Band Range RMS in Millimeters

The monitored Ku-Band CAL-2 waveform samples in Figure 2-10 have each varied less than 1% throughout the mission, and exhibit little or no temperature dependence.

The Ku-Band STANDBY waveform samples in Figure 2-11, however, have fluctuated during the mission. The power in gate 38 has a very noticeable inverse dependence on temperature (launch-to-date temperatures are shown in Figure 2-14, on the same horizontal time scale as the waveform samples). Gate 39 is also observed to have an inverse temperature dependence and, in addition, has had about a 55% reduction in power since launch; this large power reduction is of interest to us, but does not appear to be adversely affecting altimeter performance. Gate 68 has a slight inverse dependence on temperature, and has had a small (7%) decrease in power. Gate 69 also has a modest temperature dependence, and its power level has decreased a total of about 30% during the mission.

The C-Band CAL-2 waveforms samples, shown in Figure 2-12, are similar to the Ku-Band CAL-2 waveforms in that they have varied less than about 1%, and exhibit no apparent temperature dependence.

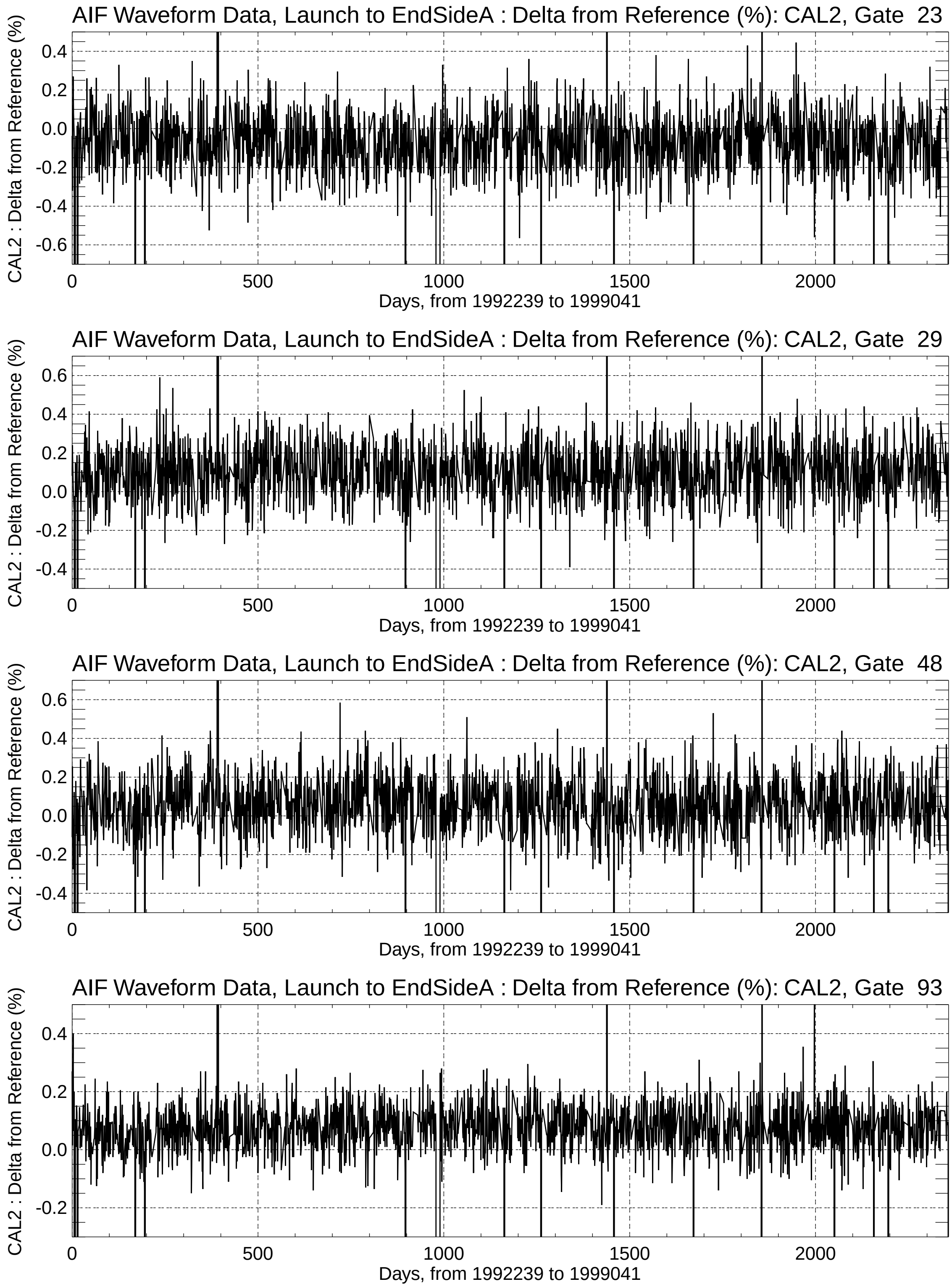

Figure 2-10 Ku-Band CAL-2 Waveform Sample History

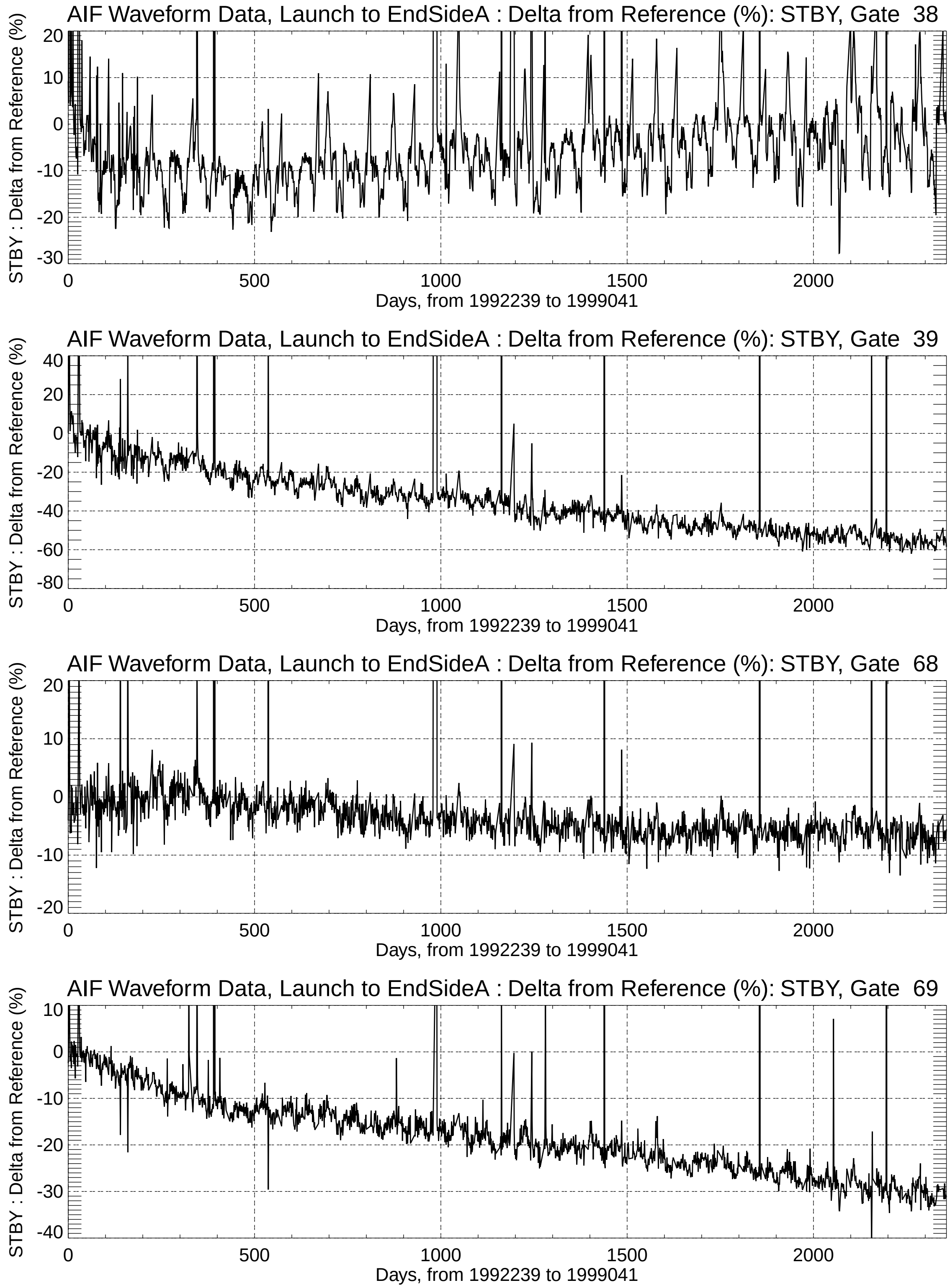

Figure 2-11 Ku-Band STANDBY Sample History

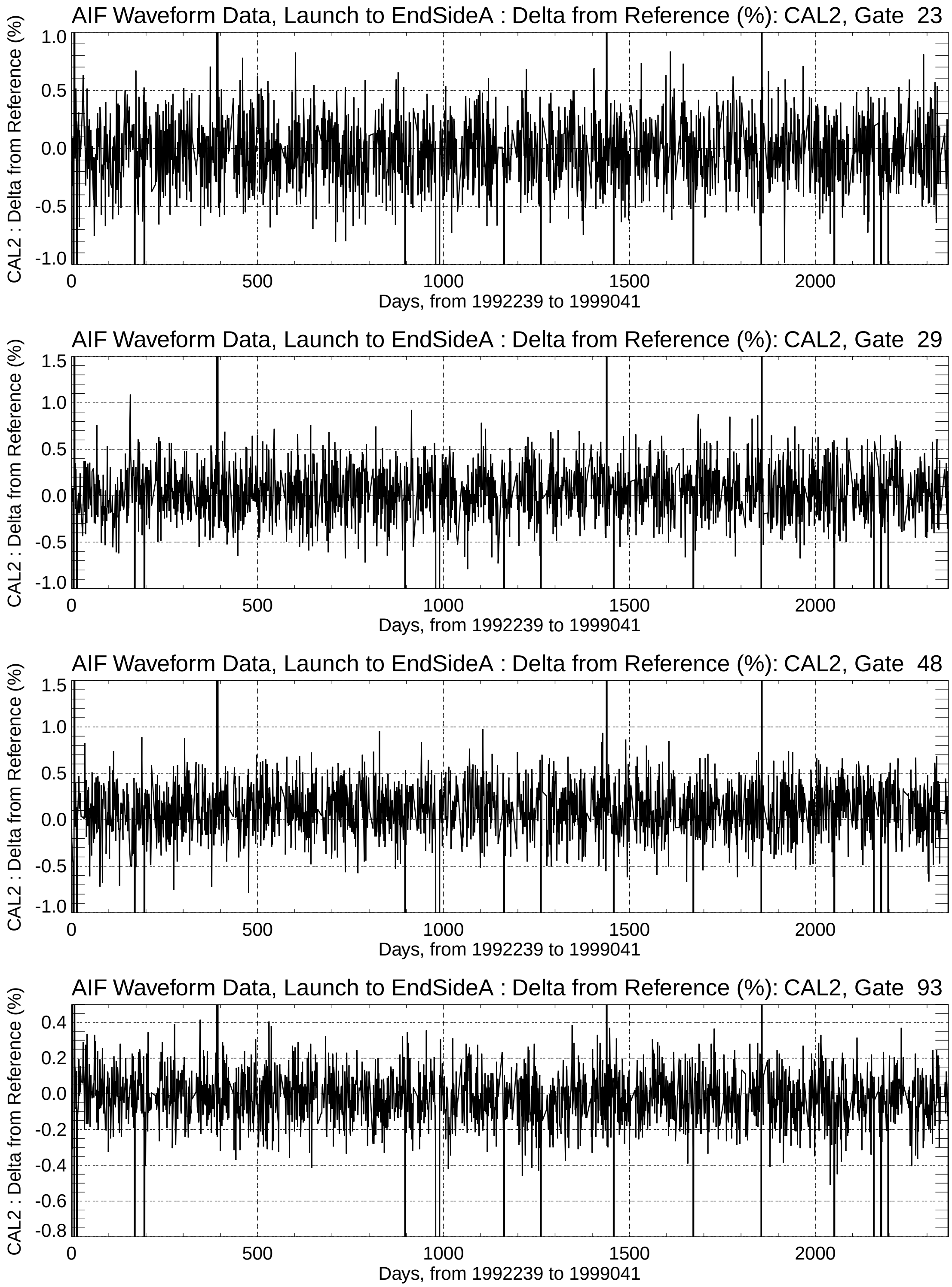

Figure 2-12 C-Band CAL-2 Waveform Samples

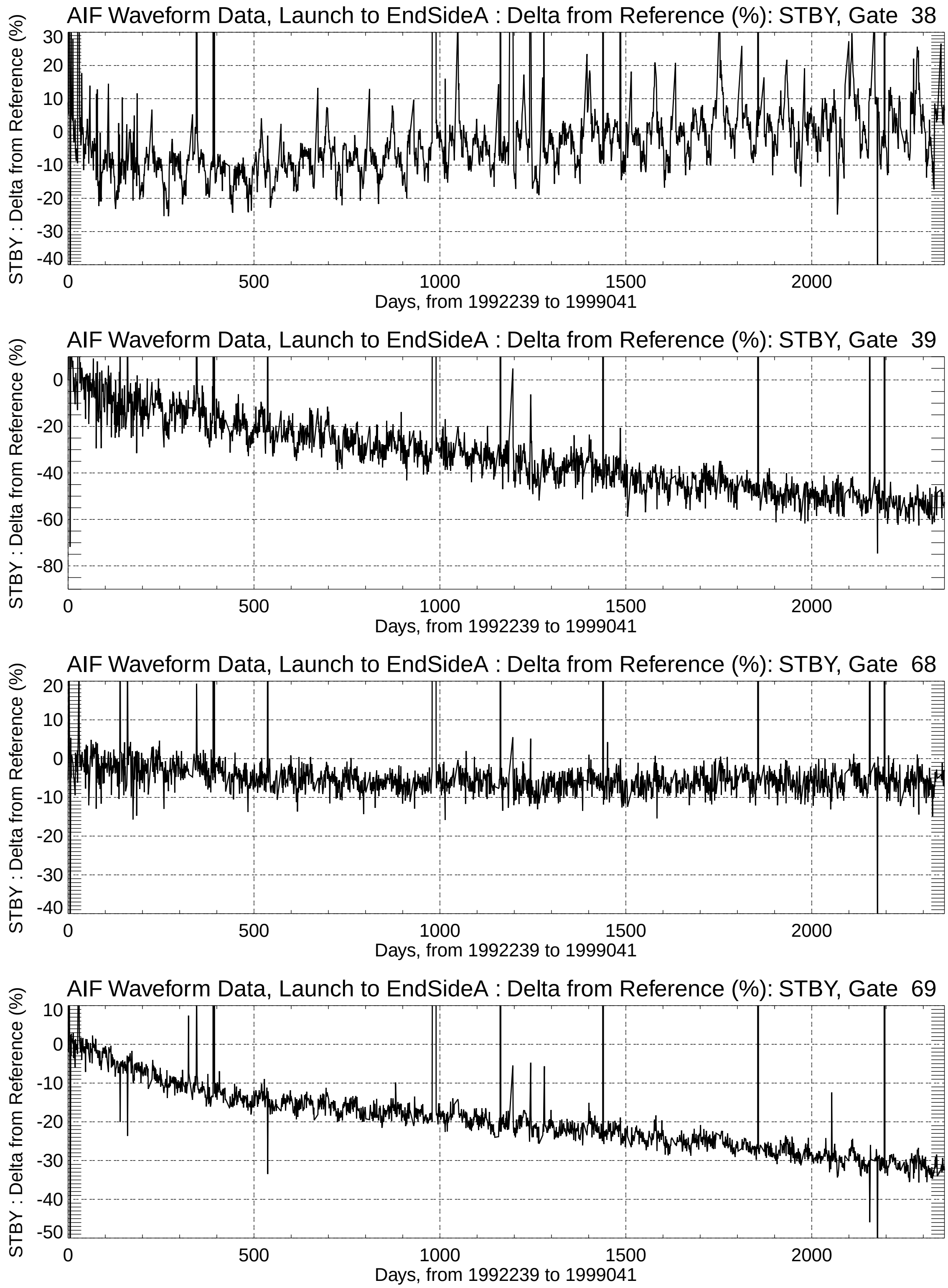

Figure 2-13 C-Band STANDBY Waveform Samples

The C-Band STANDBY waveform samples, shown in Figure 2-13, are also similar to their counterpart Ku-Band STANDBY waveforms. Gates 38, 39, 68, and 69 have an inverse dependence on temperature. Gate 39 has experienced about a 55% decrease in power since launch, gate 68 has decreased in power about 6%, and gate 69 has decreased approximately 32%. The rate of decrease for each of these three gates has been smaller since 1995 than for the prior years.

2.2.6 Engineering Monitors

Altimeter temperatures, voltages, powers and currents continue to be monitored. The system remains very stable, with no significant changes since launch. The engineering monitor plots presented in this section contain data based on 24-hour time periods, showing the average, the minimum, and the maximum values during each 24-hour period.

2.2.6.1 Temperatures

The temperatures of all 26 internal thermistors continued to be within the design temperature range and are within the ranges used during the pre-launch Hot and Cold Balance Tests. The minimum / maximum values for each of the thermistors during TRACK mode remained within the bounds listed in Table 7.1 of the February 1994 Engineering Assessment Report, and they compose plots 2 through 27 in Figure 2-14 "Engineering Monitor Histories" on page 2-18. [Note: Prior editions of this Engineering Assessment Report series included only three of the 26 internal thermistor plots. Since this is likely to be the final Engineering Assessment Report for Side A, all 26 thermistors are shown.]

Although not used during our routine monitoring, several of the altimeter-related baseplate temperature monitors serviced by Remote Interface Unit (RIU) 6B became uncalibrated on day 17 of 1995. The affected temperature monitors are listed in Section 2.2.6.1 of the 1996 Engineering Assessment Report. An abrupt change in the values occurred on that date, apparently due to a change in the current which is applied to the thermistor circuits

2.2.6.2 Voltages, Powers and Currents

The altimeter's 17 monitors for voltages, powers and currents remained at consistent levels, with little deviations. Their launch-to-date histories are also shown in Figure 2-14 "Engineering Monitor Histories".

The eight voltages [LVPS +12V, LVPS +28V, LVPS +15V, LVPS -15V, LVPS +5V(5%), LVPS +5V(1%), LVPS -5.2V and LVPS -6V], have changed very little from the minimum / maximum values listed in Table 7.2 of the February 1994 report. Four of the voltages (LVPS +12V, LVPS +28V, LVPS +15V and LVPS -5.2V) continue to exhibit more bit toggling than they did early in the mission, while the LVPS +5V(5%) is toggling less.

The following launch-to-turnoff changes for Side A are noted:

- LVPS +12V has had a generally linear 0.3V increase since launch.
- LVPS +28V has linearly increased from about 30.1 to 30.3V.

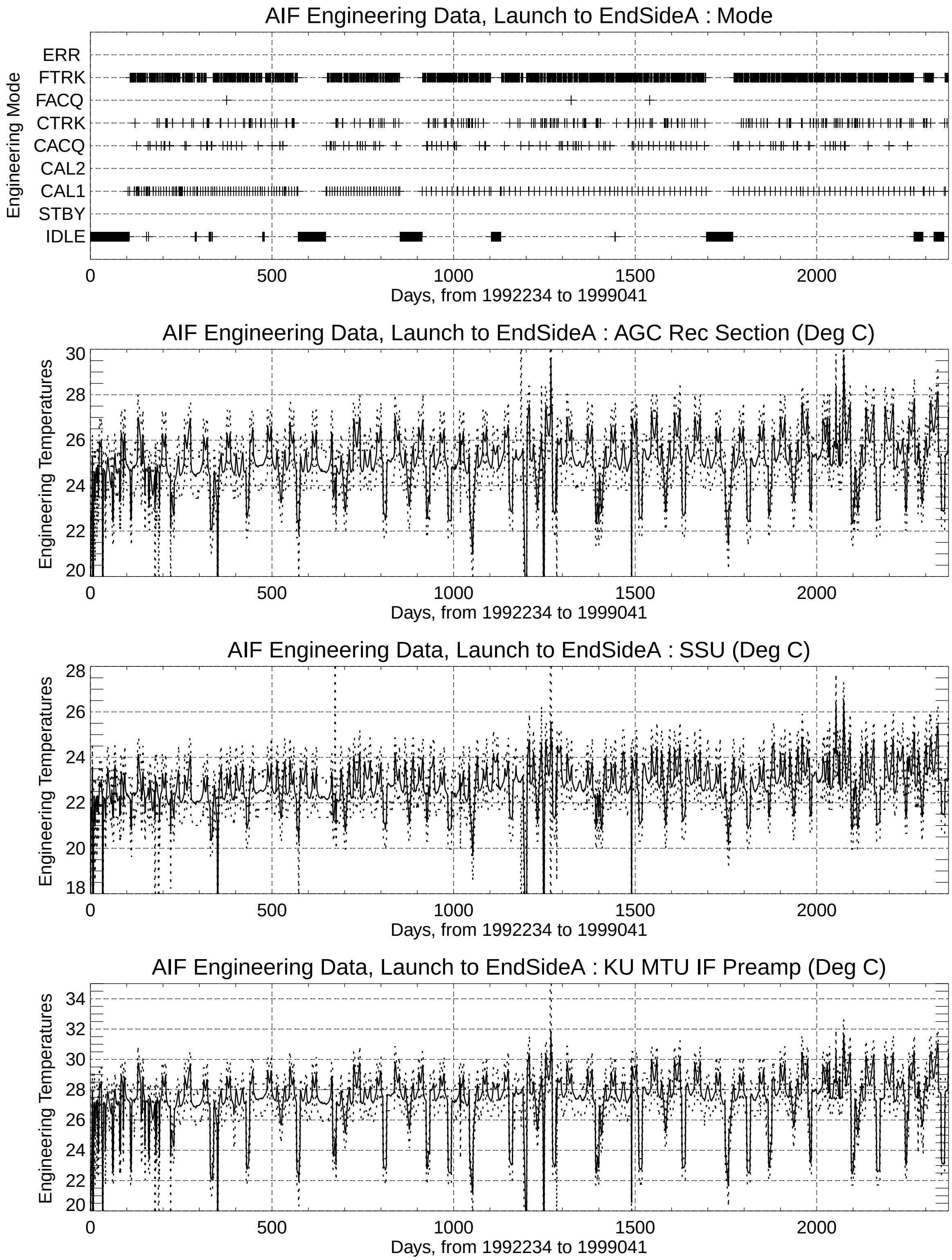

Figure 2-14 Engineering Monitor Histories

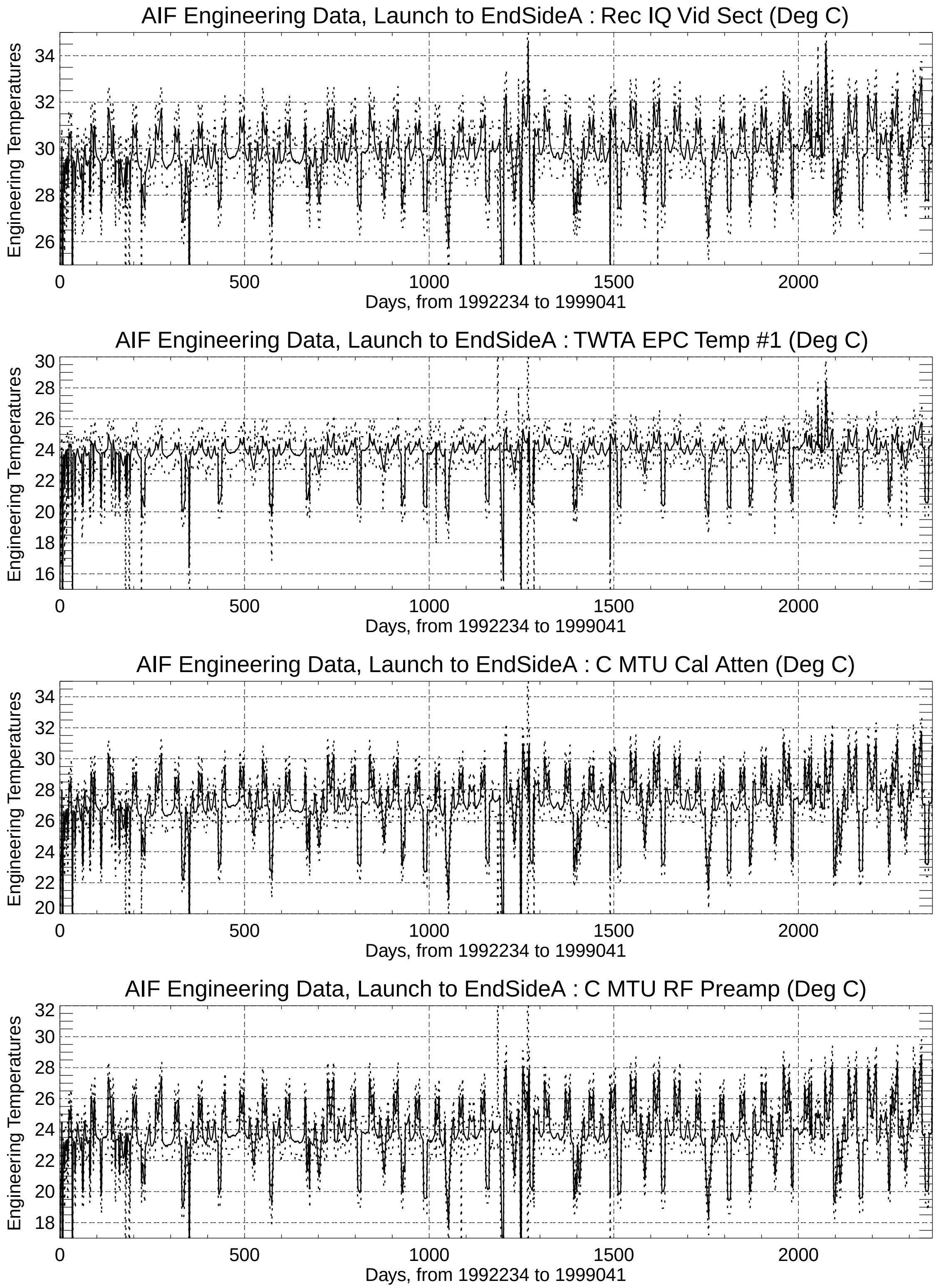

Figure 2-14 Engineering Monitor Histories (Continued)

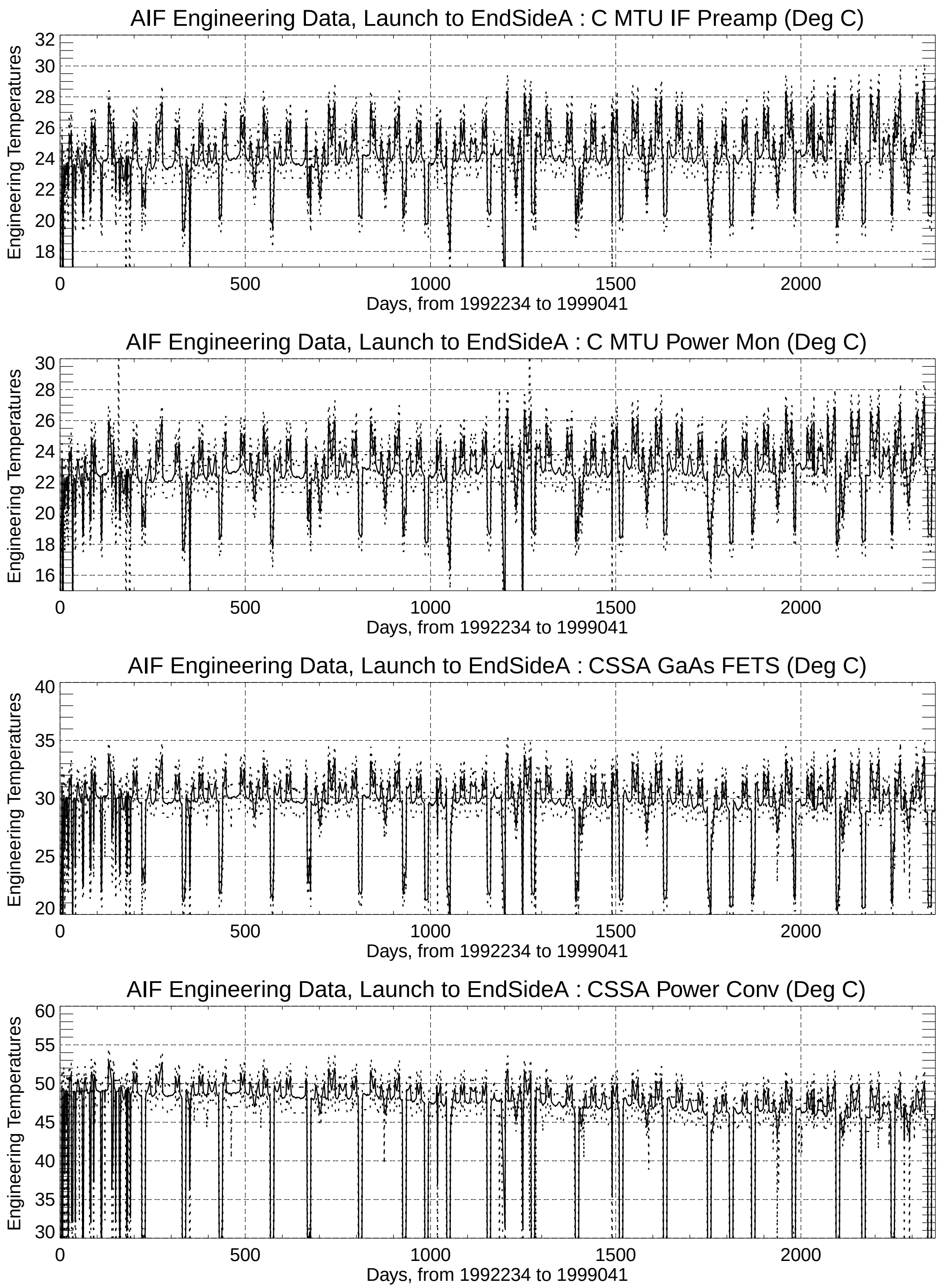

Figure 2-14 Engineering Monitor Histories (Continued)

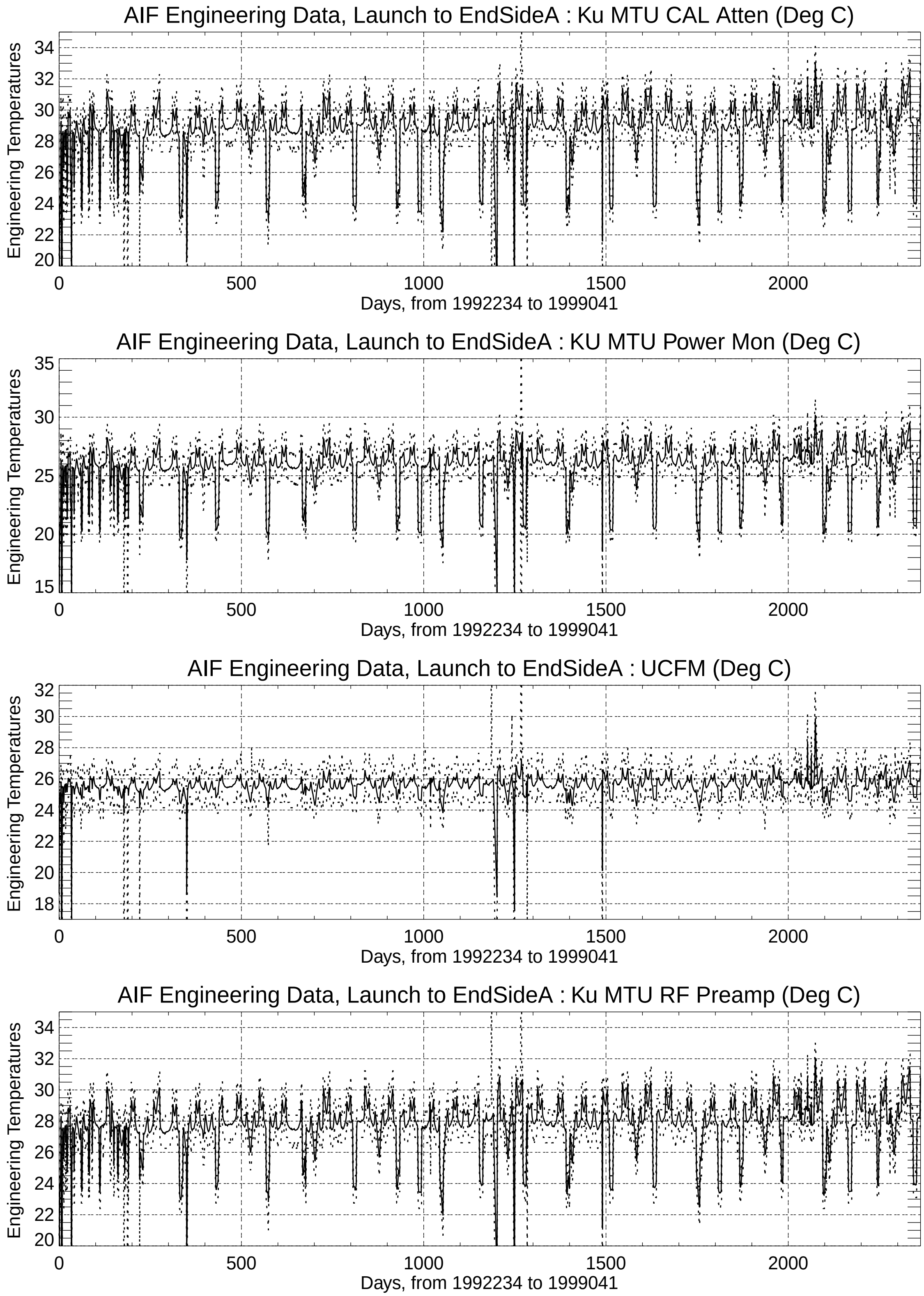

Figure 2-14 Engineering Monitor Histories (Continued)

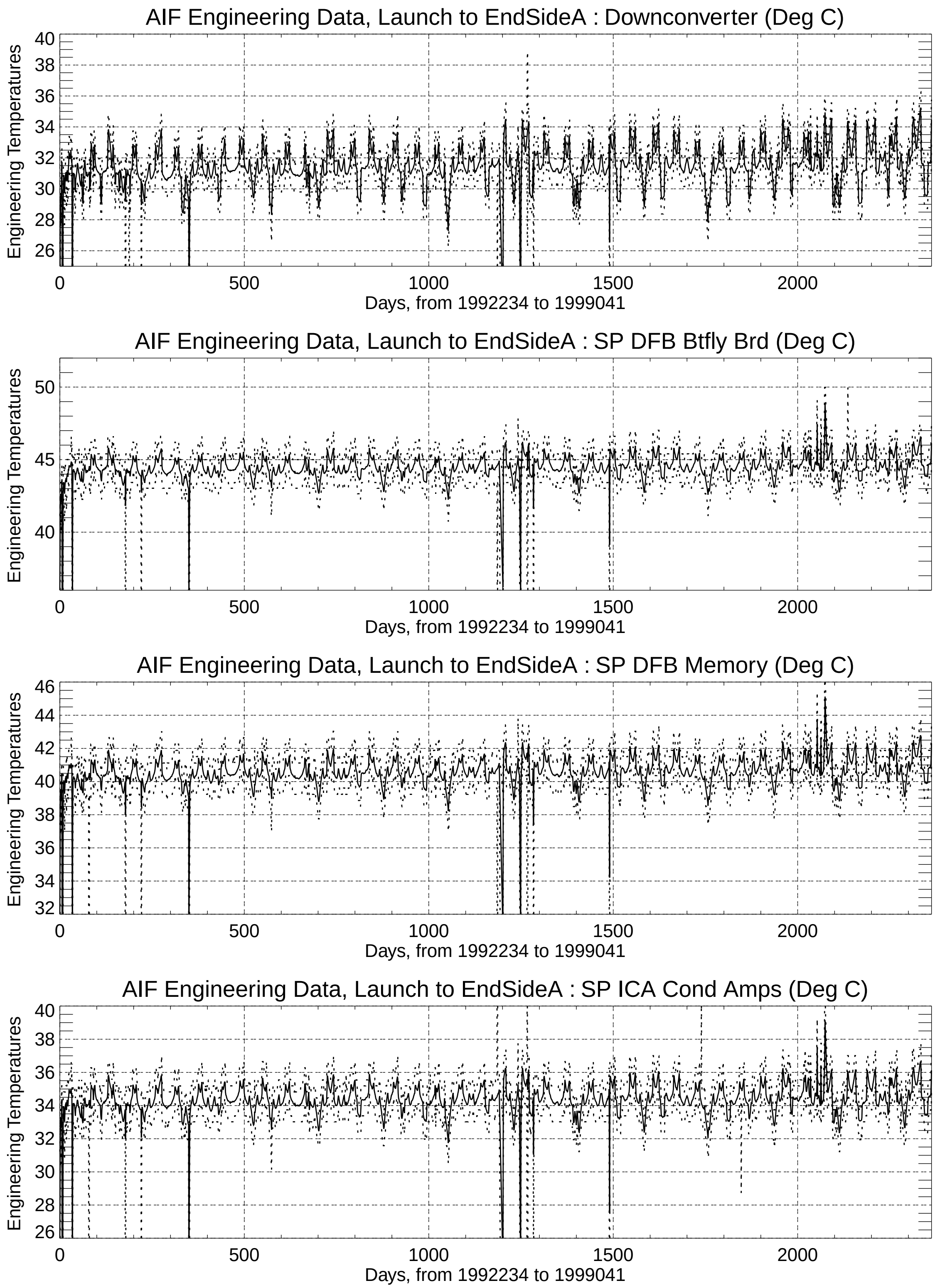

Figure 2-14 Engineering Monitor Histories (Continued)

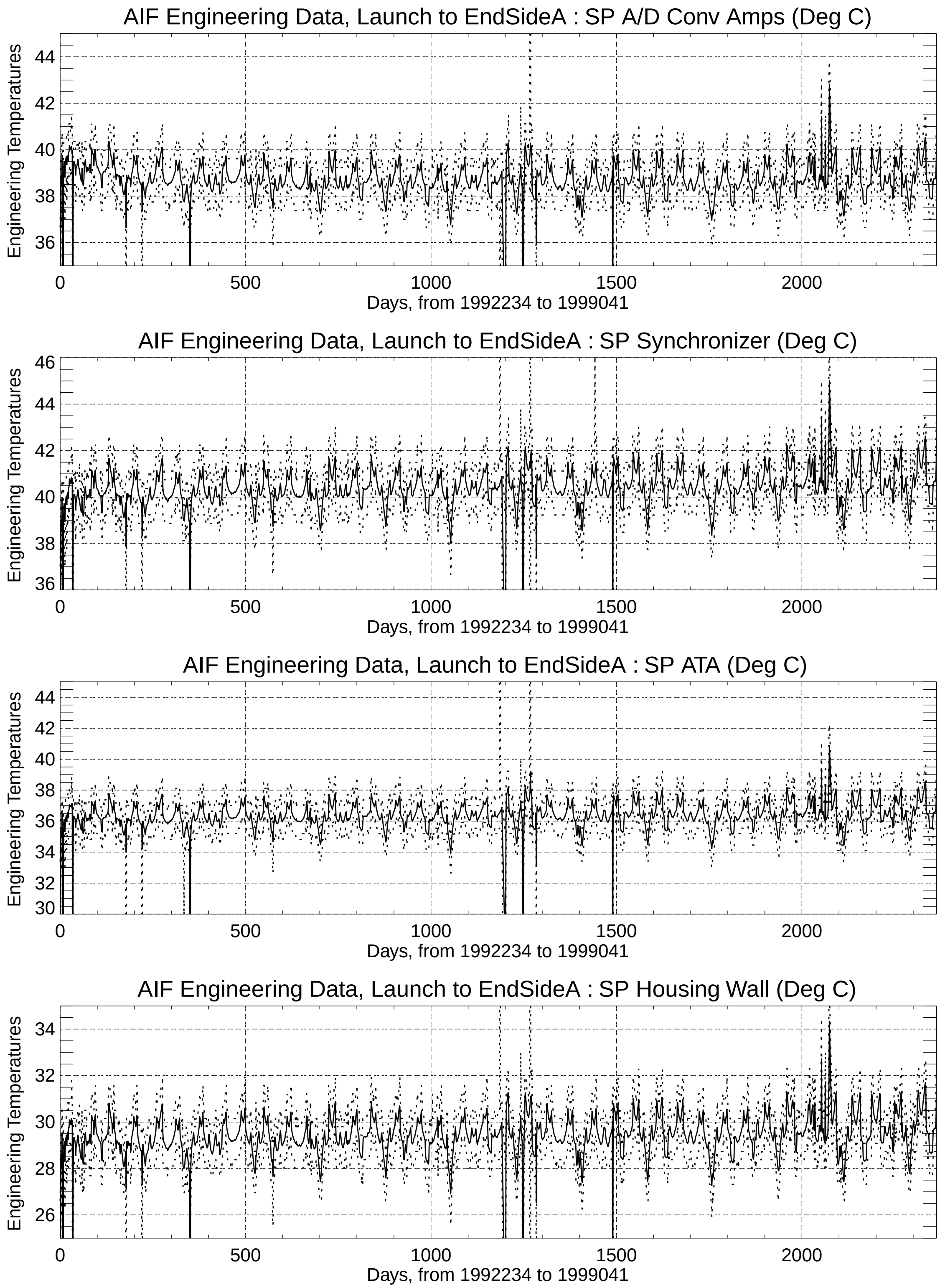

Figure 2-14 Engineering Monitor Histories (Continued)

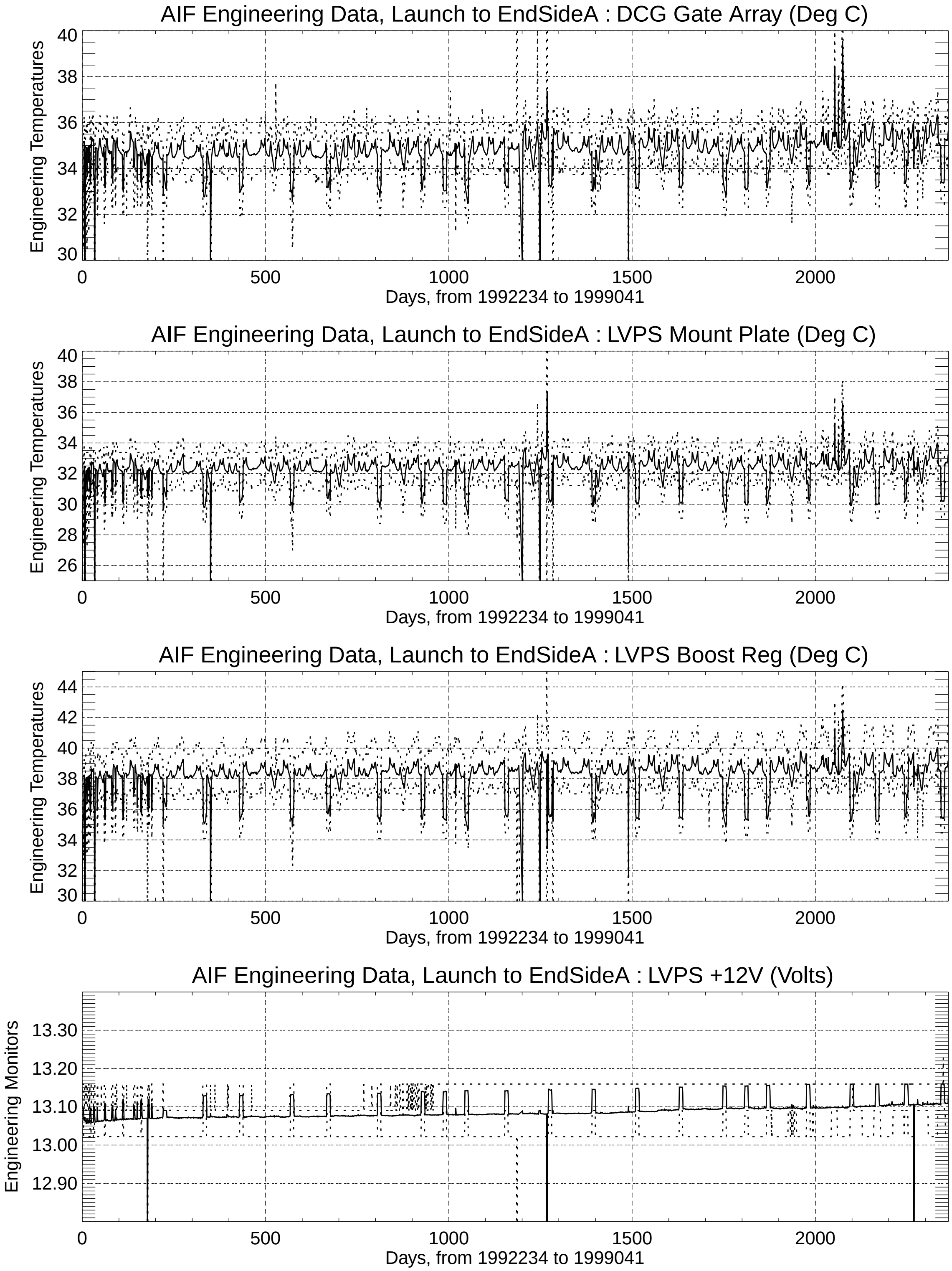

Figure 2-14 Engineering Monitor Histories (Continued)

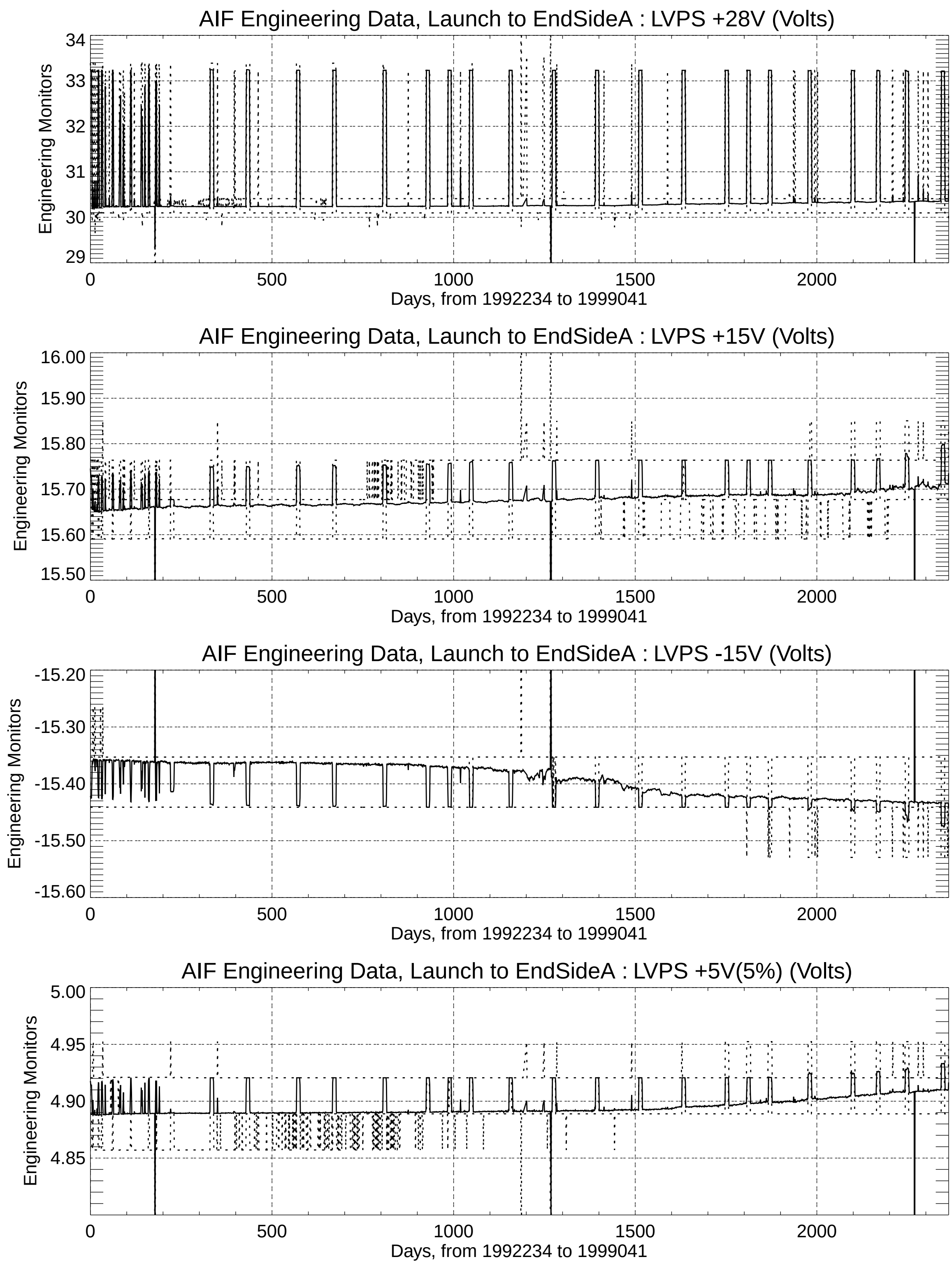

Figure 2-14 Engineering Monitor Histories (Continued)

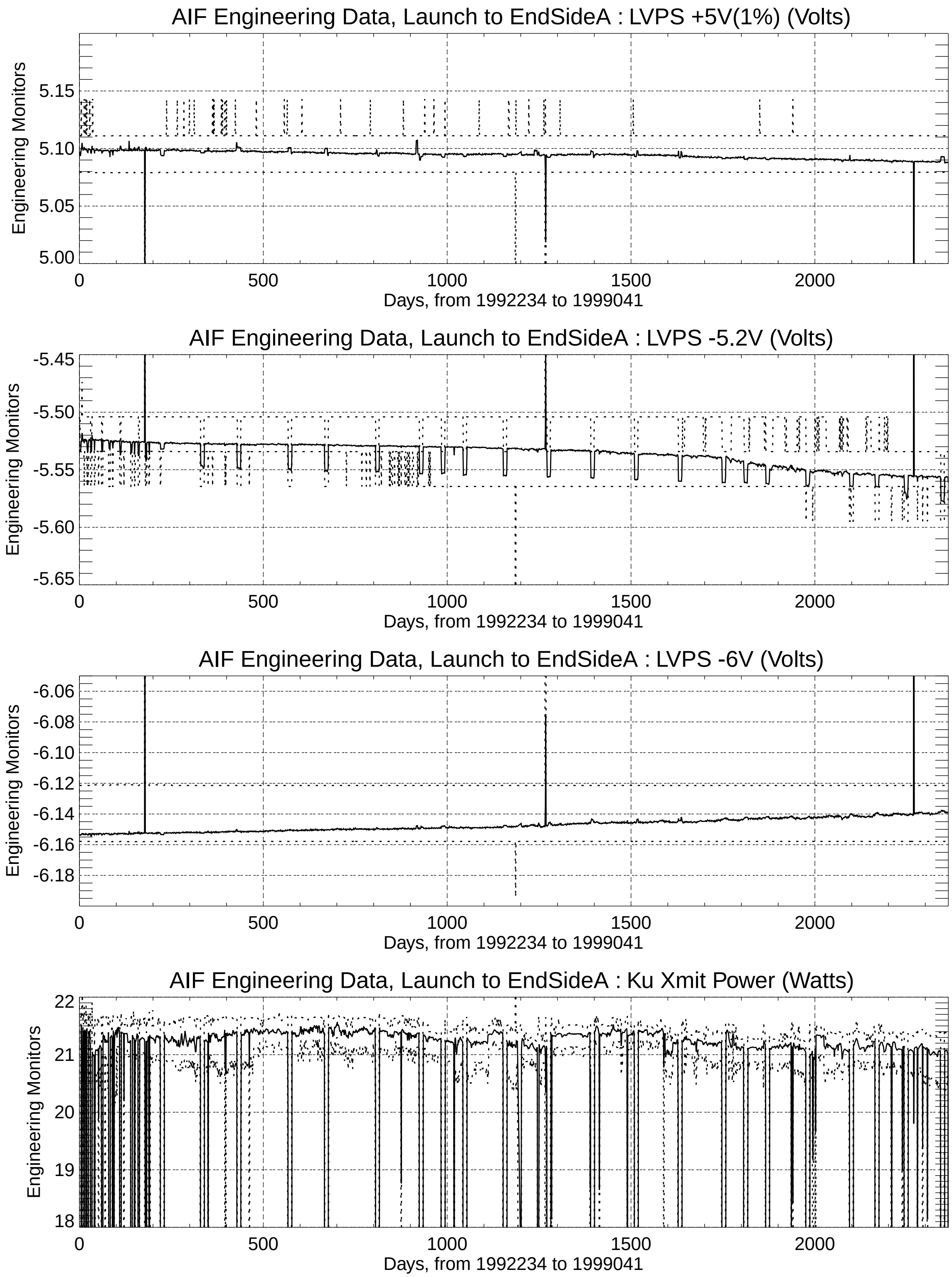

Figure 2-14 Engineering Monitor Histories (Continued)

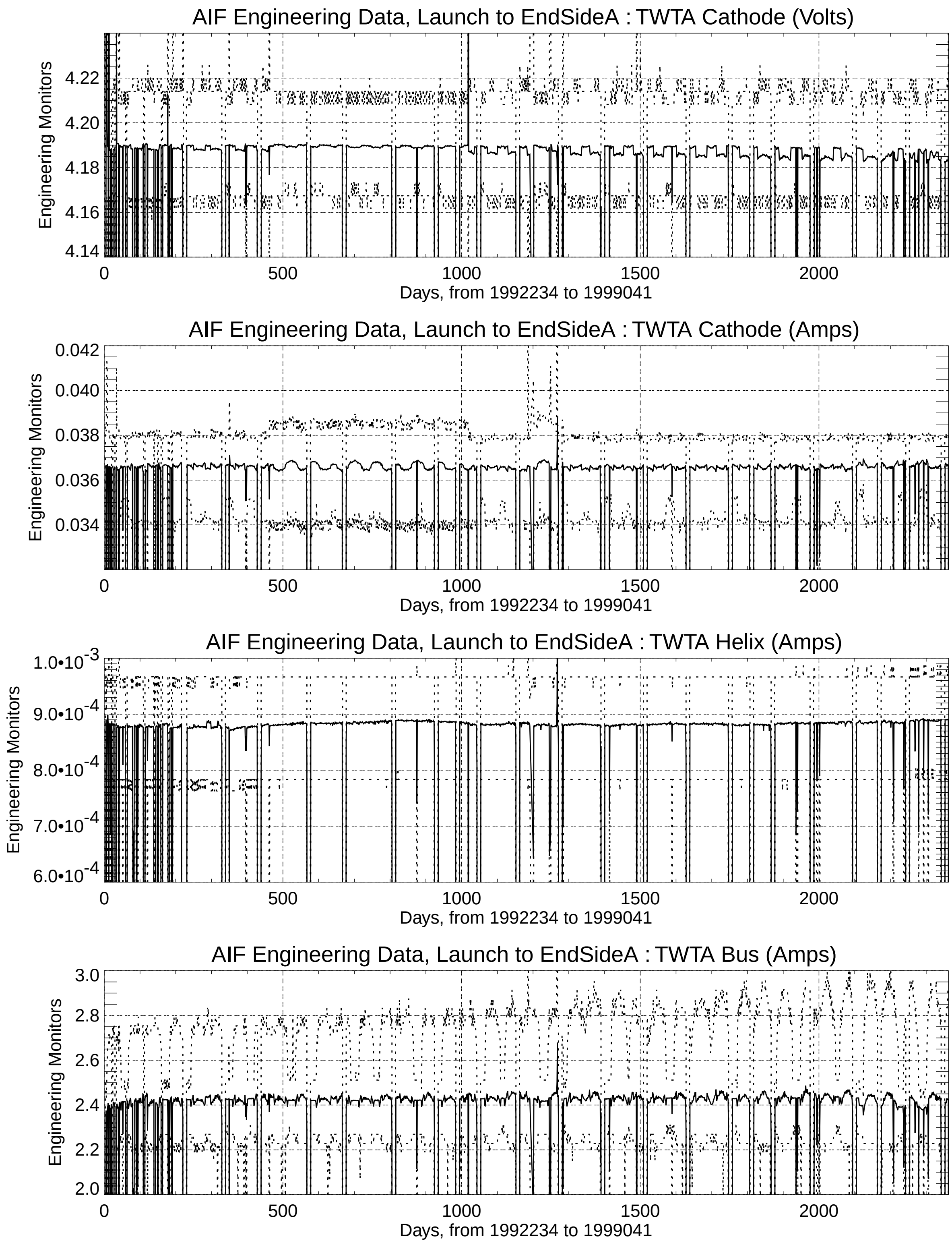

Figure 2-14 Engineering Monitor Histories (Continued)

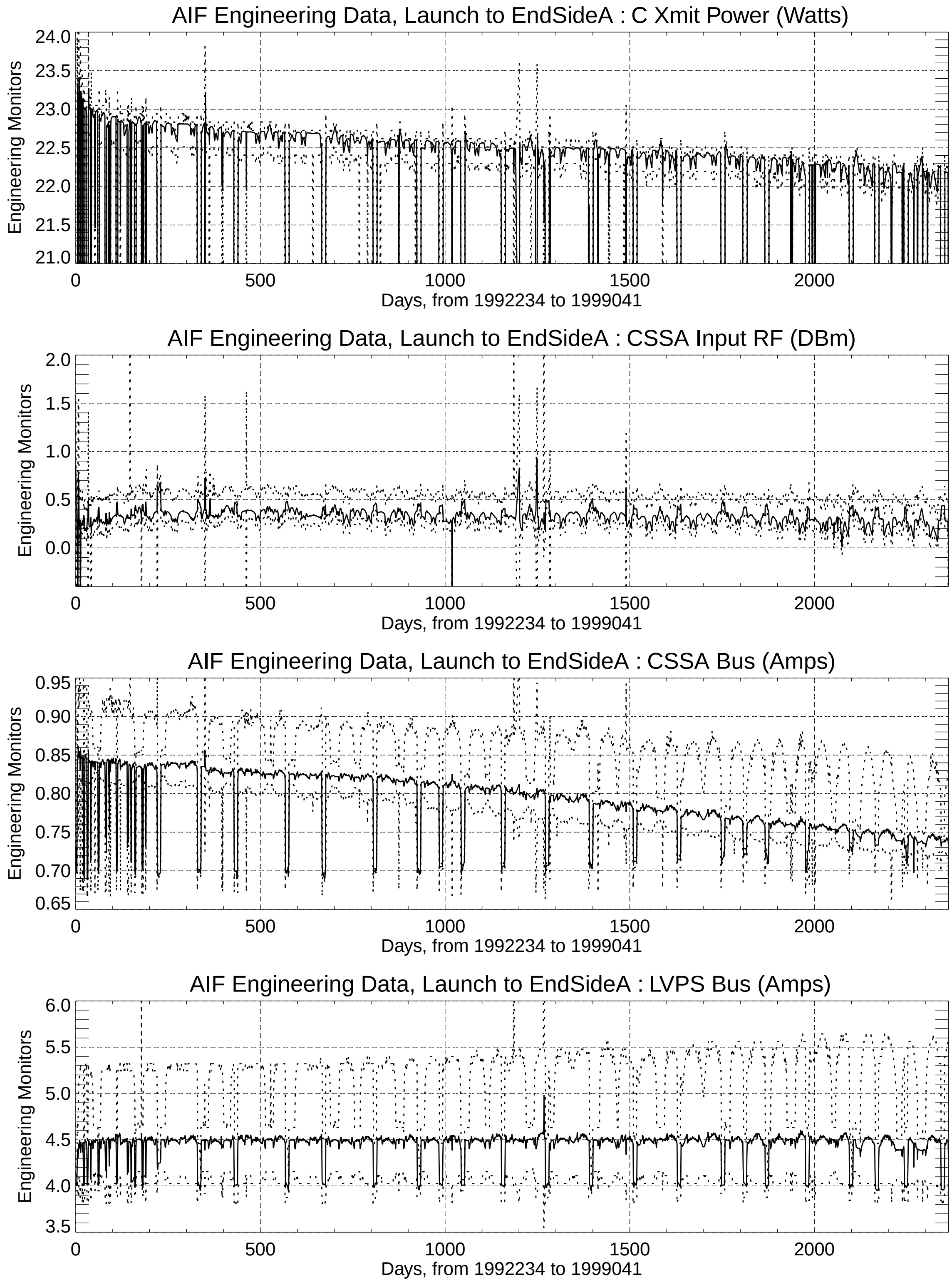

Figure 2-14 Engineering Monitor Histories (Continued)

- LVPS +15V has had a linear increase of 0.05V since launch.
- LVPS -15V has decreased about 0.9V; the decrease has generally been linear except for a ramp-down which occurred in 1996.
- LVPS +5V(5%) remained steady until 1997; since then, it has linearly increased 0.2V
- LVPS +5V(1%) has had a slight 0.01V linear decrease since launch.
- LVPS -5.2V has had a 0.03Vdecrease, with 0.01V of the decrease occurring in the past year.
- LVPS -6V has increased about 0.015V since launch.
- The Ku-Band Transmit Power decreased about 0.2 watt at the beginning of 1997, and decreased another 0.1 watt during each of the last two years. We have observed the effects of occasional bit toggling, or “clicking,” in the Ku transmit power monitor. The nature of the clicking is that the monitored power will decrease either 1, 2, 3 or 4 bits (a bit is equivalent to about 0.123 watt) for a few minutes, and then step back up to its nominal value. These observed short-duration power changes, whether real or not, do not appear to have affected the altimeter performance.
- The C-Band Transmit Power decreased an additional 0.2 watt during the past year, and its level is about 0.9 watt lower than its initial on-orbit level.
- There are no significant changes in the operating levels of the TWTA Cathode voltage, TWTA Cathode amperage, TWTA Helix current, CSSA Input RF power, or LVPS Bus Current.
- There continues to be gradual decrease in the CSSA Bus current level; the level has decreased 0.10 amp since launch.
- There has been a gradual increase in the maximum level of the TWTA Bus current; the increase has been 0.2 amps since launch.

2.2.7 Single Event Upsets

There have been a total of 322 Single Event Upsets (SEUs) from launch to the Side A turnoff on February 10, 1999. The vast majority of them occurred in the South Atlantic Anomaly, as shown in Figure 2-15 "Locations of SEU Occurrences" on page 2-30.

The altimeter processor automatically recovered from 286 of the SEUs; the other 36 required manual (ground-based command) resets. While the automatic resets generally resulted in the loss of only a few seconds of data, nine of them had data effects of longer duration. As of the Side A turnoff date, there have been a total of 46 anomalous resets (34 manual resets plus the 12 abnormal automatic resets); Table 2-1 "Anomalous Single Event Upsets" lists the dates of these 46 SEUs, along with the type of on-board reset and the duration of the effect on the data.

The dots in Figure 2-15 denote the locations of normal SEU occurrences, while the diamonds indicate that the SEU was abnormal.

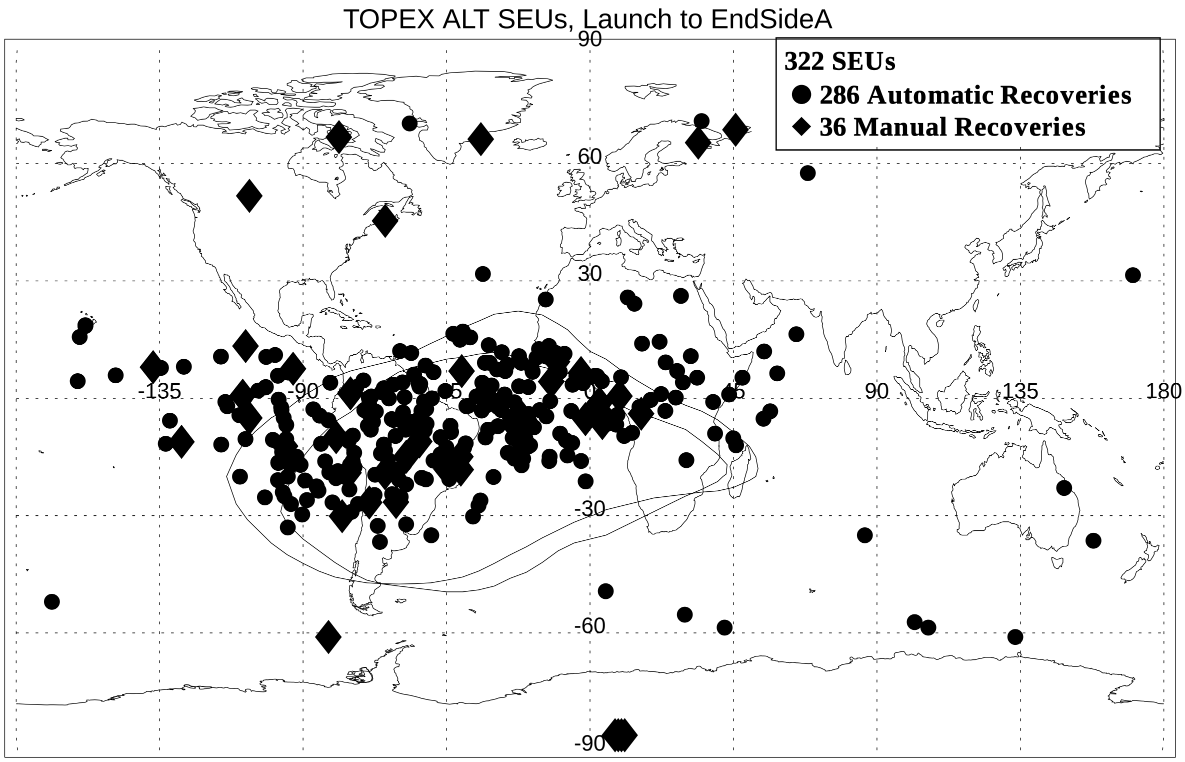

Figure 2-15 Locations of SEU Occurrences

Table 2-1 Anomalous Single Event Upsets

Year	Day	Duration (Hr)	Reset Type
1992	247	11.0	Automatic
1992	354	16.8	Manual
1993	012	0.5	Automatic
1993	230	1.3	Automatic
1993	264	14.5	Manual
1993	266	7.5	Manual
1993	307	2.3	Manual
1993	330	8.3	Manual
1994	001	3.8	Manual
1994	112	1.1	Manual
1994	256	4.3	Manual
1994	271	0.1	Automatic
1994	288	2.5	Manual

Table 2-1 Anomalous Single Event Upsets (Continued)

Year	Day	Duration (Hr)	Reset Type
1994	294	1.3	Automatic
1994	324	3.1	Manual
1995	012	0.7	Automatic
1995	083	1.6	Manual
1995	132	0.2	Manual
1995	157	8.4	Manual
1995	251	3.9	Manual
1995	306	3.4	Manual
1995	325	1.8	Manual
1995	327	3.5	Manual
1995	361	3.3	Manual
1996	018	2.0	Automatic
1996	041	3.1	Manual
1996	057	2.2	Manual
1996	077	1.6	Manual
1996	162	0.8	Automatic
1996	185	0.7	Automatic
1996	197	1.1	Manual
1996	217	2.8	Manual
1996	226	4.9	Manual
1996	362	4.8	Manual
1997	048	0.1	Automatic
1997	099	1.0	Manual
1997	191	0.1	Automatic
1997	237	1.6	Manual
1997	253	4.1	Manual
1997	268	2.8	Manual
1997	332	3.5	Manual
1998	013	3.9	Manual
1998	164	3.4	Manual

Table 2-1 Anomalous Single Event Upsets (Continued)

Year	Day	Duration (Hr)	Reset Type
1998	243	2.7	Manual
1998	254	2.5	Manual
1998	296	0.1	Automatic
		Total = 155.4 Hours	

The three diamonds at latitude -90 degrees were placed there because their occurrence times (and corresponding geographic locations) could not be pin-pointed due to the altimeter's being in IDLE mode, and because procedures had not, at that time, been implemented to record the IDLE-mode SEU times.

There were a total of 71 SEUs since the beginning of 1998, or about one every 5.8 days. For the total mission, the Side A SEU occurrence average has been one every 7.0 days.

There were five anomalous SEUs since the beginning of 1998; for four of them, the TOPEX/POSEIDON POCC reset the altimeter by transmitting Command Block SA28 (Processor Error Reset in Track Mode).

2.3 Launch-to-Date Key Events

The launch-to-date key events for the TOPEX Radar Altimeter are summarized in the NASA Altimeter - Key Events table given below.

On days 343, 346, and 347 in 1997, software was uploaded and tested with the expectation of extending the resolution of the AGC measurement from 0.25 dB to 0.015625 dB. The testing was successful, and the extended AGC software patch was implemented in February 1998 as a part of the routine on-board processing.

Another aspect of this February 1998 software patch is that coding was added with the goal of reducing the number of anomalous SEUs. Prior to the patch, the average time between required manual resets was 43.9 days. Subsequent to the patch, the average time between manual resets has been 92.7 days.

In response to the altimeter's PTR change (see Section 3.3), a Cal Sweep software patch was developed, and was uploaded on day 250 of 1998. The purpose of this patch is to monitor the shape of the altimeter's CAL-1 waveform, looking for changes over time. Cal Sweeps are now regularly performed, beginning with Side A on day 251 of 1998 and continuing through Side B operations.

Table 2-2 NASA Altimeter - Key Events

Day	Event
92/234	Altimeter Turned On to IDLE Mode
92/238	First TRACK
92/240	Safehold During Inclination Maneuver
92/242	Returned to TRACK Mode
92/242	Turned Off by TMON at Start of Eclipse
92/242	Returned to TRACK Mode
92/247	Improper SEU Recovery due to Corruption of Pulse Count Variable
92/268	Safehold
92/269	Returned to TRACK Mode
92/304	50ms Acquisition Parameter Set Upload
92/328	Software Patch to Refresh Pulse Count (see Day 247 above)
92/354	Loss of Science Data and Clock Between SEUs (lost 16 hours of data)
93/012	Improper SEU Recovery (lost 12 min. of data)
93/033	Transmit Test
93/069	Digital Filter-Bank Leakage Test
93/089	Turned Off by TMON
93/089	Changed to IDLE Mode For SSALT
93/089	Returned to TRACK Mode
93/089	Changed to IDLE Mode for SSALT
93/099	Returned to TRACK Mode
93/198	Changed to IDLE Mode For SSALT
93/208	Returned to TRACK Mode
93/218	Turned Off by TMON
93/219	Returned to TRACK Mode
93/230	Improper SEU Recovery (lost 1.5 hours of data)
93/264	Improper SEU Recovery (lost 14.5 hours of data)
93/266	Improper SEU Recovery (lost 7.5 hours of data)

Table 2-2 NASA Altimeter - Key Events (Continued)

Day	Event
93/297	Changed to IDLE Mode For SSALT
93/307	Returned to TRACK Mode
93/307	Improper SEU Recovery (lost 2.3 hours of data)
93/330	Improper SEU Recovery (lost 8.2 hours of data)
94/001	Improper SEU Recovery (lost 3.7 hours of data)
94/041	Transmit Test
94/042	Transmit Test
94/045	Transmit Test
94/071	Changed to IDLE Mode For SSALT
94/081	Returned to TRACK Mode
94/112	Improper SEU Recovery (lost 1.1 hours of data)
94/170	Changed to IDLE Mode For SSALT
94/180	Returned to TRACK Mode
94/256	Improper SEU Recovery (lost 4.3 hours of data)
94/288	Improper SEU Recovery (lost 2.5 hours of data)
94/294	Improper SEU Recovery (lost 1.3 hours of data)
94/309	Changed to IDLE Mode for SSALT
94/319	Returned to TRACK Mode
94/324	Improper SEU Recovery (lost 3.1 hours of data)
95/013	Warm boot (lost 0.7 hours of data)
95/040	Changed Operating Parameter Set for Faster Acquisition after a Reset
95/040	Digital Filter-Bank Leakage Test (lost 0.3 hours of data)
95/063	Changed to IDLE Mode for SSALT
95/073	Returned to TRACK Mode
95/083	Improper SEU Recovery (lost 1.6 hours of data)
95/123	Changed to IDLE Mode for SSALT
95/132	Returned to TRACK Mode

Table 2-2 NASA Altimeter - Key Events (Continued)

Day	Event
95/157	Improper SEU Recovery (lost 8.4 hours of data)
95/182	Changed to IDLE Mode for SSALT
95/192	Returned to TRACK Mode
95/251	Improper SEU Recovery (lost 3.9 hours of data)
95/291	Changed to IDLE Mode for SSALT
95/301	Returned to TRACK Mode
95/306	Improper SEU Recovery (lost 3.4 hours of data)
95/325	Improper SEU Recovery (lost 1.8 hours of data)
95/327	Improper SEU Recovery (lost 3.5 hours of data)
95/330	Spacecraft Safehold (lost 230 hours of data)
95/340	Returned to TRACK Mode
95/361	Improper SEU Recovery (lost 3.3 hours of data)
96/019	Warm boot (lost 2.0 hours of data)
96/020	Spacecraft Safehold (lost 68 hours of data)
96/040	Digital Filter-Bank Leakage Test (lost 0.3 hours of data)
96/041	Improper SEU Recovery (lost 3.1 hours of data)
96/046	Changed to IDLE Mode for SSALT
96/056	Returned to TRACK Mode
96/057	Improper SEU Recovery (lost 2.2 hours of data)
96/058	Turned Off by TMON (lost 5.3 hours of data)
96/077	Improper SEU Recovery (lost 1.6 hours of data)
96/083	Onboard Tape Recorder Problem (lost 0.5 hours of data)
96/150	Onboard Tape Recorder Problem (lost 1.6 hours of data)
96/162	Warm boot (lost 0.8 hours of data)
96/164	Changed to IDLE Mode for SSALT
96/174	Returned to TRACK Mode
96/178	Onboard Tape Recorder Problem (lost 0.4 hours of data)

Table 2-2 NASA Altimeter - Key Events (Continued)

Day	Event
96/187	Warm boot (lost 0.7 hours of data)
96/197	Improper SEU Recovery (lost 1.1 hours of data)
96/217	Improper SEU Recovery (lost 2.8 hours of data)
96/226	Improper SEU Recovery (lost 4.9 hours of data)
96/236	Digital Filter-Bank Leakage Test (lost 0.8 hours of data)
96/263	Turned off by TMON (lost 19.0 hours of data)
96/283	Changed to IDLE Mode for SSALT
96/293	Returned to TRACK Mode
96/362	C-Band Transmit on Side B (lost 4.8 hours of data)
97/036	Changed to IDLE Mode for SSALT
97/046	Returned to TRACK Mode
97/084	Digital Filter-Bank Leakage Test (lost 0.6 hours of mostly land data)
97/099	Improper SEU Recovery (lost 1.0 hours of data)
97/155	Changed to IDLE Mode for SSALT
97/165	Returned to TRACK Mode
97/215	Changed to IDLE Mode for SSALT
97/224	Returned to TRACK Mode
97/237	Improper SEU Recovery (lost 1.6 hours of data)
97/253	Improper SEU Recovery (lost 4.1 hours of data)
97/267	Digital Filter-Bank Leakage Test (lost 0.3 hours of land data)
97/268	Improper SEU Recovery (lost 2.8 hours of data)
97/274	Changed to IDLE Mode for SSALT
97/284	Returned to TRACK Mode
97/332	Improper SEU Recovery (lost 3.5 hours of data)
97/343	Uploaded Extended AGC Software (lost 1.4 hours of data)
97/346	Uploaded Extended AGC Software (lost 0.4 hours of land data)
97/347	Uploaded Extended AGC Software (lost 0.3 hours of land data)

Table 2-2 NASA Altimeter - Key Events (Continued)

Day	Event
97/349	ASTRA1-A SEU (off-nadir excursion affected 11.9 hours of data)
98/013	Improper SEU Recovery (lost 3.9 hours of data)
98/018	Changed to IDLE Mode for SSALT
98/028	Returned to TRACK Mode
98/028	Uploaded Extended AGC Software (lost 0.3 hours of land data)
98/029	Tested Extended AGC Software (lost 0.7 hours of mostly land data)
98/037	Tested Extended AGC Software (lost 0.3 hours of mostly land data)
98/044	Enabled Extended AGC Software (lost 0.1 hours of mostly land data)
98/077	LAM (off-nadir excursion affected 3.0 hours of data - data still usable)
98/098	Digital Filter-Bank Leakage Test (lost 0.3 hours of land data)
98/137	Changed to IDLE Mode for SSALT
98/147	Returned to TRACK Mode
98/155	Command Generation Error (lost 7.3 hours of data)
98/164	Improper SEU Recovery (lost 3.4 hours of data)
98/204	Transmit Test (lost 0.8 hours of data)
98/205	Digital Filter-Bank Leakage Test (lost 0.2 hours of data)
98/206	Changed to IDLE Mode for SSALT
98/216	Returned to TRACK Mode
98/224	C100 CAL Mode Test (lost 0.1 hours of land data)
98/243	Improper SEU Recovery (lost 2.7 hours of data)
98/250	Loaded Cal Sweep Software (lost 0.2 hours of land data)
98/251	Executed Cal Sweep Software (lost 0.5 hours of land data)
98/254	Improper SEU Recovery (lost 2.5 hours of data)
98/280	Executed Cal Sweep Software (lost 0.5 hours of land data)
98/286	Changed to IDLE Mode for SSALT
98/296	Returned to TRACK Mode
98/296	Improper SEU Recovery (lost 2.1 hours of data)

Table 2-2 NASA Altimeter - Key Events (Continued)

Day	Event
98/321	Changed to IDLE Mode for Leonid Meteor Shower (lost 6.0 hours of data)
98/335	Changed to IDLE Mode for Orbital Maneuver (lost 2.4 hours of data)
98/349	Executed Cal Sweep Software (lost 0.4 hours of land data)
99/020	Changed to IDLE Mode for SSALT
99/030	Returned to TRACK Mode
99/040	Special Testing Prior to Side A Turn-Off (Testing Began at 1604 UTC and Ended at 2350 UTC)
99/041	Side A Turn-Off at 02:55:30 UTC for Side B Testing

Section 3

Assessment of Instrument Performance

3.1 Range

The following range discussion is similar to last year's assessment update; a change is that Table 3-1 "TOPEX Range Bias Changes Based on Calibration Mode 1 Step 5" has been updated to include all the data up to the time of the Side A turnoff. The contents of Table 3-1 have been regularly updated on our TOPEX Web site, at http://topex.wff.nasa.gov/docs/RangeStabUpdate.html

The CAL-1 Step-5 Ku-Band and C-Band delta ranges have been processed to form a set of delta combined range values. There are about twenty delta combined ranges for each TOPEX data cycle, corresponding to the two calibrations per day during the 10-day cycle.

Range bias changes for the NASA radar altimeter of the TOPEX/POSEIDON mission are described by Hayne, et al (1994). Reported here are the additional bias change results. Table 3-1 lists values for the combined (Ku&C) delta range, in millimeters, with the same sign convention used in the October 1994 article. We made one change in Table 3-1 as of February 1996: the table contains bias change results both with and without temperature correction. Before February 1996, the versions of Table 3-1 contained only the temperature corrected results; we are now also providing results with no temperature correction. For the TOPEX GDR data end user who does not have easy access to the temperature data, it would be more appropriate to use the combined delta range results NOT corrected for temperature.

Temperatures are measured at about two dozen different positions within the TOPEX altimeter. Because all these temperatures move up and down together, it is not possible to determine which of these temperatures is the most important to range bias, and for our analyses we use the temperature of the upconverter/ frequency multiplier (UCFM) unit; this will be designated as T_u below. There is a correlation of the individual delta range measurement with T_u, and we have found a simple quadratic correction of the delta range for T_u variation. Using the individual delta range estimates from calibration mode 1 step 5 together with the T_u data for cycles 10-87, we have used simple least-squares fitting to find that an additive delta range adjustment Da in millimeters is approximately

$$Da = -1.817*(T_u - 25.5) - 0.073*(T_u - 25.5)**2,$$

where T_u is in degrees C and Da is in millimeters.

The temperature correction Da both smooths out the trend of cycle averages of combined delta range and reduces the standard deviations of the cycle averages. From our instrument science interests, it is appropriate to examine and to report the combined range bias changes AFTER correction for the T_u; as noted above, the data user would more appropriately use combined delta range NOT corrected for temperature.

Table 3-1 TOPEX Range Bias Changes Based on Calibration Mode 1 Step 5

Cycle #	Count	Mean dR(comb), no Tucfm corr, mm	Standard deviation dR(comb), no Tucfm corr	Mean dR(comb) after Tucfm corr, mm	Standard deviation dR(comb) after Tucfm corr	Mean Tucfm	Standard deviation Tucfm
001	15	+2.795	1.691	+2.003	0.645	25.086	0.834
002	18	+1.867	0.644	+1.747	0.725	25.488	0.166
003	18	+2.527	1.191	+1.792	1.085	25.143	0.239
004	18	+1.811	0.929	+1.731	0.827	25.507	0.335
005	20	+1.947	0.808	+1.611	0.680	25.368	0.207
006	20	+1.792	0.975	+2.305	0.578	25.826	0.433
007	14	+1.602	0.178	+2.104	0.625	25.823	0.331
008	18	+1.799	0.194	+1.534	0.411	25.408	0.149
009	17	+1.751	0.661	+1.437	0.524	25.378	0.282
010	20	+1.594	0.253	+1.780	0.618	25.651	0.376
011	20	+1.342	0.500	+2.350	0.481	26.092	0.316
012	19	+1.645	0.757	+1.978	0.614	25.732	0.332
013	15	+1.622	0.236	+1.475	0.285	25.473	0.113
014	17	+1.941	0.532	+1.181	0.592	25.129	0.227
015	19	+1.985	0.474	+1.288	0.702	25.163	0.328
016	20	+2.060	0.461	+1.772	0.511	25.393	0.266
017	21	+1.723	0.319	+2.023	0.393	25.715	0.299
018	18	+1.484	0.223	+1.867	0.394	25.761	0.202
019	16	+1.615	0.151	+1.039	0.359	25.234	0.163
021	20	+2.047	0.149	+1.713	0.336	25.368	0.236
022	20	+1.672	0.205	+1.657	0.562	25.544	0.278
023	19	+1.354	0.355	+1.505	0.341	25.635	0.246
024	21	+0.624	0.289	+1.229	0.349	25.881	0.191
025	20	+0.553	0.545	+1.454	0.439	26.031	0.462
026	19	+1.517	0.155	+1.080	0.260	25.313	0.153
027	20	+1.517	0.131	+1.019	0.287	25.278	0.165
028	20	+1.131	0.217	+1.074	0.307	25.523	0.201
029	20	+0.614	0.255	+1.040	0.486	25.784	0.241

Table 3-1 TOPEX Range Bias Changes Based on Calibration Mode 1 Step 5 (Continued)

Cycle #	Count	Mean dR(comb), no Tucfm corr, mm	Standard deviation dR(comb), no Tucfm corr	Mean dR(comb) after Tucfm corr, mm	Standard deviation dR(comb) after Tucfm corr	Mean Tucfm	Standard deviation Tucfm
030	18	+0.924	0.372	+0.726	0.337	25.443	0.267
032	18	+1.727	0.397	+0.882	0.209	25.079	0.291
033	17	+0.805	0.869	+0.561	0.337	25.409	0.540
034	20	+0.023	0.152	-0.126	0.491	25.471	0.242
035	18	-0.490	0.606	-0.061	0.431	25.784	0.295
036	20	-0.777	0.667	-0.181	0.461	25.876	0.189
037	18	+0.283	0.482	+0.049	0.526	25.426	0.129
038	19	+0.734	0.322	+0.622	0.250	25.491	0.268
039	20	+0.834	0.406	+0.629	0.315	25.440	0.260
040	21	+0.690	0.419	+0.607	0.242	25.507	0.246
042	20	-0.609	0.536	+0.224	0.422	26.002	0.185
043	19	-0.081	0.240	+0.043	0.344	25.621	0.216
044	17	+0.152	0.227	-0.027	0.370	25.455	0.169
045	20	+0.170	0.223	+0.156	0.267	25.547	0.099
046	19	-0.316	0.655	+0.208	0.514	25.837	0.212
047	19	-1.348	0.334	-0.496	0.422	26.012	0.168
048	19	-0.148	0.588	+0.136	0.375	25.707	0.268
049	18	-0.165	0.421	-0.318	0.434	25.468	0.266
050	19	+1.349	0.603	-0.001	0.309	24.789	0.255
051	20	-0.076	0.723	-0.183	0.427	25.493	0.294
052	20	-0.183	0.270	-0.398	0.344	25.436	0.122
053	20	-1.823	0.666	-1.079	0.389	25.954	0.254
054	21	-0.810	0.702	-0.609	0.310	25.661	0.269
056	20	-0.435	0.715	-0.561	0.697	25.483	0.269
057	20	-1.059	0.418	-0.691	0.448	25.752	0.285
058	20	-0.957	0.323	-1.188	0.293	25.427	0.167
059	20	-2.053	0.580	-1.487	0.450	25.860	0.194
060	20	-2.299	0.543	-1.664	0.346	25.895	0.288

Table 3-1 TOPEX Range Bias Changes Based on Calibration Mode 1 Step 5 (Continued)

Cycle #	Count	Mean dR(comb), no Tucfm corr, mm	Standard deviation dR(comb), no Tucfm corr	Mean dR(comb) after Tucfm corr, mm	Standard deviation dR(comb) after Tucfm corr	Mean Tucfm	Standard deviation Tucfm
061	19	-1.569	0.236	-1.709	0.307	25.477	0.155
062	20	-1.455	0.157	-1.837	0.282	25.344	0.128
063	20	-1.392	0.158	-1.864	0.294	25.293	0.124
064	21	-2.245	0.554	-1.866	0.469	25.758	0.274
066	20	-1.488	0.154	-1.910	0.221	25.321	0.131
067	19	-1.843	0.400	-2.031	0.349	25.449	0.245
068	20	-0.302	0.639	-1.938	0.390	24.621	0.261
069	20	-2.039	0.472	-1.956	0.324	25.598	0.260
070	20	-2.554	1.102	-2.351	0.458	25.657	0.479
071	20	-3.780	0.575	-3.011	0.456	25.968	0.197
072	20	-4.598	1.804	-3.667	1.111	26.046	0.491
073	19	-2.411	0.518	-2.456	0.281	25.528	0.236
074	20	-2.742	0.410	-2.917	0.276	25.458	0.138
075	20	-3.112	0.595	-2.958	0.292	25.637	0.239
076	19	-2.598	0.483	-2.794	0.390	25.446	0.157
077	19	-3.883	0.374	-3.314	0.407	25.862	0.192
078	20	-3.715	0.444	-3.132	0.632	25.867	0.299
080	19	-3.059	0.350	-2.809	0.308	25.690	0.157
081	20	-3.526	0.300	-3.114	0.340	25.778	0.125
082	20	-5.491	1.251	-4.348	0.960	26.163	0.283
083	20	-4.814	0.724	-3.974	0.844	26.006	0.198
084	20	-3.976	0.258	-4.118	0.322	25.476	0.137
085	20	-3.276	1.038	-3.712	0.418	25.304	0.512
086	20	-1.596	1.172	-2.628	0.637	24.970	0.384
087	20	-4.199	0.212	-3.843	0.433	25.746	0.282
088	21	-4.296	0.252	-3.827	0.502	25.808	0.216
089	20	-4.434	0.327	-3.561	0.493	26.023	0.194
090	20	-4.181	0.262	-3.921	0.625	25.691	0.393

Table 3-1 TOPEX Range Bias Changes Based on Calibration Mode 1 Step 5 (Continued)

Cycle #	Count	Mean dR(comb), no Tucfm corr, mm	Standard deviation dR(comb), no Tucfm corr	Mean dR(comb) after Tucfm corr, mm	Standard deviation dR(comb) after Tucfm corr	Mean Tucfm	Standard deviation Tucfm
092	20	-3.337	0.855	-2.838	0.681	25.824	0.202
093	20	-3.732	0.244	-3.631	0.540	25.608	0.236
094	20	-3.918	0.273	-3.481	0.422	25.791	0.205
095	20	-4.374	0.294	-3.650	0.486	25.945	0.143
096	19	-4.268	0.248	-4.079	0.502	25.656	0.240
098	19	-3.373	0.152	-3.689	0.297	25.379	0.142
099	20	-3.528	0.161	-3.660	0.408	25.481	0.176
100	19	-3.759	1.072	-3.452	0.572	25.714	0.468
101	20	-4.003	0.232	-3.706	0.551	25.714	0.265
102	20	-3.895	0.161	-4.137	0.408	25.420	0.217
104	20	-2.646	1.185	-3.306	0.504	25.177	0.545
105	20	-3.457	0.213	-3.126	0.497	25.732	0.276
106	20	-3.779	0.499	-3.170	0.592	25.882	0.229
107	20	-4.509	0.207	-3.579	0.481	26.053	0.244
108	19	-3.955	0.196	-3.961	0.352	25.551	0.177
109	19	-3.808	0.168	-3.531	0.415	25.704	0.240
110	20	-3.705	0.252	-3.311	0.296	25.769	0.152
111	20	-3.727	0.143	-3.807	0.260	25.511	0.149
112	20	-4.028	0.351	-3.418	0.255	25.884	0.173
113	20	-4.251	0.202	-3.275	0.277	26.078	0.174
115	17	-3.092	0.336	-2.734	0.321	25.748	0.167
116	20	-3.045	0.295	-2.779	0.391	25.699	0.127
117*	16	-3.191	0.299	-2.586	0.430	25.881	0.194
118*	2	-1.832	3.533	-3.328	1.335	24.670	1.301
119	17	-5.211	1.013	-3.527	0.925	26.438	0.482
120	20	-4.668	0.454	-4.420	0.593	25.689	0.207
121	19	-3.735	0.675	-4.940	0.315	24.869	0.430
122	20	-4.013	0.622	-4.076	0.563	25.509	0.556

Table 3-1 TOPEX Range Bias Changes Based on Calibration Mode 1 Step 5 (Continued)

Cycle #	Count	Mean dR(comb), no Tucfm corr, mm	Standard deviation dR(comb), no Tucfm corr	Mean dR(comb) after Tucfm corr, mm	Standard deviation dR(comb) after Tucfm corr	Mean Tucfm	Standard deviation Tucfm
123**	13	-4.242	0.658	-4.225	0.524	25.559	0.348
124	20	-4.758	0.797	-3.166	1.176	26.394	0.359
125	21	-4.860	0.574	-3.307	0.712	26.376	0.280
127	19	-3.726	0.617	-2.929	0.385	25.981	0.315
128	20	-3.983	0.310	-3.239	0.384	25.954	0.279
129	20	-3.722	0.214	-3.439	0.352	25.708	0.206
130	20	-4.125	0.783	-3.060	0.693	26.123	0.279
131	20	-2.970	0.615	-2.191	0.512	25.973	0.243
132	19	-2.120	0.172	-2.254	0.321	25.481	0.122
133	20	-1.948	0.127	-2.096	0.296	25.473	0.129
134	20	-1.764	0.184	-2.089	0.323	25.375	0.118
135	20	-2.604	0.710	-2.016	0.347	25.870	0.297
136	20	-2.878	0.371	-2.320	0.344	25.856	0.194
137	21	-1.968	0.904	-2.072	0.465	25.490	0.456
139	20	+0.712	0.893	-0.705	0.404	24.746	0.391
140	20	-1.252	0.839	-1.133	0.388	25.615	0.360
141	20	-1.464	0.285	-1.528	0.380	25.519	0.186
142	20	-2.613	0.539	-1.793	0.411	25.994	0.235
143	19	-2.626	0.558	-1.854	0.392	25.967	0.318
144	18	-1.490	0.210	-1.795	0.364	25.386	0.159
145	21	-1.980	0.377	-1.535	0.358	25.793	0.288
146	20	-1.569	0.408	-1.827	0.293	25.411	0.218
147	19	-1.736	0.341	-1.645	0.230	25.604	0.136
148	18	-3.065	0.336	-1.783	0.538	26.235	0.315
149	20	-2.741	0.630	-2.075	0.393	25.910	0.369
151	20	-1.701	1.027	-1.119	0.675	25.868	0.249
152	20	-1.737	0.208	-1.379	0.324	25.749	0.146
153	20	-2.548	0.751	-1.350	0.471	26.191	0.322

Table 3-1 TOPEX Range Bias Changes Based on Calibration Mode 1 Step 5 (Continued)

Cycle #	Count	Mean dR(comb), no Tucfm corr, mm	Standard deviation dR(comb), no Tucfm corr	Mean dR(comb) after Tucfm corr, mm	Standard deviation dR(comb) after Tucfm corr	Mean Tucfm	Standard deviation Tucfm
154	20	-2.961	0.288	-1.738	0.292	26.206	0.234
155	20	-2.214	0.683	-1.804	0.431	25.769	0.480
156	19	-1.607	0.511	-1.587	0.281	25.562	0.312
157	20	-1.144	0.562	-0.699	0.510	25.794	0.262
158	20	-1.144	0.562	-0.699	0.510	25.794	0.262
159	20	-1.162	0.776	-0.691	0.400	25.803	0.456
160	20	-2.779	0.385	-1.668	0.416	26.147	0.255
161	21	-2.641	0.886	-1.594	0.401	26.108	0.461
163	19	-1.277	0.296	-0.515	0.233	25.965	0.168
164	20	-0.881	0.186	-0.718	0.269	25.644	0.107
165	20	-2.058	1.000	-1.086	0.632	26.073	0.327
166	20	-2.405	0.241	-1.430	0.393	26.077	0.208
167	20	-1.566	0.707	-1.132	0.485	25.783	0.451
168	19	-0.960	0.235	-0.949	0.379	25.559	0.221
169	20	-1.283	0.219	-1.070	0.326	25.669	0.238
170	20	-0.935	0.159	-1.159	0.273	25.431	0.144
171	21	-1.454	0.400	-0.814	0.323	25.899	0.245
172	20	-1.447	0.453	-1.039	0.305	25.775	0.225
173	20	-0.380	0.227	-0.846	0.356	25.296	0.187
175	16	+1.732	0.436	+0.764	0.428	25.006	0.430
176	20	+0.317	0.346	+0.599	0.400	25.706	0.274
177	21	+0.428	0.383	+0.709	0.400	25.706	0.245
178	20	-0.382	0.186	+0.588	0.326	26.075	0.174
179	20	+0.148	0.671	+0.451	0.504	25.716	0.334
181	19	+1.211	0.886	+1.215	0.686	25.555	0.217
182	20	+1.084	0.150	+1.188	0.339	25.611	0.156
183	20	+0.556	0.510	+1.274	0.449	25.940	0.252
184	19	+0.142	0.253	+0.926	0.419	25.975	0.262

Table 3-1 TOPEX Range Bias Changes Based on Calibration Mode 1 Step 5 (Continued)

Cycle #	Count	Mean dR(comb), no Tucfm corr, mm	Standard deviation dR(comb), no Tucfm corr	Mean dR(comb) after Tucfm corr, mm	Standard deviation dR(comb) after Tucfm corr	Mean Tucfm	Standard deviation Tucfm
185	20	+0.616	0.170	+0.433	0.367	25.453	0.180
187	20	+0.845	0.719	+1.660	0.841	25.992	0.265
188	20	+0.638	0.242	+0.922	0.443	25.709	0.170
189	20	+0.183	0.410	+1.439	0.385	26.223	0.232
190	20	+0.302	0.348	+1.430	0.543	26.155	0.305
191	20	+0.898	0.213	+0.960	0.505	25.587	0.242
192	20	+1.983	1.237	+1.189	0.785	25.099	0.589
193	20	+3.390	1.249	+2.995	0.789	25.329	0.458
194	17	+1.498	0.814	+2.070	0.844	25.861	0.315
195	19	+1.046	0.888	+2.530	1.285	26.336	0.450
196	18	+0.543	0.504	+1.775	0.756	26.211	0.238
198	19	+2.804	0.583	+3.141	0.861	25.737	0.173
199	19	+2.757	0.229	+3.053	0.366	25.715	0.169
200	20	+2.735	0.224	+3.430	0.456	25.929	0.158
201	20	+1.946	0.222	+3.202	0.783	26.220	0.393
202	19	+2.042	0.302	+3.036	0.710	26.082	0.409
203	18	+2.720	0.419	+2.730	0.452	25.557	0.317
204	17	+2.915	0.220	+4.184	1.987	26.199	0.962
205	20	+3.023	0.269	+3.337	1.378	25.709	0.664
206	19	+3.051	0.640	+4.677	2.699	26.335	1.499
207	19	+3.062	0.652	+5.094	1.630	26.582	1.078
208	20	+3.043	0.689	+4.083	0.655	26.102	0.532
210	17	+5.088	0.196	+3.851	0.663	24.848	0.476
211	15	+4.662	0.297	+4.411	0.706	25.406	0.532
212	20	+4.712	0.365	+4.753	0.437	25.576	0.199
213	20	+3.015	0.603	+4.365	0.471	26.269	0.388
214	20	+3.668	0.389	+4.692	0.436	26.101	0.293
215	21	+3.534	0.862	+4.286	0.546	25.945	0.647

Table 3-1 TOPEX Range Bias Changes Based on Calibration Mode 1 Step 5 (Continued)

Cycle #	Count	Mean dR(comb), no Tucfm corr, mm	Standard deviation dR(comb), no Tucfm corr	Mean dR(comb) after Tucfm corr, mm	Standard deviation dR(comb) after Tucfm corr	Mean Tucfm	Standard deviation Tucfm
217	20	+4.867	0.356	+4.637	0.368	25.427	0.206
218	20	+3.684	0.759	+4.878	0.342	26.185	0.481
219	19	+4.089	0.307	+4.728	0.359	25.899	0.170
220	19	+3.935	0.655	+5.374	0.386	26.313	0.442
221	19	+5.502	0.294	+5.326	0.705	25.456	0.254
222	20	+5.536	0.254	+5.956	0.332	25.782	0.173
223	20	+5.537	0.291	+6.010	0.594	25.808	0.326
225	20	+4.867	0.407	+6.124	0.356	26.225	0.166
226	19	+4.488	0.733	+5.949	0.492	26.321	0.547
227	21	+5.880	0.332	+6.073	0.855	25.650	0.504
228	21	+6.780	0.662	+5.596	0.44	24.883	0.335
229	20	+6.738	0.591	+7.146	0.411	25.768	0.471
230	20	+6.430	0.594	+7.210	0.499	25.971	0.354
231	20	+5.453	0.591	+7.001	0.283	26.373	0.296
232	20	+5.259	0.647	+7.162	0.369	26.552	0.364
233	19	+6.365	0.897	+7.087	0.521	25.931	0.621
235	18	+7.086	0.266	+7.904	0.374	25.994	0.174

* Late part of cycle 117 and most of cycle 118 lost because of TOPEX SafeHold / PowerOff condition. Power was restored to the altimeter late in cycle 118, but remaining cycle 118 calibrations were removed from our analysis data set to allow altimeter temperatures to stabilize.

** SafeHold / PowerOff during cycle 123; then both calibrations on 1996 day 023 were edited out of the altimeter data to allow altimeter temperatures to stabilize after power was restored.

For the results reported in Table 3-1, very slightly different edit criteria were used on the calibration mode data than in the October 1994 article, and the data fit for temperature effects includes 13 more data cycles than the October 1994 results. The edit criteria and the temperature fit have not been changed since February 1996. The result of the different fit is that the combined delta range values here may differ from those in the October 1994 article, typically by 0.05 mm. The delta range results reported here may be valid at levels approaching a millimeter, but we think it is unrealistic to worry about differences at the level of tenths of a millimeter.

We have less confidence in the later delta ranges, due to the (unquantifiable at this time) effect of the change in the altimeter's point target response (PTR). The PTR change is discussed in Section 3.3.

The first column in Table 3-1 is the TOPEX data cycle and the second column indicates the number of individual calibrations in each cycle average. The third column is the cycle average of the combined delta range in millimeters, with NO correction for temperature, and the standard deviation estimate of the individual combined delta range (with no temperature correction) is listed in column four. For the temperature-corrected combined delta range, the corresponding cycle averages and standard deviations are shown in columns five and six, respectively. The cycle average for UCFM temperature in degrees centigrade is listed in the next-to-last column, and the individual calibration standard deviation for this temperature is in the last column.

These delta ranges are plotted in Figure 3-1 and Figure 3-2, where Figure 3-1 contains range corrections which have not been modified for the effects of temperature; the Figure 3-2 values have been temperature-corrected.The error bars in the two Figures are the standard deviations listed in Table 3-1.

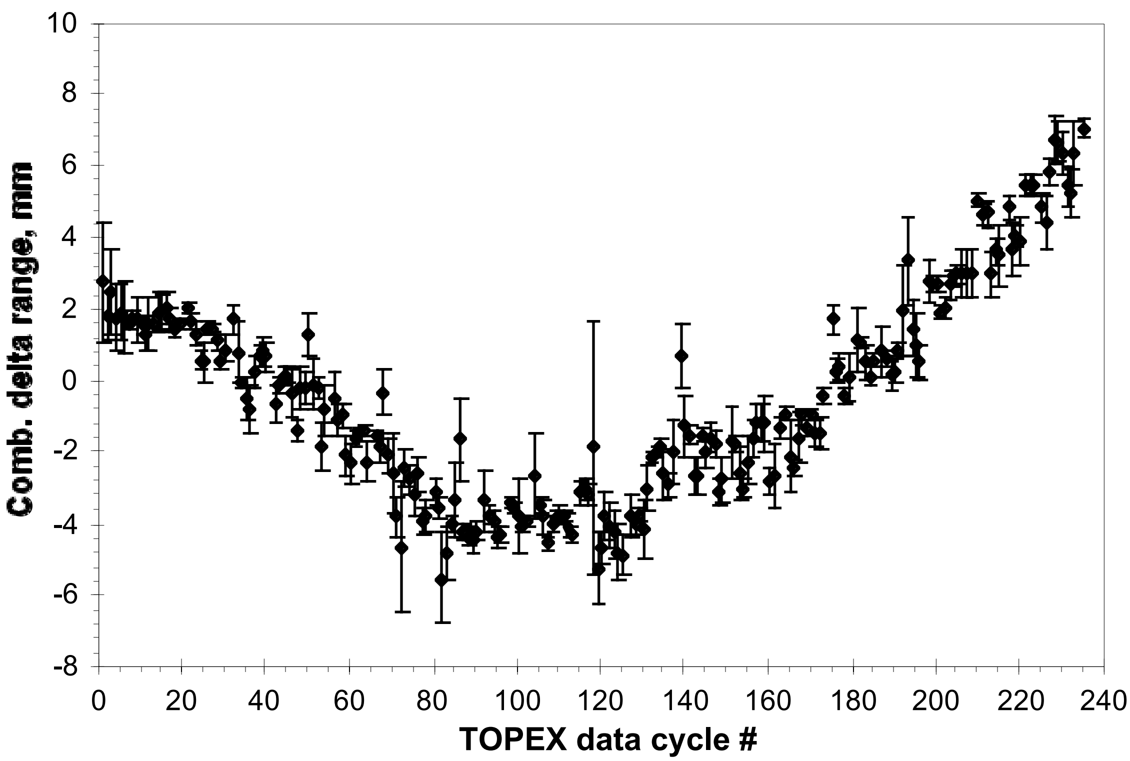

Figure 3-1 Combined (Ku & C) Delta Range vs. Cycle - Not Corrected for UCFM Temperature

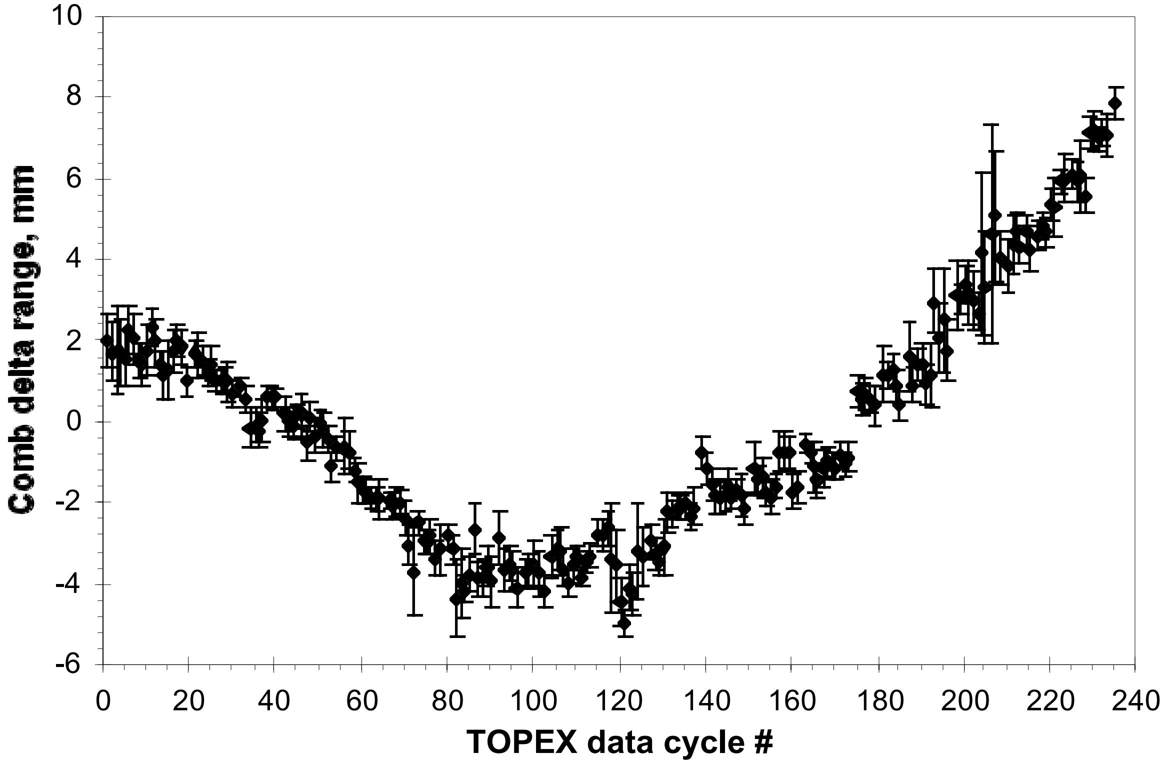

Figure 3-2 Combined (Ku & C) Delta Range vs. Cycle - With UCFM Temperature Correction

3.2 AGC/Sigma Naught

For an over-ocean radar altimeter whose transmitted power is constant, the received backscattered power is proportional to sigma-naught (often referred to as sigma0). As the altimeter ages, its transmitted power tends to drift slowly (usually downward) by a few dB, its receiver characteristics also can drift, and it is necessary to account for these drifts in power estimation when calculating sigma-naught estimates from the altimeter data.

In TOPEX ground data processing for the intermediate geophysical data record (IGDR), there is a sigma-naught calibration table which, for each TOPEX data cycle, contains one additive correction for the Ku-band sigma-naught and one additive correction for the C-band sigma-naught. WFF provides the values for the sigma-naught calibration table, which is referred to as the Cal Table in the following. The power estimation drift is slow enough that, for any data cycle, the Cal Table values do not change for any passes within the cycle, but need to be changed only every several cycles.

At launch, the Cal Table values were set to zero for both Ku- and C-band. We had expected to provide Cal Table updates based on calibration mode data. When, by data cycle 048, it became clear that the Cal Table values needed to be updated, the calibration mode results disagreed somewhat with cycle averages of global over-ocean sigma-naught, and we decided to make the Cal Table update based on the trend in the global over-ocean sigma-naught_uncorr. By sigma-naught_uncorr, we mean the GDR sigma-naught value with the Cal Table correction removed. In effect, the sigma-naught_uncorr is the GDR sigma-naught which would have been produced if all the Cal Table values had been zero when producing the GDR.

For the first three years of TOPEX data, both the Ku- and the C-band global sigma-naught_uncorr appeared to decrease linearly with time (or with data cycle number), although with different slopes. However, after four years of TOPEX data, we noted that some polynomial degree higher than linear was necessary to describe the sigma-naught_uncorr time trends. After examining the approximately six years of Side A data, we feel that a quadratic polynomial form is adequate for these trends.

We will describe the Cal Table values actually used in producing the TOPEX GDR (rereleased for cycles 133 - 149) and the TOPEX altimeter part of the MGDR-B, as well as our current best hindsight estimates of what those values should have been. After briefly describing the TOPEX calibration mode, we will compare calibration mode data with the sigma-naught_uncorr data. We will describe how the Cal Table values are documented and how to find what Cal Table values were used for each TOPEX cycle's GDR production. We will then describe the time trend fitting for cycles 017 through 235 of the sigma-naught_uncorr data, and provide tables which allow the TOPEX data user to make small improvements to the sigma-naught estimates from the GDR or the MGDR-B.

3.2.1 Internal Calibration Mode

The TOPEX altimeter's internal calibration mode has two submodes, referred to as CAL-1 and CAL-2. In CAL-1, a portion of the transmitter output is fed back to the receiver through a digitally controlled calibration attenuator and a delay line. The altimeter acquires and tracks this calibration signal for 10 seconds for each of 17 different preset attenuator values (each step change is 2 dB). The altimeter's automatic gain control (AGC) loop is active during each CAL-1 step, so CAL-1 should provide information on changes in the altimeter's range and power estimation. The altimeter's CAL-1 and its normal fine-track mode have the same hardware except that CAL-1 has a delay line, a different attenuator, and switches to select these components; in principle, the CAL-1 AGC measurements should be directly relatable to changes in the altimeter's power estimation. In CAL-2 the altimeter processes receiver thermal noise, with no transmitted signal present, primarily to characterize the waveform sampler response, but CAL-2 should also provide additional information on the received power estimation.

When commanded to the calibration mode, the TOPEX altimeter first enters CAL-1 and then CAL-2. CAL-1 has 17 different steps, each lasting about 10 seconds, and CAL-2 lasts about a minute, so the entire calibration mode lasts about 4 minutes. There are normally two calibration modes (separated by approximately 12 hours) commanded in each day of TOPEX altimeter operation, and these calibrations are scheduled over land to avoid loss of ocean data.

3.2.2 Calibration Mode Results Compared with Uncorrected Global Sigma-Naught Averages

As part of our continuing TOPEX support, we do daily quick-look processing of all TOPEX altimeter data for performance monitoring, providing performance summaries for the engineering and science data. The daily processing results are used to update a launch-to-date engineering database. Also, the two daily calibration mode data are processed and the results used to update a WFF launch-to-date calibration database. We also process the intermediate geophysical data record (IGDR) data as they become available for network access, normally several days after the altimeter acquires the data. The IGDR data are processed for altimeter performance, and 1-minute summary records are produced and are added to a WFF launch-to-date IGDR database. When the GDR data become available, they replace the IGDR data already in our database. There is no difference, however, between sigma-naught data on the IGDR and the GDR, because no further sigma-naught corrections are made in going from the IGDR to the GDR.

We have been very concerned about contamination of the data by what we have come to call “sigma-naught blooms”, regions of over-ocean altimeter data characterized by unusually high apparent sigma-naught values accompanied by unusual altimeter waveform shapes. Generally the Ku-and the C-band sigma-naught show the same behavior in a bloom region. Such blooms in the TOPEX data can persist for several tens of seconds, and the waveforms in a bloom region generally have too rapid a plateau decay. Many of these waveforms are too sharply peaked ("specular"), indicating a breakdown in the general incoherent scattering theory used to characterize the rough surface scattering. The sigma-naught blooms exist in perhaps 5% of all TOPEX over-ocean data (there is additional sigma-naught bloom information on our web page at http://topex.wff.nasa.gov/blooms/blooms.html). For input to our GDR database 1-minute averages, we require all the available altimeter flags to show normal tracking and the land/water flag to show deep water. When the data are extracted from this database for the sigma-naught calibration, all records are rejected that have Ku-band sigma-naught estimates of 16 dB or greater or that have waveform-estimated attitude angles of 0.12 degrees or greater; these criteria effectively delete the majority of the sigma-naught blooms.

Because our analysis is based on sigma-naught_uncorr, we need to know what Cal Table values have been already applied to the GDR (or IGDR) data in order to “undo” these corrections. There have been eighteen Cal Table adjustments over the time of TOPEX Side A operation, as discussed briefly in the following sub-section “History of Cal Table Values Used in GDR Production”. There exists no single summary of exactly when each of the Cal Table changes was implemented in the TOPEX ground processing, so we will try to provide that summary here.

Each time that the Cal Table contents are changed in the TOPEX ground data processing at JPL, there are at least these three items created within the Mission Operations System (MOS):

- The MOS Change Request Form (the MCR) bears an origination date, describes the change to be made and the desired operational date for the change, and also has the date when the MCR was approved (by a change control board at JPL).
- The Parameter File is the text file to be actually used in the data processing and containing the Cal Table values for each cycle.
- The File Release Form contains the Parameter File creation date, the release approval date, and the date at which file execution is to begin.

The MCR Form is usually accompanied by other supporting information from WFF describing why the change is being requested, but what is being discussed now is not why but when the change was actually implemented. In Table 3-2, we have summarized information from copies of the sigma-naught-related MCRs and File Release Forms relevant to the rereleased GDRs and the MGDR-Bs. Columns 1 to 4 of Table 3-2 are transcribed from the MCR Forms, columns 5 to 7 from the File Release Forms, and column 8 contains a brief indication of what change the MCR made and why.

Column 9 of Table 3-2 indicates which of the TOPEX GDRs were governed by each MCR. MCR #618, October 1996, contains the Cal Table values for the MGDR-Bs up through cycle149, and the MGDR-B and GDR. For TOPEX cycles numbered 133 or greater, the MGDR-Bs had the same Cal Table values as the rereleased GDRs. Because this report is restricted to only the rereleased GDRS (for cycles 133 - 149) we have not included in Table 3-2 the MCRs #598, #608, and #614 because those MCRs are relevant only to the originally released GDRs.

Table 3-2 TOPEX MCR Information Summary

(from MCR Form)				(from File Release Form)				
(1) MCR #	**(2) MCR Origination Date**	**(3) Desired Operational Date**	**(4) Comments on MCR Form**	**(5) File Creation Date**	**(6) Release Approval Date**	**(7) File Execution to Begin *(cycle begin)***	**(8) Comments on MCR actions and reasons**	**(9) Cycles Under This MCR**
432	93/05/11 1993-131	93/05/12		93/05/12 1993-132 ?	start of mission		At start of mission, had zeros in both Ku and C AGC table	001 - 047
492	94/01/10 1994-010	cycle 048 94/01/12	reprocess cycle 48 IGDRs, process all from 48 on using this file	94/01/10 1994-010 T18:05:00	94/01/12	94/01/02 1994-002 T04:28:00 (cycle 048)	First non-zero entries. Start applying to IGDRs at cycle 048, and add steps backward at cycles 015, 021, and 029.	048 - 055
501	94/03/30 1994-089	cycle 056 94/03/31	change to start at cycle 56 IGDRs	94/03/30 1994-089 T23:00:00	94/03/31	94/03/22 1994-081 T12:17:00 (cycle 056)	Add another step starting at cycle 056, keep rest of values same as MCR 492.	056 - 075
529	94/10/18 1994-291	cycle 076 94/10/19	use for cycle 76 IGDRs	94/10/17 1994-290 T14:00:00	94/10/19	94/10/06 1994-279 T19:47:00 (cycle 076)	Start at cycle 076, and replace earlier cycle values by linear ramp at 0.05 dB steps.	076 - 081
539	95/01/05 1995-005	95/01/04	reprocess cycle 80-83, use for 84 onward	95/01/04 1995-004 T19:40:00	95/01/04	94/12/05 1994-339 T07:38:00 (cycle 082)	Start at cycle 082. Extend linear ramp of MCR 529, predicting next cycles correction.	082 - 092

Table 3-2 TOPEX MCR Information Summary (Continued)

(from MCR Form)				(from File Release Form)				
(1) MCR #	**(2) MCR Origination Date**	**(3) Desired Operational Date**	**(4) Comments on MCR Form**	**(5) File Creation Date**	**(6) Release Approval Date**	**(7) File Execution to Begin *(cycle begin)***	**(8) Comments on MCR actions and reasons**	**(9) Cycles Under This MCR**
548	95/03/24 1995-083	cycle 93 95/03/29	use for cycle 93 IGDRs	95/03/29 1995-088 T21:20:00	95/03/29	95/01/13 1995-013 T23:32:43 (cycle 086)	Start at 093. Use linear prediction for next cycles, earlier values same as MCR 539. Note that begin exec. date is earlier than file creation, for reprocessing.	093 - 102
562	95/07/10 1995-191	95/07/12	use for cycle 103	95/07/10 1995-191 T20:52:00	95/07/11	95/07/01 1995-182 T13:07:39 (cycle 103)	Start at cycle 103 (a SSALT cycle). Extend linear ramp of MCR 548, predicting next cycles correction.	103 - 109
530	95/09/13 1995-256	95/09/15	use for cycle 110	95/09/14 1995-257 T18:10:00	95/09/15	95/09/08 1995-251 T22:57:19 (cycle 110)	Start at cycle 110. Refitted linear trend, extend backward, now using 0.03 dB steps.	110 - 121
585	95/12/13 1995-347	cycle 122 96/01/03	use for cycle 122	96/01/04 1996-004 T23:21:45	96/01/04	96/01/05 1996-005 T22:39:35 (cycle 122)	Start at cycle 122. Linear trend from MCR 530 was extended forward.	122 - 132

Table 3-2 TOPEX MCR Information Summary (Continued)

(from MCR Form)				(from File Release Form)				
(1) MCR #	**(2) MCR Origination Date**	**(3) Desired Operational Date**	**(4) Comments on MCR Form**	**(5) File Creation Date**	**(6) Release Approval Date**	**(7) File Execution to Begin *(cycle begin)***	**(8) Comments on MCR actions and reasons**	**(9) Cycles Under This MCR**
618	96/10/01 1996-275	96/10/02	use as part of reprocessing from cycle 133	96/10/07 1996-281 T17:31:00	96/10/07	96/09/19 1996-263 T18:01:15 (cycle 148)	Cycle 150 was SSALT. Execution date earlier than creation date for reprocessed 133-153. Values same as MCR 614 for cycles 001-086, then different (line segment fit). MCR 618 values used in MGDR-B for cycles	133 - 153
629	96/12/04 1996-339	cycle 156 96/12/11	change before processing cycle 156	96/12/09 1996-344 T22:44:00	96/12/11	96/11/18 1996-323 T05:52:26 (cycle 154)	Keep Ku values of MCR 618, but freeze C-band value starting at cycle 154.	154 - 159
630	97/01/20 1997-020	97/01/22	use for cycle 160	97/01/22 1997-022 T16:44:00	97/01/22	97/01/16 1997-016 T17:43:34 (cycle 160)	Use new line segment fit, start with cycle 160. Values same as MCR 629 until cycle 156.	160 - 164
632	97/03/13 1997-072	97/03/17	Freeze C-band value at cycle 164 value; reprocess 165.	97/03/14 1997-073 T21:44:00	97/03/17	97/02/25 1997-056 T09:37:41 (cycle 164)	Freeze C-band value at cycle 164 value, otherwise same values as MCR 630.	165 - 173

Table 3-2 TOPEX MCR Information Summary (Continued)

(from MCR Form)				(from File Release Form)				
(1) MCR #	**(2) MCR Origination Date**	**(3) Desired Operational Date**	**(4) Comments on MCR Form**	**(5) File Creation Date**	**(6) Release Approval Date**	**(7) File Execution to Begin *(cycle begin)***	**(8) Comments on MCR actions and reasons**	**(9) Cycles Under This MCR**
638	97/06/09 1997-160	97/06/14	update before processing cycle 175	97/06/16 1997-167 T17:25:55	97/06/18	97/06/14 1997-165 T11:21:23 (cycle 175)	Cycle 174 was SSALT. Continue Ku-band trend, continue to freeze C-band value; earlier cycles same as MCR 632	175 - 179
643	97/08/13 225	97/08/12	update before processing cycle 181	97/08/18 1997-230 T16:00:00	97/08/18	97/08/12 1997-224 T23:12:33 (cycle 181)	Cycle 180 was SSALT. Use new trend fits for Ku- and C-band, starting with cycle 181; earlier cycles same as MCR 638.	181 - 196
654	98/01/23 1998-023	98/01/28	update before processing cycle 198	98/01/28 1998-028 T22:40:00	98/01/28	98/01/28 1998-028 12:47:30 (cycle 198)	Cycle 197 was SSALT. Put in 3-cycle freeze starting at cycle 195, then continue same trends as MCR 643; earlier cycles same as MCR 643.	198 -

Figure 3-3 and Figure 3-4 show our Ku- and C-band calibration database and GDR database comparisons for TOPEX cycle-averages. The several curves in Figure 3-3 and Figure 3-4 have been shifted in order to be plotted on common y-axes, and the figure legend indicates the shift value. In all discussions of sigma-naught_uncorr trends, the TOPEX cycles 1 - 10 should be ignored, because of early operational procedures. In the earlier work there had been an adjustment to the sigma-naught_uncorr as a function of SWH; we do not make any SWH compensation of sigma-naught_uncorr in the work now being described. Only one of the CAL-1 steps, Step 5, is shown because Step 5 operates at an altimeter AGC level close to that of normal over-ocean tracking; however, the other CAL-1 steps show the same general trends as Step 5.

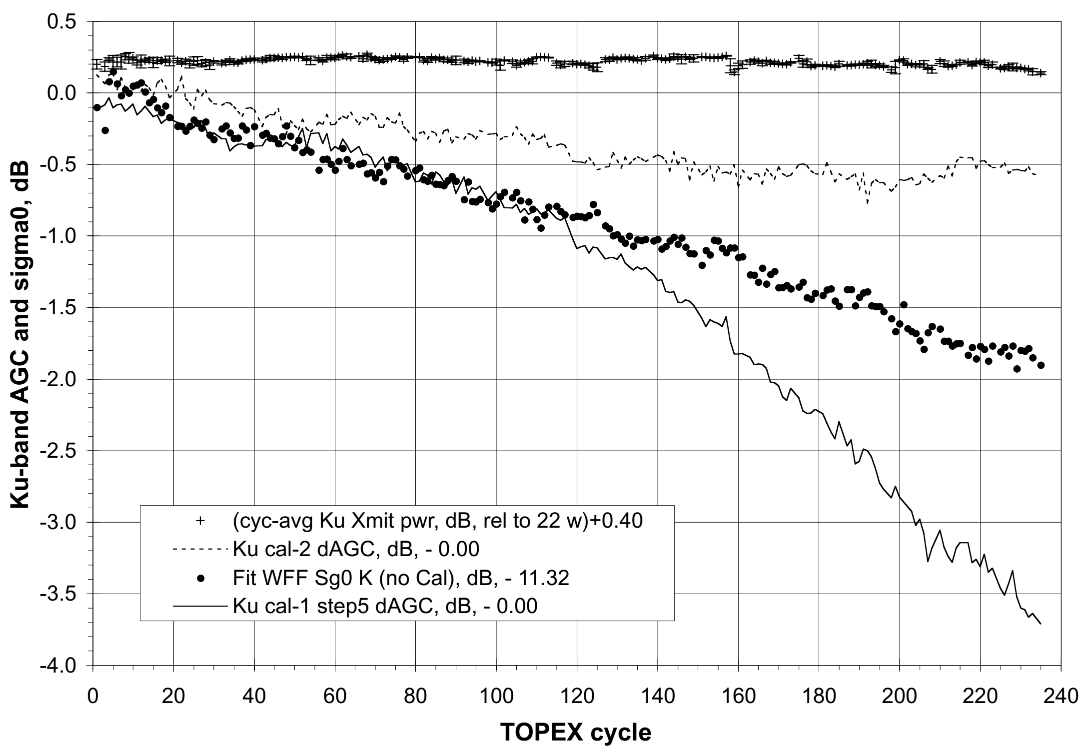

Figure 3-3 Ku-Cycle-Average CAL1 and CAL 2 Delta AGC and Sigma-Nauight (CAL TABLE CORRECTIONS REMOVED)

In the Ku-band results in Figure 3-3, the sigma-naught_uncorr trend is shown by the solid dots. The Ku-band CAL-2 results, shown by the dotted line in Figure 3-3, have the same general downward trend until cycle 50 or so, after which the CAL-2 data seem to level off although there is still a slow gradual downward trend with time. The Ku-band CAL-1 data, shown by the solid line in Figure 3-3, have the same general time trend as the sigma-naught_uncorr, but show slope differences around cycle 50 and then around cycle 118.

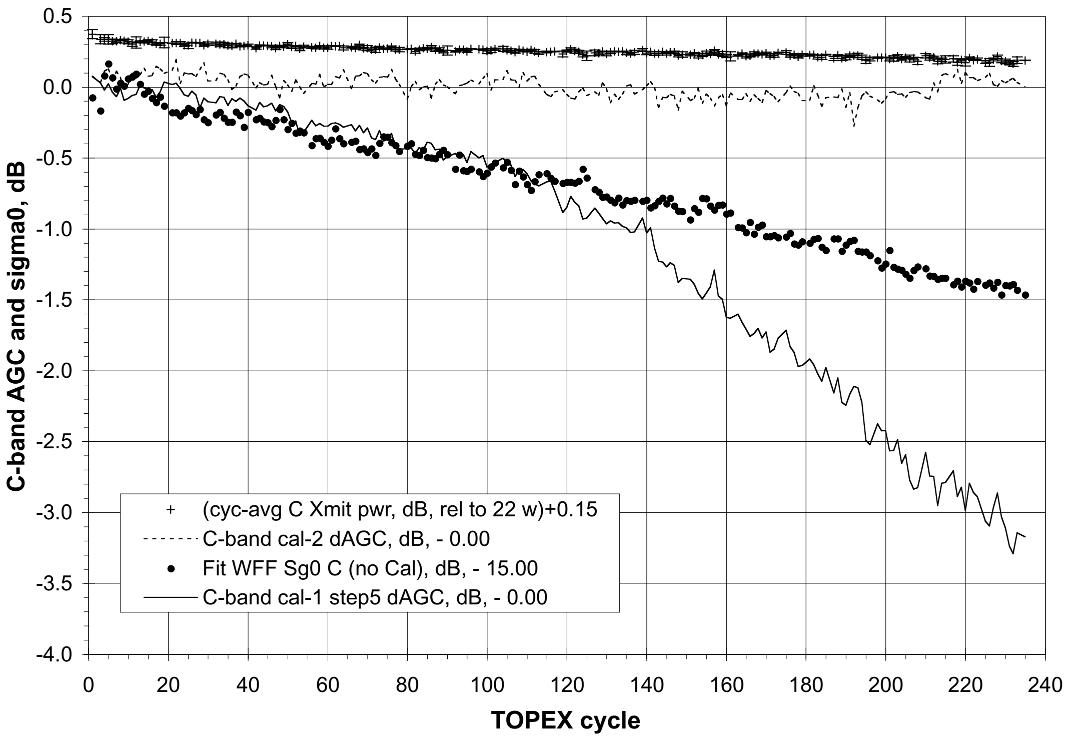

Figure 3-4 C-Band Cycle-Average CAL 1 and CAL 2 Delta AGC and Sigma-Naught (CAL TABLE CORRECTIONS REMOVED)

The C-band results in Figure 3-4 have a different CAL-2 behavior, nearly constant with time for cycles 001 to 162. We do not know why the Ku- and C-band CAL-2 results show such different behavior. The C-band CAL-1 data in Figure 3-4 show overall agreement with the C-band sigma-naught_uncorr, but there is still a puzzling C-band CAL-1 change around cycle 118.

Transmitted power monitor values for both the Ku- and the C-band in the TOPEX engineering data are also plotted as the uppermost data shown in Figure 3-3 and Figure 3-4. The transmitted power monitor variations are not large enough to explain the observed trends in the CAL-1 data relative to the sigma-naught_uncorr.

For the sigma-naught calibration work reported in Callahan et al. [1994], we had decided that there were small anomalies in the Calibration Mode behavior, and that it would be more realistic to use time trends of global average over-ocean sigma-naught_uncorr to produce the Cal Table values; this remains our approach in the work reported here. There is some risk in this, because we do not want to remove actual changes in the global over-ocean sigma-naught. There are certainly annual variations in the global sigma-naught, and perhaps semiannual and higher frequency variations as well, so we want to use only longer term secular trends in the sigma-naught_uncorr to provide the Cal Table values. We will describe the Cal Table values actually used in the production of the TOPEX GDRs to date, and then will describe the sigma-naught_uncorr trend fitting.

3.2.3 History of Cal Table Values Used in GDR Production

Early in the TOPEX mission, there were zero values in Ku- and C-band Cal Table. Eventually the sigma-naught_uncorr appeared to be drifting downward, and two step corrections were put into the Cal Table to compensate for the drift. Later in the mission, the sigma-naught_uncorr drift over time appeared to be linear, and the linear Ku- and C-band trends were used to predict further entries for the Cal Table. The linear steps were first 0.05 dB, and then later the steps were provided at 0.03 dB increments. Later (April 1996), a change in the linear trend became necessary. Subsequently, there have been additional changes in the linear trends used in predicting Cal Table values, and occasionally several-cycle “holds” or “freezes”.

Here is a narrative summary of the Cal Table changes for computing the TOPEX GDR Ku- and C-band sigma-naught estimates (see also column 8 of Table 3-2):

- Initially, the Cal Table values were zero.
- In January and March 1994, installed step corrections (reacting only after drift had occurred).
- In October 1994, began treating sigma-naught_uncorr trends as linear in time, making corrections on 0.05 dB quantization. Used the current time trends to predict Cal Table values for 10 or so cycles into the future, at each MCR change. We described in Callahan et al. [1994] the linear trend back to cycle 001, for recorrecting the GDR estimates.
- In September 1995, continued treating sigma-naught_uncorr trends as linear in time, but began making Cal Table changes on 0.03 dB quantization.
- By May 1996, it became clear that the downward drift in sigma-naught_uncorr departed from being purely linear with time, with downward slope greater for later cycles. Used step-change in Cal Table values and a new linear trend, still changing at 0.03 dB quantization. In September 1996 put in another jump and slope change.
- In October 1996, for both Ku- and C-band, fit the sigma-naught_uncorr trend by set of line segments continuous in value but discontinuous in slope, with slope changes made on time scale no shorter than 1/2 year. This new set of table values (in MCR 618) was used for the sigma-naught values on the MGDR-B for cycles 001-132.
- In December 1996, the C-band sigma-naught_uncorr data seemed to be departing from the trend already in the Cal Table and the C-band Cal Table was frozen at one constant value for the next data cycles.
- In August 1997, the Ku- and C-band Cal Table values were projected on new linear trends quantized at 0.03 dB steps. The Ku-band slope was the same as before, but the C-band slope was different.
- In January 1998, there was a three-cycle hold or “freeze” starting at cycle 195, and then the linear trends of August 1997 were continued.

- In May 1998, used quadratic trend fit to project correction values for another dozen cycles, for cycles 210 through 221.
- In January 1999, another quadratic trend projected correction values for cycles 228 through 235. Distracted by the apparent change in Side A point target response (PTR, discussed in Section 3.3) and its consequences for SWH estimation, we failed to keep up with the correction table values after the May 1998 change; the result was that the processing "ran off the end" of the May 1998 table so that cycles 222 through 227 had constant Cal Table values.

Table 3-3, columns 5 and 6, lists the Ku- and C-band Cal Table values used in JPL's ground data processing to produce the distributed TOPEX GDRs for cycles 001 through 235; cycles 133-149 in this table are for the reprocessed and re-released GDRs. Table 3-3 is also applicable to the MGDR-Bs for cycles 133 and greater. Table 3-4, columns 5 and 6, lists the Ku- and C-band Cal Table values used in the MGDR-B for cycles 001 - 132. Note that Table 3-3 and Table 3-4 use NRA (for NASA radar altimeter) to designate what we have been calling the TOPEX altimeter in this report. The SSALT in those tables is the French CNES solid-state altimeter which also flew on the TOPEX/Poseidon mission.

Table 3-3 TOPEX Cal Table Entries for GDRs (Reprocessed and Rereleased Cycles 133-149); Also Applies to MGDR-Bs for Cycle 133 and Greater

(1) Data Cycle	(2) Start Year-Day	(3) Altimeter Operating	(4) Applicable MCR	(5) Ku CalTable Entry, dB	(6) C CalTable Entry, dB	(7) Poly Fit Ku Value, dB	(8) Poly fit C Value, dB
001	1992-267	mixed	MCR432	0.00	0.00	-0.038	-0.021
002	1992-277	mixed	MCR432	0.00	0.00	-0.034	-0.019
003	1992-286	mixed	MCR432	0.00	0.00	-0.030	-0.017
004	1992-296	mixed	MCR432	0.00	0.00	-0.026	-0.015
005	1992-306	mixed	MCR432	0.00	0.00	-0.022	-0.012
006	1992-316	mixed	MCR432	0.00	0.00	-0.018	-0.010
007	1992-326	mixed	MCR432	0.00	0.00	-0.013	-0.008
008	1992-336	mixed	MCR432	0.00	0.00	-0.009	-0.005
009	1992-346	mixed	MCR432	0.00	0.00	-0.004	-0.003
010	1992-356	mixed	MCR432	0.00	0.00	0.000	0.000
011	1992-366	mixed	MCR432	0.00	0.00	0.005	0.003
012	1993-010	mixed	MCR432	0.00	0.00	0.009	0.005
013	1993-020	mixed	MCR432	0.00	0.00	0.014	0.008

Table 3-3 TOPEX Cal Table Entries for GDRs (Reprocessed and Rereleased Cycles 133-149); Also Applies to MGDR-Bs for Cycle 133 and Greater (Continued)

(1) Data Cycle	(2) Start Year-Day	(3) Altimeter Operating	(4) Applicable MCR	(5) Ku CalTable Entry, dB	(6) C CalTable Entry, dB	(7) Poly Fit Ku Value, dB	(8) Poly fit C Value, dB
014	1993-030	mixed	MCR432	0.00	0.00	0.018	0.011
015	1993-039	mixed	MCR432	0.00	0.00	0.023	0.014
016	1993-049	mixed	MCR432	0.00	0.00	0.028	0.017
017	1993-059	NRA	MCR432	0.00	0.00	0.033	0.020
018	1993-069	NRA	MCR432	0.00	0.00	0.038	0.023
019	1993-079	NRA	MCR432	0.00	0.00	0.043	0.027
020	1993-089	SSALT					
021	1993-099	NRA	MCR432	0.00	0.00	0.053	0.033
022	1993-109	NRA	MCR432	0.00	0.00	0.058	0.037
023	1993-119	NRA	MCR432	0.00	0.00	0.064	0.040
024	1993-129	NRA	MCR432	0.00	0.00	0.069	0.044
025	1993-139	NRA	MCR432	0.00	0.00	0.074	0.047
026	1993-149	NRA	MCR432	0.00	0.00	0.080	0.051
027	1993-158	NRA	MCR432	0.00	0.00	0.085	0.055
028	1993-168	NRA	MCR432	0.00	0.00	0.091	0.059
029	1993-178	NRA	MCR432	0.00	0.00	0.096	0.062
030	1993-188	NRA	MCR432	0.00	0.00	0.102	0.066
031	1993-198	SSALT					
032	1993-208	NRA	MCR432	0.00	0.00	0.113	0.074
033	1993-218	NRA	MCR432	0.00	0.00	0.119	0.079
034	1993-228	NRA	MCR432	0.00	0.00	0.125	0.083
035	1993-238	NRA	MCR432	0.00	0.00	0.131	0.087
036	1993-248	NRA	MCR432	0.00	0.00	0.137	0.091
037	1993-258	NRA	MCR432	0.00	0.00	0.143	0.096
038	1993-268	NRA	MCR432	0.00	0.00	0.149	0.100
039	1993-277	NRA	MCR432	0.00	0.00	0.156	0.105
040	1993-287	NRA	MCR432	0.00	0.00	0.162	0.109

Table 3-3 TOPEX Cal Table Entries for GDRs (Reprocessed and Rereleased Cycles 133-149); Also Applies to MGDR-Bs for Cycle 133 and Greater (Continued)

(1) Data Cycle	(2) Start Year-Day	(3) Altimeter Operating	(4) Applicable MCR	(5) Ku CalTable Entry, dB	(6) C CalTable Entry, dB	(7) Poly Fit Ku Value, dB	(8) Poly fit C Value, dB
041	1993-297	SSALT					
042	1993-307	NRA	MCR432	0.00	0.00	0.175	0.119
043	1993-317	NRA	MCR432	0.00	0.00	0.181	0.123
044	1993-327	NRA	MCR432	0.00	0.00	0.187	0.128
045	1993-337	NRA	MCR432	0.00	0.00	0.194	0.133
046	1993-347	NRA	MCR432	0.00	0.00	0.201	0.138
047	1993-357	NRA	MCR432	0.00	0.00	0.207	0.143
048	1994-002	NRA	MCR492	0.25	0.10	0.214	0.148
049	1994-012	NRA	MCR492	0.25	0.10	0.221	0.153
050	1994-022	NRA	MCR492	0.25	0.10	0.228	0.159
051	1994-031	NRA	MCR492	0.25	0.10	0.234	0.164
052	1994-041	NRA	MCR492	0.25	0.10	0.241	0.169
053	1994-051	NRA	MCR492	0.25	0.10	0.248	0.175
054	1994-061	NRA	MCR492	0.25	0.10	0.256	0.180
055	1994-071	SSALT					
056	1994-081	NRA	MCR501	0.30	0.15	0.270	0.192
057	1994-091	NRA	MCR501	0.30	0.15	0.277	0.197
058	1994-101	NRA	MCR501	0.30	0.15	0.284	0.203
059	1994-111	NRA	MCR501	0.30	0.15	0.292	0.209
060	1994-121	NRA	MCR501	0.30	0.15	0.299	0.215
061	1994-131	NRA	MCR501	0.30	0.15	0.307	0.221
062	1994-141	NRA	MCR501	0.30	0.15	0.314	0.227
063	1994-150	NRA	MCR501	0.30	0.15	0.322	0.233
064	1994-160	NRA	MCR501	0.30	0.15	0.330	0.239
065	1994-170	SSALT					
066	1994-180	NRA	MCR501	0.30	0.15	0.345	0.251
067	1994-190	NRA	MCR501	0.30	0.15	0.353	0.258

Table 3-3 TOPEX Cal Table Entries for GDRs (Reprocessed and Rereleased Cycles 133-149); Also Applies to MGDR-Bs for Cycle 133 and Greater (Continued)

(1) Data Cycle	(2) Start Year-Day	(3) Altimeter Operating	(4) Applicable MCR	(5) Ku CalTable Entry, dB	(6) C CalTable Entry, dB	(7) Poly Fit Ku Value, dB	(8) Poly fit C Value, dB
068	1994-200	NRA	MCR501	0.30	0.15	0.361	0.264
069	1994-210	NRA	MCR501	0.30	0.15	0.369	0.271
070	1994-220	NRA	MCR501	0.30	0.15	0.377	0.277
071	1994-230	NRA	MCR501	0.30	0.15	0.385	0.284
072	1994-240	NRA	MCR501	0.30	0.15	0.393	0.291
073	1994-250	NRA	MCR501	0.30	0.15	0.401	0.297
074	1994-259	NRA	MCR501	0.30	0.15	0.410	0.304
075	1994-269	NRA	MCR501	0.30	0.15	0.418	0.311
076	1994-279	NRA	MCR529	0.45	0.35	0.426	0.318
077	1994-289	NRA	MCR529	0.45	0.35	0.435	0.325
078	1994-299	NRA	MCR529	0.45	0.35	0.443	0.332
079	1994-309	SSALT					
080	1994-319	NRA	MCR529	0.45	0.35	0.460	0.346
081	1994-329	NRA	MCR529	0.45	0.35	0.469	0.354
082	1994-339	NRA	MCR539	0.50	0.40	0.478	0.361
083	1994-349	NRA	MCR539	0.50	0.40	0.487	0.368
084	1994-359	NRA	MCR539	0.50	0.40	0.495	0.376
085	1995-004	NRA	MCR539	0.50	0.40	0.504	0.383
086	1995-013	NRA	MCR539	0.55	0.45	0.513	0.391
087	1995-023	NRA	MCR539	0.55	0.45	0.522	0.399
088	1995-033	NRA	MCR539	0.55	0.45	0.532	0.406
089	1995-043	NRA	MCR539	0.55	0.45	0.541	0.414
090	1995-053	NRA	MCR539	0.55	0.45	0.550	0.422
091	1995-063	SSALT					
092	1995-073	NRA	MCR539	0.55	0.45	0.568	0.438
093	1995-083	NRA	MCR548	0.55	0.45	0.578	0.446
094	1995-093	NRA	MCR548	0.55	0.45	0.587	0.454

Table 3-3 TOPEX Cal Table Entries for GDRs (Reprocessed and Rereleased Cycles 133-149); Also Applies to MGDR-Bs for Cycle 133 and Greater (Continued)

(1) Data Cycle	(2) Start Year-Day	(3) Altimeter Operating	(4) Applicable MCR	(5) Ku CalTable Entry, dB	(6) C CalTable Entry, dB	(7) Poly Fit Ku Value, dB	(8) Poly fit C Value, dB
095	1995-103	NRA	MCR548	0.55	0.45	0.597	0.462
096	1995-113	NRA	MCR548	0.55	0.45	0.606	0.470
097	1995-123	SSALT					
098	1995-132	NRA	MCR548	0.55	0.45	0.626	0.487
099	1995-142	NRA	MCR548	0.60	0.45	0.635	0.496
100	1995-152	NRA	MCR548	0.60	0.45	0.645	0.504
101	1995-162	NRA	MCR548	0.60	0.45	0.655	0.513
102	1995-172	NRA	MCR548	0.60	0.45	0.665	0.521
103	1995-182	SSALT					
104	1995-192	NRA	MCR562	0.65	0.50	0.685	0.539
105	1995-202	NRA	MCR562	0.65	0.50	0.695	0.548
106	1995-212	NRA	MCR562	0.65	0.50	0.705	0.556
107	1995-222	NRA	MCR562	0.70	0.55	0.716	0.565
108	1995-232	NRA	MCR562	0.70	0.55	0.726	0.574
109	1995-242	NRA	MCR562	0.70	0.55	0.736	0.584
110	1995-251	NRA	MCR530	0.75	0.57	0.747	0.593
111	1995-261	NRA	MCR530	0.75	0.57	0.757	0.602
112	1995-271	NRA	MCR530	0.75	0.60	0.767	0.611
113	1995-281	NRA	MCR530	0.75	0.60	0.778	0.621
114	1995-291	SSALT					
115	1995-301	NRA	MCR530	0.78	0.60	0.799	0.639
116	1995-311	NRA	MCR530	0.78	0.60	0.810	0.649
117	1995-321	NRA	MCR530	0.78	0.63	0.821	0.659
118	1995-331	NRA	MCR530	0.81	0.63	0.832	0.668
119	1995-341	NRA	MCR530	0.81	0.63	0.843	0.678
120	1995-351	NRA	MCR530	0.81	0.63	0.854	0.688
121	1995-361	NRA	MCR530	0.81	0.63	0.865	0.698

Table 3-3 TOPEX Cal Table Entries for GDRs (Reprocessed and Rereleased Cycles 133-149); Also Applies to MGDR-Bs for Cycle 133 and Greater (Continued)

(1) Data Cycle	(2) Start Year-Day	(3) Altimeter Operating	(4) Applicable MCR	(5) Ku CalTable Entry, dB	(6) C CalTable Entry, dB	(7) Poly Fit Ku Value, dB	(8) Poly fit C Value, dB
122	1996-005	NRA	MCR585	0.84	0.63	0.876	0.708
123	1996-015	NRA	MCR585	0.84	0.66	0.887	0.718
124	1996-025	NRA	MCR585	0.84	0.66	0.898	0.728
125	1996-035	NRA	MCR585	0.84	0.66	0.910	0.738
126	1996-045	SSALT					
127	1996-055	NRA	MCR585	0.87	0.66	0.932	0.758
128	1996-065	NRA	MCR585	0.87	0.69	0.944	0.769
129	1996-075	NRA	MCR585	0.87	0.69	0.955	0.779
130	1996-085	NRA	MCR585	0.90	0.69	0.967	0.790
131	1996-095	NRA	MCR585	0.90	0.69	0.978	0.800
132	1996-105	NRA	MCR585	0.90	0.69	0.990	0.811
133	1996-115	NRA	MCR618	1.05	0.81	1.002	0.821
134	1996-124	NRA	MCR618	1.05	0.81	1.014	0.832
135	1996-134	NRA	MCR618	1.08	0.84	1.026	0.843
136	1996-144	NRA	MCR618	1.08	0.84	1.038	0.854
137	1996-154	NRA	MCR618	1.08	0.84	1.050	0.865
138	1996-164	SSALT					
139	1996-174	NRA	MCR618	1.11	0.90	1.074	0.887
140	1996-184	NRA	MCR618	1.14	0.93	1.086	0.898
141	1996-194	NRA	MCR618	1.14	0.93	1.098	0.909
142	1996-204	NRA	MCR618	1.17	0.96	1.110	0.920
143	1996-214	NRA	MCR618	1.17	0.99	1.123	0.932
144	1996-224	NRA	MCR618	1.20	1.02	1.135	0.943
145	1996-234	NRA	MCR618	1.20	1.05	1.148	0.954
146	1996-243	NRA	MCR618	1.23	1.05	1.160	0.966
147	1996-253	NRA	MCR618	1.23	1.08	1.173	0.977
148	1996-263	NRA	MCR618	1.26	1.11	1.185	0.989

Table 3-3 TOPEX Cal Table Entries for GDRs (Reprocessed and Rereleased Cycles 133-149); Also Applies to MGDR-Bs for Cycle 133 and Greater (Continued)

(1) Data Cycle	(2) Start Year-Day	(3) Altimeter Operating	(4) Applicable MCR	(5) Ku CalTable Entry, dB	(6) C CalTable Entry, dB	(7) Poly Fit Ku Value, dB	(8) Poly fit C Value, dB
149	1996-273	NRA	MCR618	1.26	1.14	1.198	1.001
150	1996-283	SSALT					
151	1996-293	NRA	MCR618	1.29	1.17	1.224	1.024
152	1996-303	NRA	MCR618	1.32	1.20	1.237	1.036
153	1996-313	NRA	MCR618	1.32	1.23	1.249	1.048
154	1996-323	NRA	MCR629	1.35	1.26	1.262	1.060
155	1996-333	NRA	MCR629	1.35	1.26	1.276	1.072
156	1996-343	NRA	MCR629	1.38	1.26	1.289	1.085
157	1996-352	NRA	MCR629	1.38	1.26	1.302	1.097
158	1996-362	NRA	MCR629	1.41	1.26	1.315	1.109
159	1997-006	NRA	MCR629	1.41	1.26	1.328	1.121
160	1997-016	NRA	MCR630	1.41	1.29	1.342	1.134
161	1997-026	NRA	MCR630	1.41	1.29	1.355	1.146
162	1997-036	SSALT					
163	1997-046	NRA	MCR630	1.44	1.32	1.382	1.172
164	1997-056	NRA	MCR630	1.47	1.35	1.396	1.184
165	1997-066	NRA	MCR632	1.47	1.35	1.409	1.197
166	1997-076	NRA	MCR632	1.50	1.35	1.423	1.210
167	1997-086	NRA	MCR632	1.50	1.35	1.437	1.223
168	1997-096	NRA	MCR632	1.53	1.35	1.451	1.236
169	1997-105	NRA	MCR632	1.53	1.35	1.465	1.249
170	1997-115	NRA	MCR632	1.56	1.35	1.478	1.262
171	1997-125	NRA	MCR632	1.56	1.35	1.492	1.275
172	1997-135	NRA	MCR632	1.59	1.35	1.507	1.288
173	1997-145	NRA	MCR632	1.59	1.35	1.521	1.301
174	1997-155	SSALT					
175	1997-165	NRA	MCR638	1.62	1.35	1.549	1.328

Table 3-3 TOPEX Cal Table Entries for GDRs (Reprocessed and Rereleased Cycles 133-149); Also Applies to MGDR-Bs for Cycle 133 and Greater (Continued)

(1) Data Cycle	(2) Start Year-Day	(3) Altimeter Operating	(4) Applicable MCR	(5) Ku CalTable Entry, dB	(6) C CalTable Entry, dB	(7) Poly Fit Ku Value, dB	(8) Poly fit C Value, dB
176	1997-175	NRA	MCR638	1.62	1.35	1.563	1.342
177	1997-185	NRA	MCR638	1.65	1.35	1.578	1.355
178	1997-195	NRA	MCR638	1.65	1.35	1.592	1.369
179	1997-205	NRA	MCR638	1.68	1.38	1.607	1.382
180	1997-215	SSALT					
181	1997-224	NRA	MCR643	1.71	1.41	1.636	1.410
182	1997-234	NRA	MCR643	1.71	1.41	1.650	1.424
183	1997-244	NRA	MCR643	1.74	1.44	1.665	1.438
184	1997-254	NRA	MCR643	1.74	1.44	1.680	1.452
185	1997-264	NRA	MCR643	1.77	1.47	1.695	1.466
186	1997-274	SSALT					
187	1997-284	NRA	MCR643	1.80	1.50	1.725	1.494
188	1997-294	NRA	MCR643	1.80	1.50	1.740	1.508
189	1997-304	NRA	MCR643	1.83	1.53	1.755	1.523
190	1997-314	NRA	MCR643	1.83	1.53	1.770	1.537
191	1997-324	NRA	MCR643	1.86	1.56	1.785	1.551
192	1997-334	NRA	MCR643	1.86	1.56	1.800	1.566
193	1997-343	NRA	MCR643	1.89	1.59	1.816	1.580
194	1997-353	NRA	MCR643	1.89	1.59	1.831	1.595
195	1997-363	NRA	MCR643	1.89	1.59	1.846	1.610
196	1998-008	NRA	MCR643	1.89	1.59	1.862	1.625
197	1998-018	SSALT					
198	1998-028	NRA	MCR654	1.92	1.62	1.893	1.654
199	1998-038	NRA	MCR654	1.92	1.62	1.909	1.669
200	1998-048	NRA	MCR654	1.95	1.65	1.924	1.684
201	1998-058	NRA	MCR654	1.95	1.65	1.968	1.705
202	1998-068	NRA	MCR654	1.98	1.68	1.984	1.720

Table 3-3 TOPEX Cal Table Entries for GDRs (Reprocessed and Rereleased Cycles 133-149); Also Applies to MGDR-Bs for Cycle 133 and Greater (Continued)

(1) Data Cycle	(2) Start Year-Day	(3) Altimeter Operating	(4) Applicable MCR	(5) Ku CalTable Entry, dB	(6) C CalTable Entry, dB	(7) Poly Fit Ku Value, dB	(8) Poly fit C Value, dB
203	1998-078	NRA	MCR654	1.98	1.68	2.001	1.735
204	1998-088	NRA	MCR654	2.01	1.71	2.018	1.750
205	1998-097	NRA	MCR654	2.01	1.71	2.036	1.766
206	1998-107	NRA	MCR654	2.04	1.74	2.053	1.781
207	1998-117	NRA	MCR654	2.04	1.74	2.070	1.797
208	1998-127	NRA	MCR654	2.07	1.77	2.087	1.812
209	1998-137	SSALT					
210	1998-147	NRA	MCR666	2.10	1.77	2.122	1.844
211	1998-157	NRA	MCR666	2.13	1.80	2.140	1.860
212	1998-167	NRA	MCR666	2.13	1.83	2.157	1.875
213	1998-177	NRA	MCR666	2.16	1.83	2.175	1.891
214	1998-187	NRA	MCR666	2.16	1.86	2.193	1.907
215	1998-197	NRA	MCR666	2.19	1.86	2.210	1.923
216	1998-207	SSALT	MCR666				
217	1998-216	NRA	MCR666	2.22	1.92	2.246	1.956
218	1998-226	NRA	MCR666	2.22	1.92	2.264	1.972
219	1998-236	NRA	MCR666	2.25	1.95	2.282	1.988
220	1998-246	NRA	MCR666	2.28	1.95	2.300	2.005
221	1998-256	NRA	MCR666	2.28	1.98	2.319	2.021
222	1998-266	NRA	MCR666	2.28	1.98	2.337	2.038
223	1998-276	NRA	MCR666	2.28	1.98	2.355	2.054
224	1998-286	SSALT	MCR666				
225	1998-296	NRA	MCR666	2.28	1.98	2.392	2.087
226	1998-306	NRA	MCR666	2.28	1.98	2.411	2.104
227	1998-316	NRA	MCR666	2.28	1.98	2.429	2.121
228	1998-326	NRA	MCR684	2.40	2.07	2.448	2.138
229	1998-335	NRA	MCR684	2.40	2.10	2.467	2.155

Table 3-3 TOPEX Cal Table Entries for GDRs (Reprocessed and Rereleased Cycles 133-149); Also Applies to MGDR-Bs for Cycle 133 and Greater (Continued)

(1) Data Cycle	(2) Start Year-Day	(3) Altimeter Operating	(4) Applicable MCR	(5) Ku CalTable Entry, dB	(6) C CalTable Entry, dB	(7) Poly Fit Ku Value, dB	(8) Poly fit C Value, dB
230	1998-345	NRA	MCR684	2.43	2.13	2.486	2.172
231	1998-355	NRA	MCR684	2.46	2.13	2.504	2.189
232	1998-365	NRA	MCR684	2.46	2.16	2.523	2.206
233	1999-010	NRA	MCR684	2.49	2.16	2.542	2.223
234	1999-020	SSALT	MCR684				
235	1999-030	NRA	MCR684	2.52	2.19	2.581	2.258

Table 3-4 TOPEX Cal Table Entries for MGDR-Bs up to Cycle 132

(1) Data Cycle	(2) Start Year-Day	(3) Altimeter Operating	(4) Applicable MCR	(5) Ku CalTable Entry, dB	(6) C CalTable Entry, dB	(7) Poly Fit Ku Value, dB	(8) Poly fit C Value, dB
001	1992-267	mixed	MCR432	0.00	0.00	-0.038	-0.021
002	1992-277	mixed	MCR432	0.00	0.00	-0.034	-0.019
003	1992-286	mixed	MCR432	0.00	0.00	-0.030	-0.017
004	1992-296	mixed	MCR432	0.00	0.00	-0.026	-0.015
005	1992-306	mixed	MCR432	0.00	0.00	-0.022	-0.012
006	1992-316	mixed	MCR432	0.00	0.00	-0.018	-0.010
007	1992-326	mixed	MCR432	0.00	0.00	-0.013	-0.008
008	1992-336	mixed	MCR432	0.00	0.00	-0.009	-0.005
009	1992-346	mixed	MCR432	0.00	0.00	-0.004	-0.003
010	1992-356	mixed	MCR432	0.00	0.00	0.000	0.000
011	1992-366	mixed	MCR432	0.00	0.00	0.005	0.003
012	1993-010	mixed	MCR432	0.00	0.00	0.009	0.005
013	1993-020	mixed	MCR432	0.00	0.00	0.014	0.008
014	1993-030	mixed	MCR432	0.00	0.00	0.018	0.011
015	1993-039	mixed	MCR432	0.00	0.00	0.023	0.014
016	1993-049	mixed	MCR432	0.00	0.00	0.028	0.017

Table 3-4 TOPEX Cal Table Entries for MGDR-Bs up to Cycle 132 (Continued)

(1) Data Cycle	(2) Start Year-Day	(3) Altimeter Operating	(4) Applicable MCR	(5) Ku CalTable Entry, dB	(6) C CalTable Entry, dB	(7) Poly Fit Ku Value, dB	(8) Poly fit C Value, dB
017	1993-059	NRA	MCR432	0.00	0.00	0.033	0.020
018	1993-069	NRA	MCR432	0.00	0.00	0.038	0.023
019	1993-079	NRA	MCR432	0.00	0.00	0.043	0.027
020	1993-089	SSALT					
021	1993-099	NRA	MCR432	0.00	0.00	0.053	0.033
022	1993-109	NRA	MCR432	0.00	0.00	0.058	0.037
023	1993-119	NRA	MCR432	0.00	0.00	0.064	0.040
024	1993-129	NRA	MCR432	0.00	0.00	0.069	0.044
025	1993-139	NRA	MCR432	0.00	0.00	0.074	0.047
026	1993-149	NRA	MCR432	0.00	0.00	0.080	0.051
027	1993-158	NRA	MCR432	0.00	0.00	0.085	0.055
028	1993-168	NRA	MCR432	0.00	0.00	0.091	0.059
029	1993-178	NRA	MCR432	0.00	0.00	0.096	0.062
030	1993-188	NRA	MCR432	0.00	0.00	0.102	0.066
031	1993-198	SSALT					
032	1993-208	NRA	MCR432	0.00	0.00	0.113	0.074
033	1993-218	NRA	MCR432	0.00	0.00	0.119	0.079
034	1993-228	NRA	MCR432	0.00	0.00	0.125	0.083
035	1993-238	NRA	MCR432	0.00	0.00	0.131	0.087
036	1993-248	NRA	MCR432	0.00	0.00	0.137	0.091
037	1993-258	NRA	MCR432	0.00	0.00	0.143	0.096
038	1993-268	NRA	MCR432	0.00	0.00	0.149	0.100
039	1993-277	NRA	MCR432	0.00	0.00	0.156	0.105
040	1993-287	NRA	MCR432	0.00	0.00	0.162	0.109
041	1993-297	SSALT					
042	1993-307	NRA	MCR432	0.00	0.00	0.175	0.119
043	1993-317	NRA	MCR432	0.00	0.00	0.181	0.123
044	1993-327	NRA	MCR432	0.00	0.00	0.187	0.128

Table 3-4 TOPEX Cal Table Entries for MGDR-Bs up to Cycle 132 (Continued)

(1) Data Cycle	(2) Start Year-Day	(3) Altimeter Operating	(4) Applicable MCR	(5) Ku CalTable Entry, dB	(6) C CalTable Entry, dB	(7) Poly Fit Ku Value, dB	(8) Poly fit C Value, dB
045	1993-337	NRA	MCR432	0.00	0.00	0.194	0.133
046	1993-347	NRA	MCR432	0.00	0.00	0.201	0.138
047	1993-357	NRA	MCR432	0.00	0.00	0.207	0.143
048	1994-002	NRA	MCR492	0.25	0.10	0.214	0.148
049	1994-012	NRA	MCR492	0.25	0.10	0.221	0.153
050	1994-022	NRA	MCR492	0.25	0.10	0.228	0.159
051	1994-031	NRA	MCR492	0.25	0.10	0.234	0.164
052	1994-041	NRA	MCR492	0.25	0.10	0.241	0.169
053	1994-051	NRA	MCR492	0.25	0.10	0.248	0.175
054	1994-061	NRA	MCR492	0.25	0.10	0.256	0.180
055	1994-071	SSALT					
056	1994-081	NRA	MCR501	0.30	0.15	0.270	0.192
057	1994-091	NRA	MCR501	0.30	0.15	0.277	0.197
058	1994-101	NRA	MCR501	0.30	0.15	0.284	0.203
059	1994-111	NRA	MCR501	0.30	0.15	0.292	0.209
060	1994-121	NRA	MCR501	0.30	0.15	0.299	0.215
061	1994-131	NRA	MCR501	0.30	0.15	0.307	0.221
062	1994-141	NRA	MCR501	0.30	0.15	0.314	0.227
063	1994-150	NRA	MCR501	0.30	0.15	0.322	0.233
064	1994-160	NRA	MCR501	0.30	0.15	0.330	0.239
065	1994-170	SSALT					
066	1994-180	NRA	MCR501	0.30	0.15	0.345	0.251
067	1994-190	NRA	MCR501	0.30	0.15	0.353	0.258
068	1994-200	NRA	MCR501	0.30	0.15	0.361	0.264
069	1994-210	NRA	MCR501	0.30	0.15	0.369	0.271
070	1994-220	NRA	MCR501	0.30	0.15	0.377	0.277
071	1994-230	NRA	MCR501	0.30	0.15	0.385	0.284
072	1994-240	NRA	MCR501	0.30	0.15	0.393	0.291

Table 3-4 TOPEX Cal Table Entries for MGDR-Bs up to Cycle 132 (Continued)

(1) Data Cycle	(2) Start Year-Day	(3) Altimeter Operating	(4) Applicable MCR	(5) Ku CalTable Entry, dB	(6) C CalTable Entry, dB	(7) Poly Fit Ku Value, dB	(8) Poly fit C Value, dB
073	1994-250	NRA	MCR501	0.30	0.15	0.401	0.297
074	1994-259	NRA	MCR501	0.30	0.15	0.410	0.304
075	1994-269	NRA	MCR501	0.30	0.15	0.418	0.311
076	1994-279	NRA	MCR529	0.45	0.35	0.426	0.318
077	1994-289	NRA	MCR529	0.45	0.35	0.435	0.325
078	1994-299	NRA	MCR529	0.45	0.35	0.443	0.332
079	1994-309	SSALT					
080	1994-319	NRA	MCR529	0.45	0.35	0.460	0.346
081	1994-329	NRA	MCR529	0.45	0.35	0.469	0.354
082	1994-339	NRA	MCR539	0.50	0.40	0.478	0.361
083	1994-349	NRA	MCR539	0.50	0.40	0.487	0.368
084	1994-359	NRA	MCR539	0.50	0.40	0.495	0.376
085	1995-004	NRA	MCR539	0.50	0.40	0.504	0.383
086	1995-013	NRA	MCR539	0.55	0.45	0.513	0.391
087	1995-023	NRA	MCR539	0.55	0.45	0.522	0.399
088	1995-033	NRA	MCR539	0.55	0.45	0.532	0.406
089	1995-043	NRA	MCR539	0.55	0.45	0.541	0.414
090	1995-053	NRA	MCR539	0.55	0.45	0.550	0.422
091	1995-063	SSALT					
092	1995-073	NRA	MCR539	0.55	0.45	0.568	0.438
093	1995-083	NRA	MCR548	0.55	0.45	0.578	0.446
094	1995-093	NRA	MCR548	0.55	0.45	0.587	0.454
095	1995-103	NRA	MCR548	0.55	0.45	0.597	0.462
096	1995-113	NRA	MCR548	0.55	0.45	0.606	0.470
097	1995-123	SSALT					
098	1995-132	NRA	MCR548	0.55	0.45	0.626	0.487
099	1995-142	NRA	MCR548	0.60	0.45	0.635	0.496
100	1995-152	NRA	MCR548	0.60	0.45	0.645	0.504

Table 3-4 TOPEX Cal Table Entries for MGDR-Bs up to Cycle 132 (Continued)

(1) Data Cycle	(2) Start Year-Day	(3) Altimeter Operating	(4) Applicable MCR	(5) Ku CalTable Entry, dB	(6) C CalTable Entry, dB	(7) Poly Fit Ku Value, dB	(8) Poly fit C Value, dB
101	1995-162	NRA	MCR548	0.60	0.45	0.655	0.513
102	1995-172	NRA	MCR548	0.60	0.45	0.665	0.521
103	1995-182	SSALT					
104	1995-192	NRA	MCR562	0.65	0.50	0.685	0.539
105	1995-202	NRA	MCR562	0.65	0.50	0.695	0.548
106	1995-212	NRA	MCR562	0.65	0.50	0.705	0.556
107	1995-222	NRA	MCR562	0.70	0.55	0.716	0.565
108	1995-232	NRA	MCR562	0.70	0.55	0.726	0.574
109	1995-242	NRA	MCR562	0.70	0.55	0.736	0.584
110	1995-251	NRA	MCR530	0.75	0.57	0.747	0.593
111	1995-261	NRA	MCR530	0.75	0.57	0.757	0.602
112	1995-271	NRA	MCR530	0.75	0.60	0.767	0.611
113	1995-281	NRA	MCR530	0.75	0.60	0.778	0.621
114	1995-291	SSALT					
115	1995-301	NRA	MCR530	0.78	0.60	0.799	0.639
116	1995-311	NRA	MCR530	0.78	0.60	0.810	0.649
117	1995-321	NRA	MCR530	0.78	0.63	0.821	0.659
118	1995-331	NRA	MCR530	0.81	0.63	0.832	0.668
119	1995-341	NRA	MCR530	0.81	0.63	0.843	0.678
120	1995-351	NRA	MCR530	0.81	0.63	0.854	0.688
121	1995-361	NRA	MCR530	0.81	0.63	0.865	0.698
122	1996-005	NRA	MCR585	0.84	0.63	0.876	0.708
123	1996-015	NRA	MCR585	0.84	0.66	0.887	0.718
124	1996-025	NRA	MCR585	0.84	0.66	0.898	0.728
125	1996-035	NRA	MCR585	0.84	0.66	0.910	0.738
126	1996-045	SSALT					
127	1996-055	NRA	MCR585	0.87	0.66	0.932	0.758
128	1996-065	NRA	MCR585	0.87	0.69	0.944	0.769

Table 3-4 TOPEX Cal Table Entries for MGDR-Bs up to Cycle 132 (Continued)

(1) Data Cycle	(2) Start Year-Day	(3) Altimeter Operating	(4) Applicable MCR	(5) Ku CalTable Entry, dB	(6) C CalTable Entry, dB	(7) Poly Fit Ku Value, dB	(8) Poly fit C Value, dB
129	1996-075	NRA	MCR585	0.87	0.69	0.955	0.779
130	1996-085	NRA	MCR585	0.90	0.69	0.967	0.790
131	1996-095	NRA	MCR585	0.90	0.69	0.978	0.800
132	1996-105	NRA	MCR585	0.90	0.69	0.990	0.811

3.2.4 Trend Fitting of Sigma-Naught for the Estimation of Cal Table Values

During the first four years of TOPEX/Poseidon, we had done a variety of least-squares fitting of global over-ocean sigma-naught_uncorr cycle averages to a fit function whose parameters included 1) the amplitude and phase of both an annual and a semiannual sinusoid; 2) terms linear and quadratic in the Ku-band SWH; and 3) terms linear and quadratic in cycle number (equivalently, in time). In all sigma-naught_uncorr trend-fitting, we use data only from cycles 011 and higher. By assuming that the long-term true sigma-naught should be constant, the Cal Table values were taken as equal to the shifted negative values of the trend linear time term. These values were shifted to produce zero correction at cycle 011.

For the entire TOPEX altimeter Side A trend analysis, we are using data from cycles 017 through 235. Cycles lower than 017 were mixed TOPEX/SSALT cycles. For earlier modeling, it seemed reasonable to include the terms in Ku-band SWH, but since that time we have seen apparent Side A PTR changes (discussed in Section 3.3) and resulting errors in SWH. Cycles 017 through 235 represent almost six years of data, and the time trend should be adequately fitted without including a SWH dependent term in the fit. The current whole-mission sigma-naught_uncorr can be represented adequately by a quadratic polynomial for the time terms. We have tried higher order polynomials, but find virtually no improvement in the residuals compared to those for the quadratic fit. The Ku-band trend fit results are shown Figure 3-5 and the C-band trend fit results are shown in Figure 3-6. The negative shifted time trend fit values (from the quadratic polynomial in cycle number) are also listed in columns 7 and 8 of Tables 3-3 and 3-4; and these are our current best estimates of what the Ku-band and C-band Cal Table values should have been for each TOPEX altimeter data cycle.

Figure 3-7 shows the Ku-band sigma-naught_uncorr and the fitted time trend from Figure 3-5, and also shows the shifted inverted Ku-band Cal Table values used in the MGDR-B product. Figure 3-7 provides a quick visual summary of the effectiveness of the various Ku-band Cal Table adjustments summarized in Table 3-3. Figure 3-8 presents a similar summary for the C-band adjustments. In general our “on the fly” adjustments of Table 3-3 were not too bad, but there are problem areas such as cycles 145-170 for the C-band in Figure 3-8.

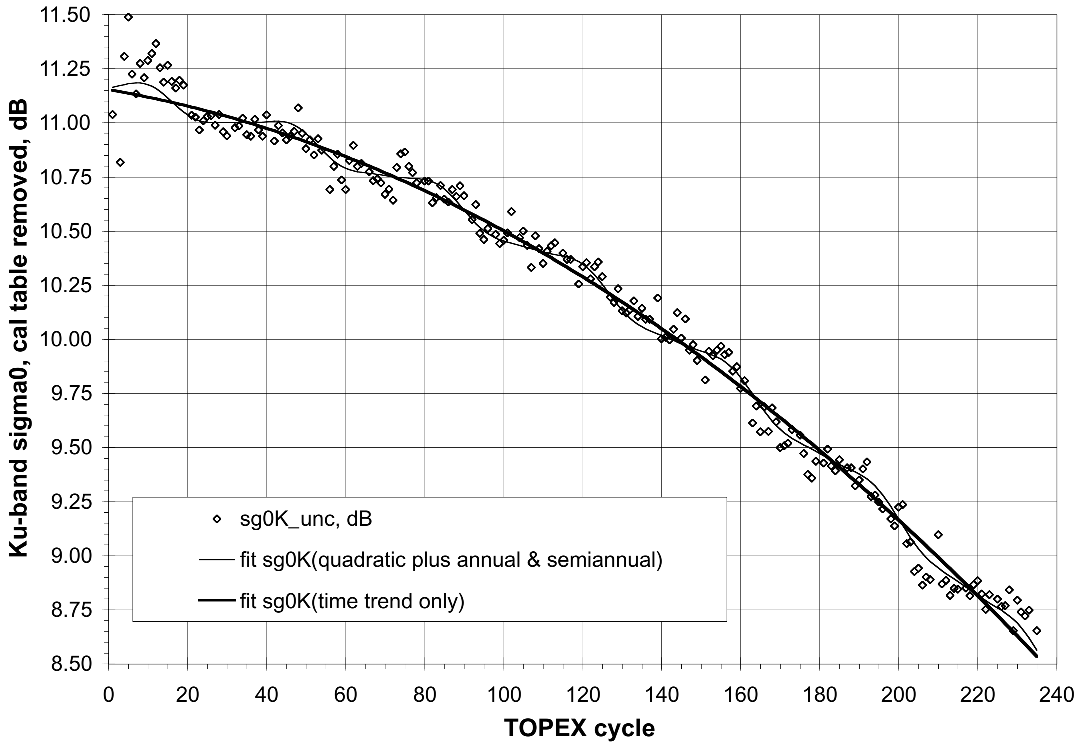

Figure 3-5 Side A Ku-Band Sigma_Naught Cycle-Averages & Cycle 017-235 Fit After Removing Calibration Table Corrections

Figure 3-9 is a comparison of the annual and semiannual sinusoid fit terms from the fits of Figure 3-5 and Figure 3-6. It is gratifying that the annual terms have approximately the same phase and similar magnitudes, saying that there are real seasonal effects in the TOPEX sigma-naught data. That is not too important for the purpose of this discussion, however, because the quadratic time trend fits would have been about the same if there had been no annual and semiannual terms included.

To use these Side A time trend estimates to revise the TOPEX Ku-band GDR sigma-naught values for GDRs already distributed, the data user should subtract the Table 3-3 / Table 3-4 column 5 value from his GDR sigma-naught and then add the Table 3-3 / Table 3-4 column 7 value. In other words, the additive adjustment to the GDR Ku-band sigma-naught is

Ku adjust = (Ku quadratic fit, Table 3-3 / Table 3-4 column 7)

minus (Ku Cal Table, Table 3-3 / Table 3-4, column 5),

and this Ku sigma-naught adjustment is plotted in Figure 3-10. Similarly, the TOPEX C-band additive adjustment is

C adjust = (C quadratic fit, Table 3-3 / Table 3-4 column 8)

minus (C Cal Table, Table 3-3 / Table 3-4, column 6),

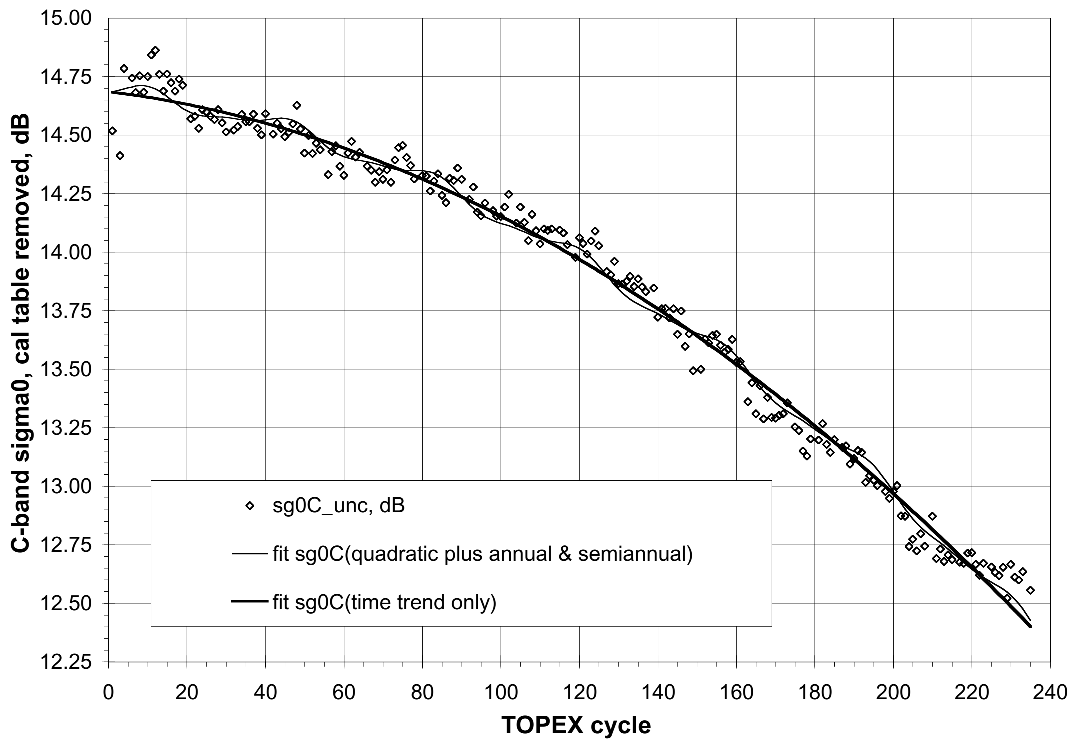

Figure 3-6 Side A C-Band Sigma-Naught Cycle-Averages & Cycle 017-235 Fit After Removing Calibration Table Corrections

and this C-band sigma-naught adjustment is plotted in Figure 3-11. We referred here simply to Table 3-3/Table 3-4, but the user has to decide whether to use Table 3-3 or Table 3-4; Table 3-3 is appropriate to the TOPEX GDRS for all cycles (with cycles 133-149 having been reprocessed and rereleased) and to the MGDR-Bs for cycle 133 and greater, while Table 3-4 should be used for MGDR-Bs for cycle 132 and less.

The fitted Ku-band quadratic time trend (Table 3-3/Table 3-4, column 7) is given by

Ku_time_trend = -0.03814 + Ncyc*(3.09049E-03 + Ncyc*3.42692E-05),

where Ncyc is the cycle number. Likewise, the fitted C-band time trend (Table 3-3/Table 3-4, column 8) is

C_time_trend = -0.02661 + Ncyc*(2.06055E-03 + Ncyc*3.26012E-05).

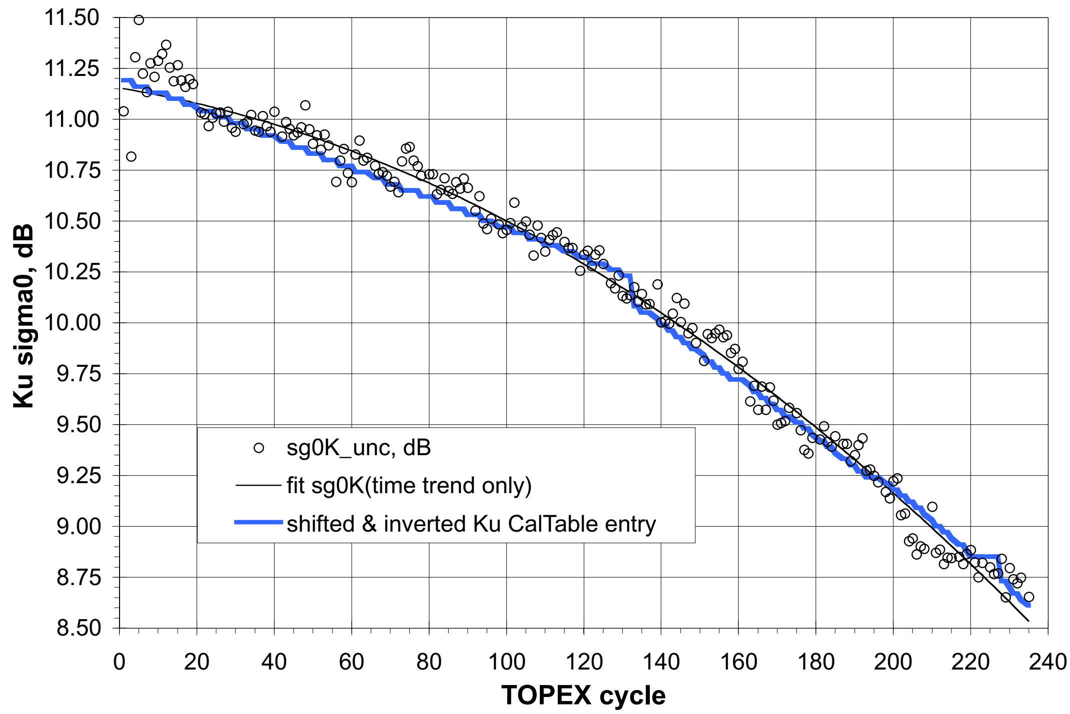

Figure 3-7 Ku-Band Sigma-Naught Cycle-Averages (Cal Table Corrections Removed)

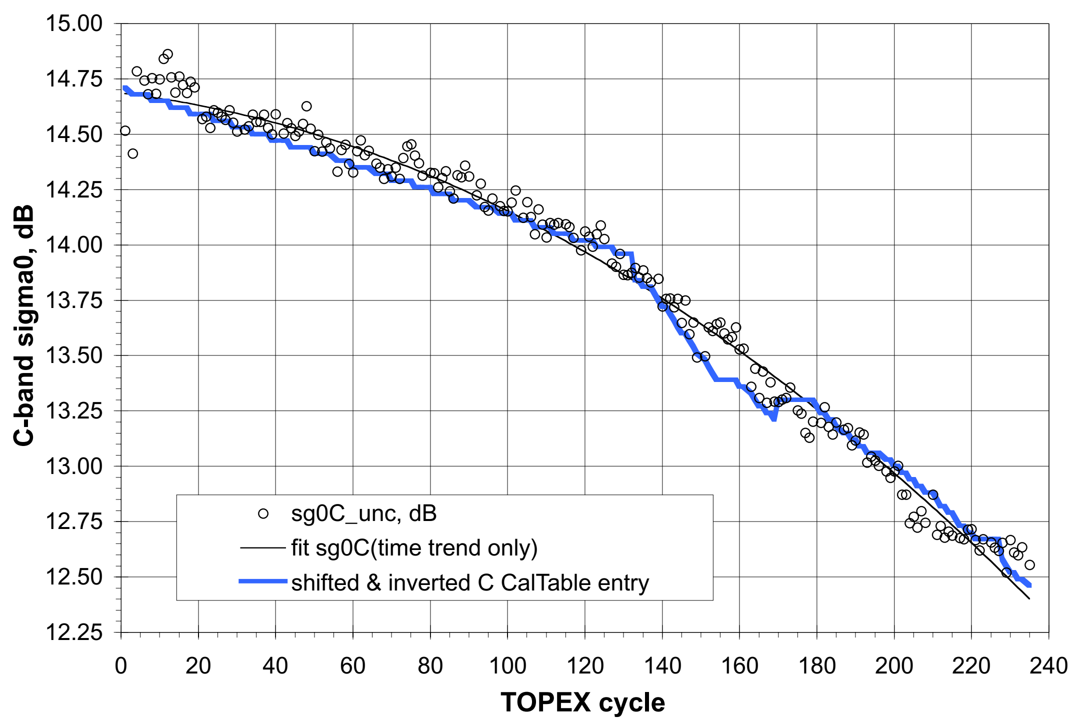

Figure 3-8 C-Band Sigma-Naught Cycle-Averages (Cal Table Corrections Removed)

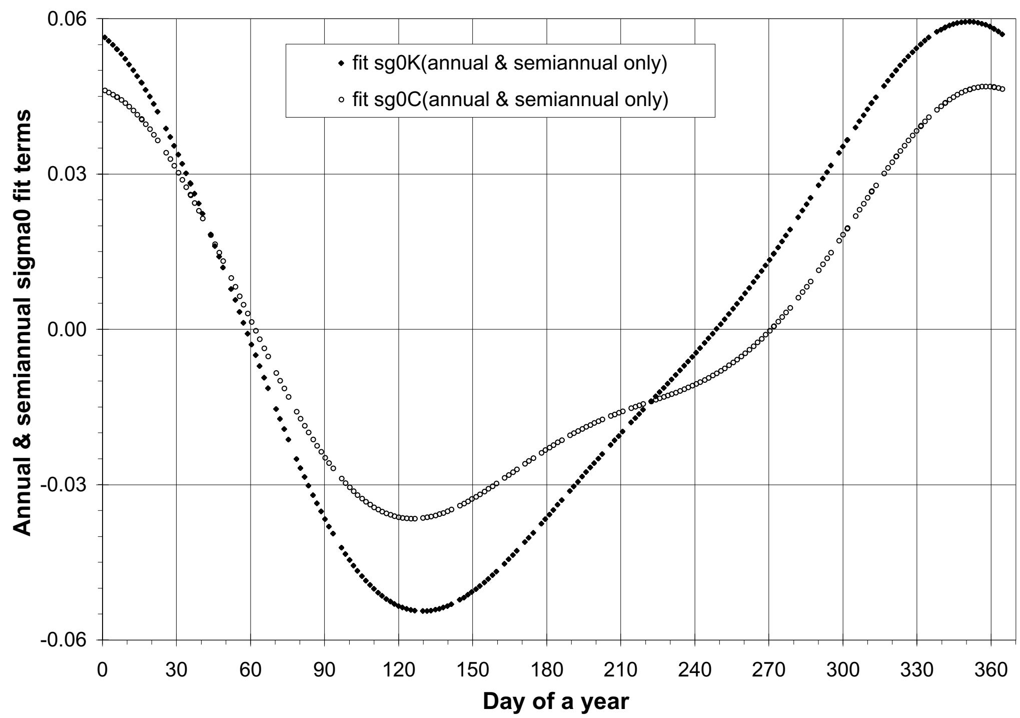

Figure 3-9 TOPEX Side A Ku-Band & C-Band Annual and Semiannual Terms in Cycle 017-235 Fit to Sigma0 (Cal Table Removed)

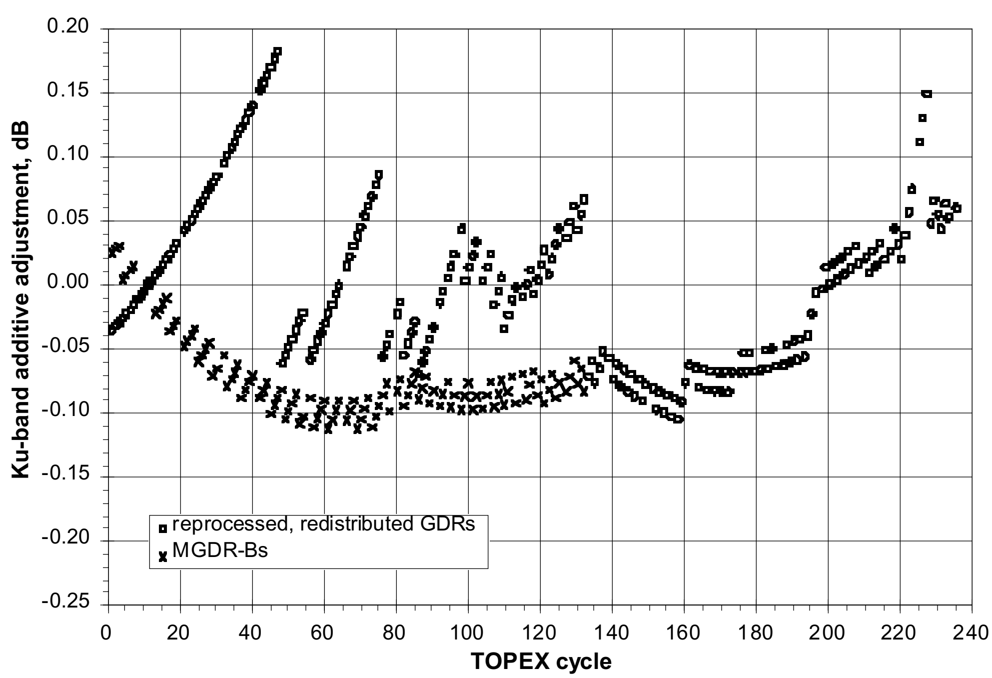

Figure 3-10 Ku-Band Additive Adjustments to GDR and MGDR-B Values

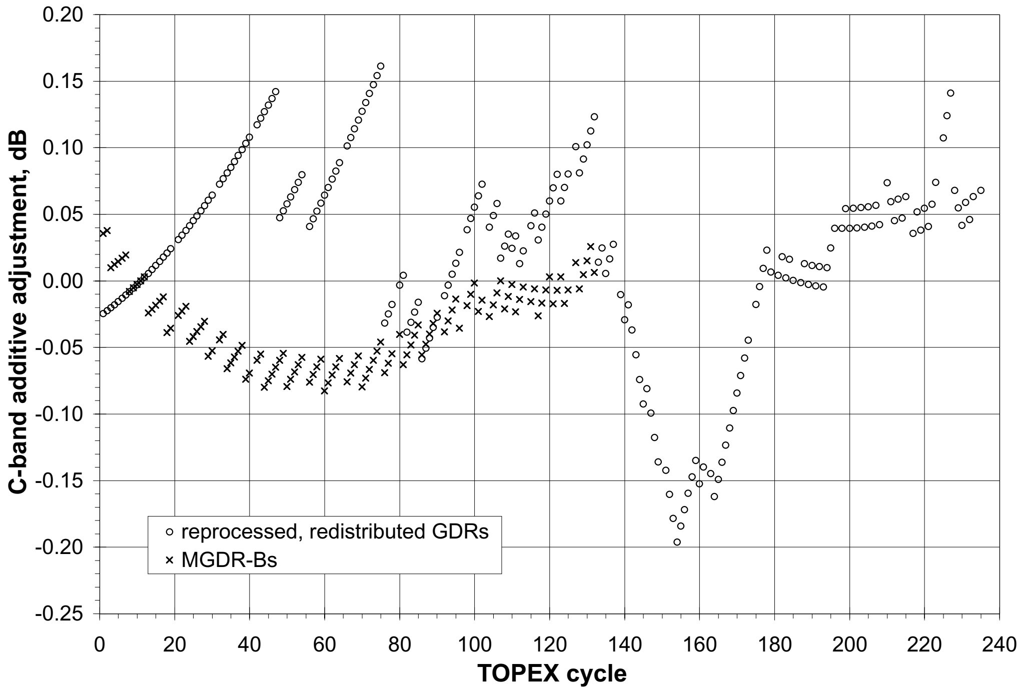

Figure 3-11 C-Band Additive Adjustments to GDR and MGDR-B Values

3.3 Side A Point Target Response Changes and Consequences

Changes in the TOPEX altimeter became apparent around the middle of 1998. The first symptoms of the changes were an increase in the altimeter's estimates of global over-ocean significant waveheight (SWH) and an increase in range rms; subsequent investigation revealed indications of change in the waveform data in Calibration Mode 1. The altimeter's effective point target response (PTR) appeared to have drifted from its shape before TOPEX launch. The PTR is, in effect, the altimeter's transmitted pulseshape as observed by the receiver system. The model return waveform from ocean surface scattering is given by the triple convolution of: i) the PTR; ii) a surface response function; and iii) a surface elevation probability function. All TOPEX data processing assumes a fixed PTR, so a change in PTR will lead to a change in the altimeter system estimates of range and SWH. The complete TOPEX altimeter included two redundant sets of parts, referred to as Side A and Side B. Both sides were tested before launch, but after launch only Side A was operated through the end of TOPEX data cycle 235. The Side A PTR changes were so large and so clearly increasing with time that the decision was made to switch to Side B of the altimeter at the start of cycle 236.

The following paragraphs will describe the SWH changes and then the calibration mode observations of PTR changes. Different time-dependent PTR models were developed to try to represent the observed PTR changes as a function of cycle number, simulation programs were run to assess the TOPEX system-estimated SWH and range errors as a function of cycle number using these PTR models, and these modeling results will be described. The section will conclude with a description of efforts by J. R. Jensen (at Johns Hopkins University's Applied Physics Laboratory) to model possible TOPEX hardware causes of the PTR changes, with description of Jensen's prediction that the PTR shape effects would be position-dependent, and with discussion of attempts to assess TOPEX system responses to Jensen's PTR models. All of the following discussion concerns TOPEX Side A only.

3.3.1 Observed Side A SWH Change

Observations from several other research groups showed later TOPEX SWH estimates to be increasing relative to those from ocean data buoys and the ERS-2 altimeter. Figure 3-12 shows TOPEX cycle-averages of the over-ocean SWH vs. cycle number for cycles 001-235. Some seasonal variation is expected in such a plot, but the upward drift in the TOPEX SWH is clearly visible at the right side of the figure. As a first approximation to the seasonal effect, a simple empirical function with constant, annual and semiannual variation was fitted to cycles 017-130. This fitted function is also shown on Figure 3-12. Cycle 017 was the lower limit to the fit because earlier cycles contained mixtures of TOPEX and SSALT data; for the upper cycle fit limit, values from 130 to 160 have been tried and the fit results are relatively insensitive to upper limit choice. Then Figure 3-13 shows the plot residuals from Figure 3-12, the differences between the cycle average SWH and the fitted function. A seven-cycle moving average of the residuals is also shown in Figure 3-13. Figure 3-13 indicates that the TOPEX Side A changes started to become significant at around cycle 160. By

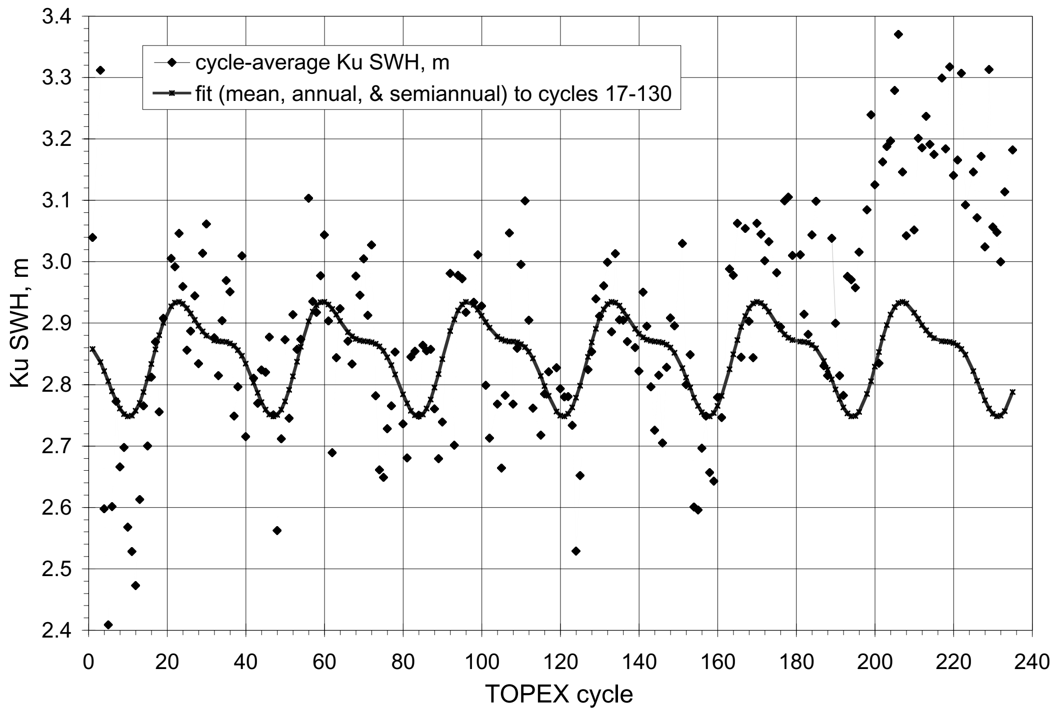

Figure 3-12 TOPEX Ku Cycle-Average SWH and Seasonal Effects Fit

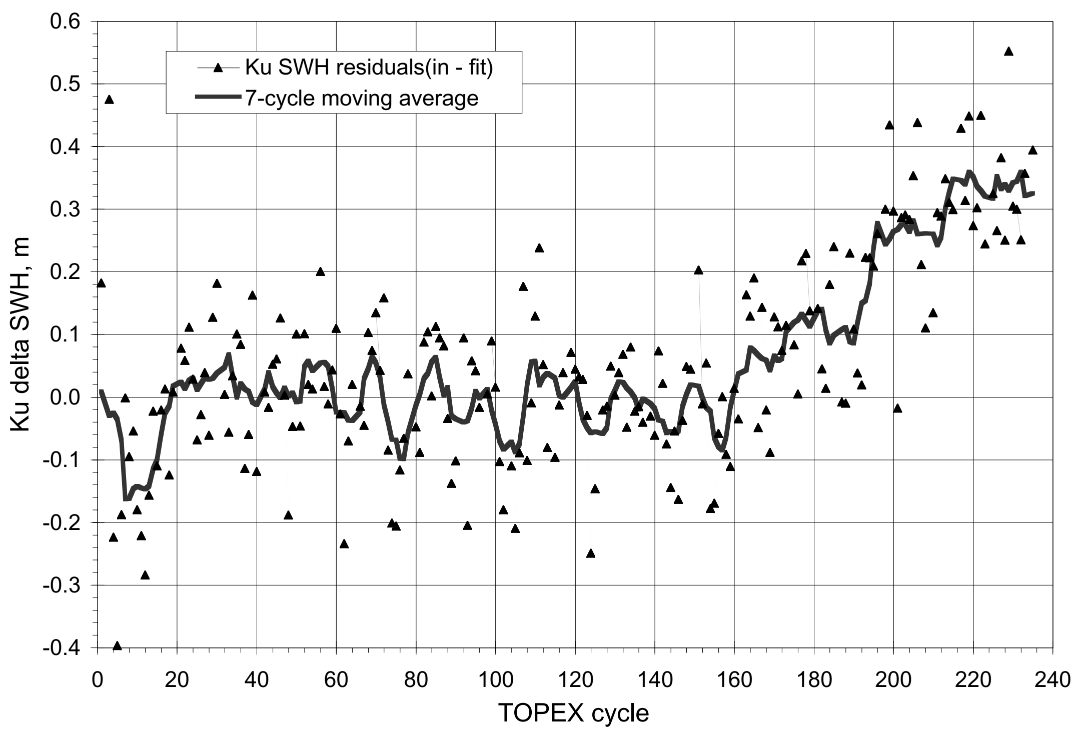

Figure 3-13 TOPEX Ku SWH Seasonal Effects Fit Residuals

cycle 220 the SWH error has become about 0.3 m, 10% of the mean SWH value of about 2.85 m.

3.3.2 PTR Changes Visible in Over-Ocean Waveforms

Figure 3-14 shows a typical over-ocean return TOPEX Ku waveform from 1995 day

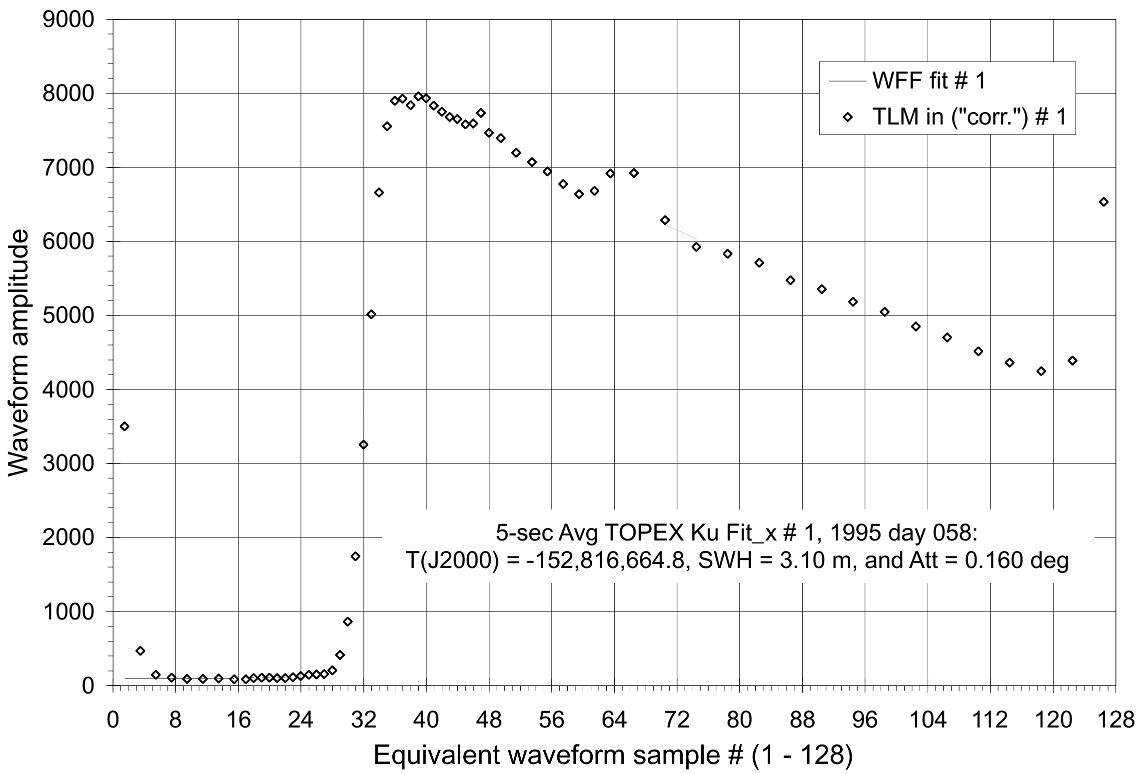

Figure 3-14 TOPEX Ku Waveform Fit, 5-Second Data Averages, 1995 Day 058 (in Cycle 090)

058. That day is in cycle 090, well before any of the Side A PTR changes appeared. Figure 3-15 shows a typical over-ocean Ku return waveform from 1998 day 176 which was in cycle 212. Model waveforms have been least-squares fitted to the TOPEX data in Figure 3-14 and Figure 3-15. Equivalent waveform sample numbers below 8 and above 112 were not included in the fits, and the region around equivalent waveform sample number 64 was also excluded from the fits. Sample 64 is the zero-frequency in the underlying FFT within the altimeter.

In Figure 3-15, there is a small excess signal visible in the waveform in the vicinity of waveform sample 24. Figure 3-16 is an enlargement of the early portion of the waveform in Figure 3-15, to make more visible the excess signal in the vicinity of waveform samples 15-30. This excess signal suggests that at least one side of the 1998 day 176 PTR had relatively higher sidelobe energy (higher relative to the PTR central peak) than did the PTR from earlier in the TOPEX mission.

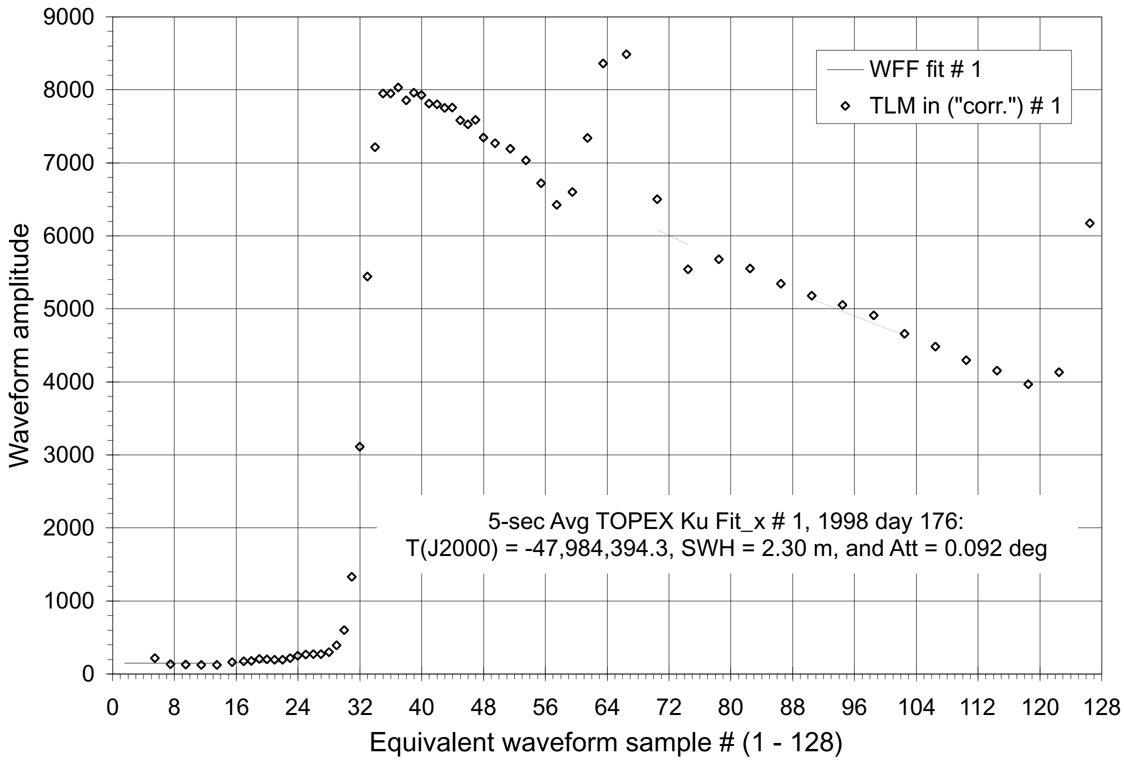

Figure 3-15 TOPEX Ku Waveform Fit, 5-Second Data Averages, 1998 Day 176 (in Cycle 212)

3.3.3 Calibration Mode Information on PTR Change

The normal TOPEX Calibration Mode 1 (CAL-1) has been executed at least twice each day throughout the entire TOPEX on-orbit time. In CAL-1 a portion of the transmitted signal is fed back into the altimeter receiver through a special calibration attenuator, and the altimeter tracks this transmitted signal, using a special tracking algorithm. The different algorithm is needed because the signal shape to be tracked (the PTR) is very different from the normal over-ocean return signal as shown in Figure 3-15. The normal over-ocean track point is waveform sample 32.5; that is, the altimeter tracking algorithm tries to keep the midpoint of the leading edge between waveform samples 32 and 33. In the CAL-1 tracking, the center of the PTR is positioned at sample 78.5.

During the preflight testing, a special calibration mode sweep test (the CalSweep) had been developed in which the altimeter did not automatically track the PTR but instead the AGC level was frozen at a preset level and the altimeter's fine-height word was incremented through its entire range (equivalent to 8 waveform sample positions). The CalSweep typically lasts about 13 minutes, time enough for about seven complete cycles through the full fine-height range, and the CalSweep waveforms can be processed to give a "fine-grained" look at the PTR. After the SWH estimate became evident and the waveform fits showed the leading edge signal excess, a software patch was uploaded to TOPEX to allow the CalSweep to be executed on-orbit. In the following, first the CalSweep results will be discussed and then observations from the waveforms in the normal CAL-1 will be described. Basically the

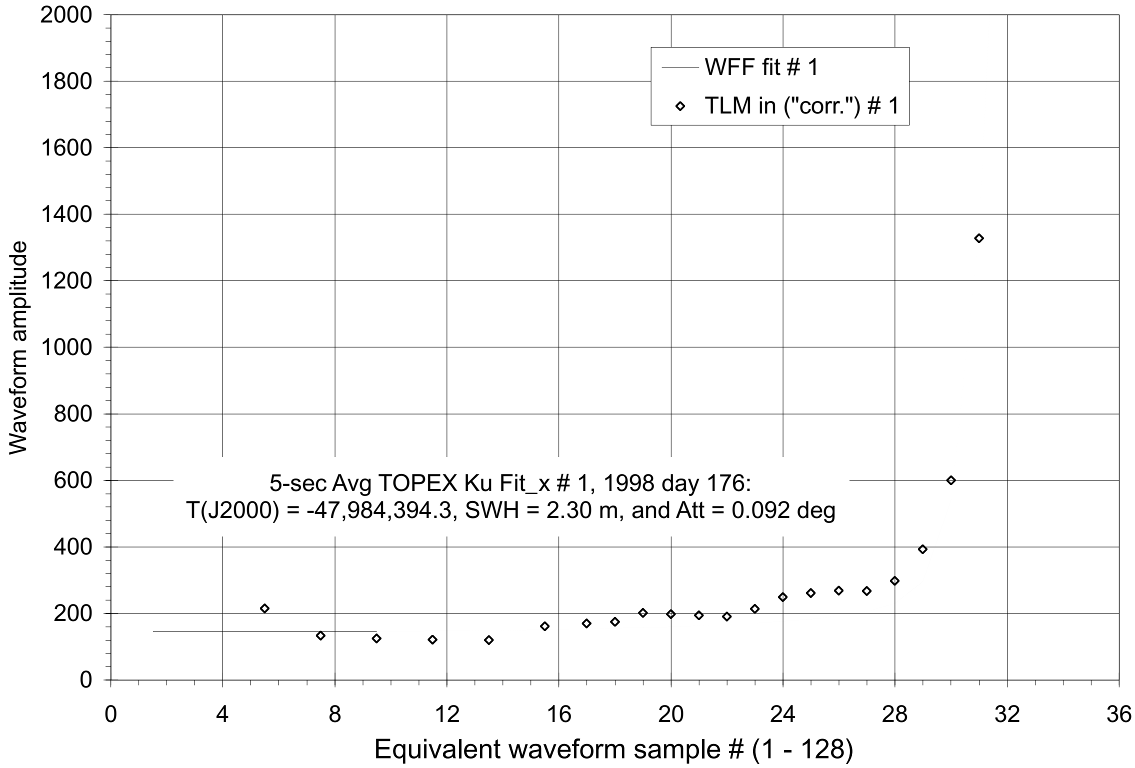

Figure 3-16 TOPEX Ku Waveform Fit, 5-Second Data Averages, 1998 Day 176 (in Cycle 212), Magnified Leading Edge

CalSweep will give an estimate of the PTR details and the normal CAL-1 will give some information on the time change of the PTR sidelobes over the Side A operation.

Figure 3-17 shows the CalSweep estimates of the TOPEX Ku-band PTR for the pre-flight test on 1991 day 155 and for 1998 day 251 (in cycle 220, the first time CalSweep had been executed since launch). Figure 3-17 also shows the CalSweep result for 1998 day 280. In all the CalSweep plots, the data have been normalized to a value of 1.00 at the center (peak) of the PTR. The sample position on the x-axis of Figure 3-17 is relative to the center of the PTR which is at on-board waveform sample number 78.5 in calibration mode. In Figure 3-17 and the following three figures the labeling should be obvious; for instance the curve labeled K98_280 refers to the Ku-band CalSweep result from 1998 day 280. Figure 3-17 shows the PTR excess sidelobe energy relative to the main lobe in the 1998 data when compared to the 1991 data. Figure 3-18 shows the CalSweep estimates of the TOPEX C-band (320 MHZ) PTR; this figure is in relatively good agreement with the Ku-band Figure 3-17, although Figure 3-18 has a slightly higher noise baseline. TOPEX Side A CalSweep data also exist for 1998 day 349 and 1999 day 040, but show effectively no change from the 1998 day 251 result.

It is easier to see the PTR sidelobes if the CalSweep results are expressed in dB relative to the peak, and Figure 3-19 and Figure 3-20 show the CalSweep comparisons

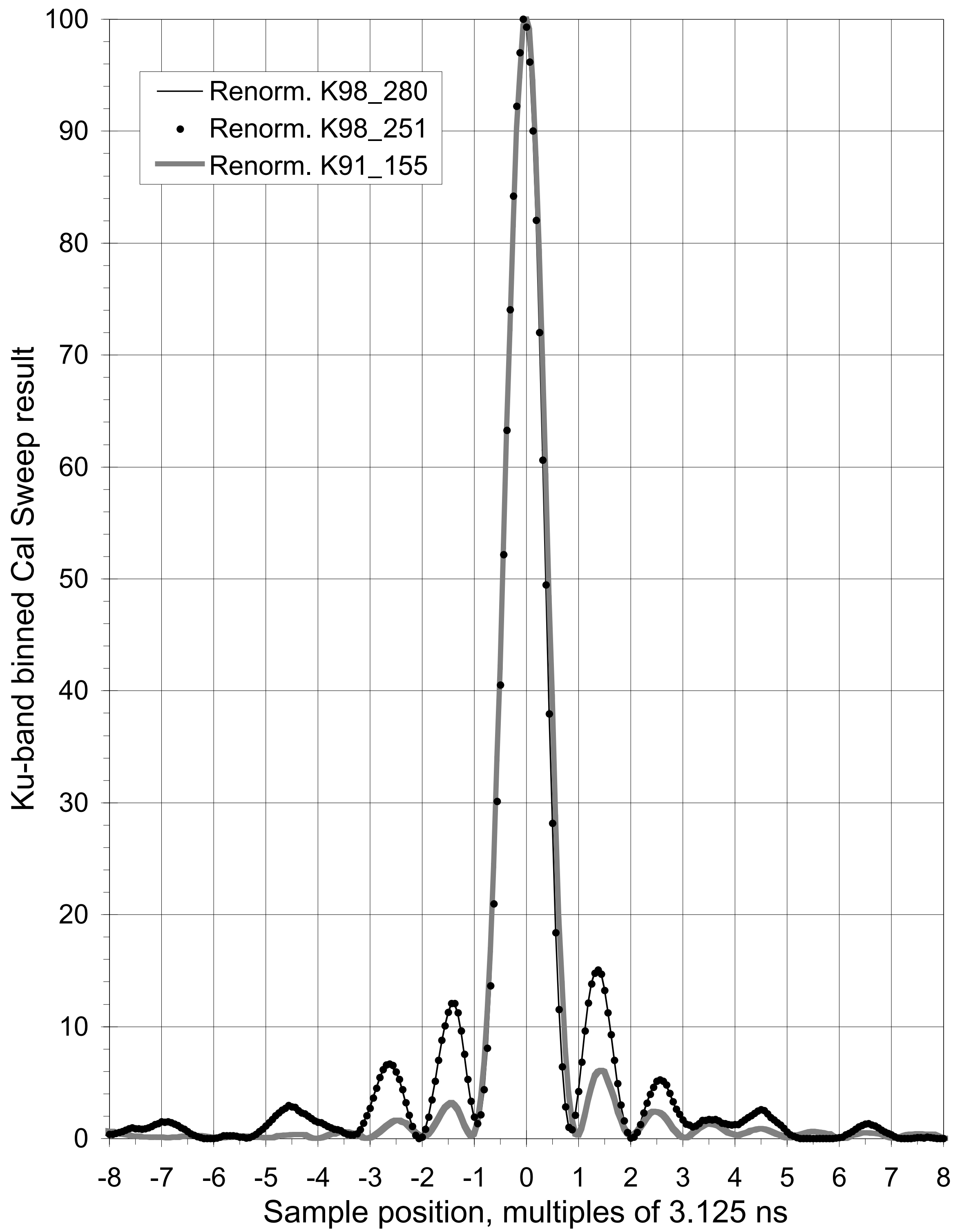

Figure 3-17 TOPEX Ku-Band Cal Sweep PTR Comparison

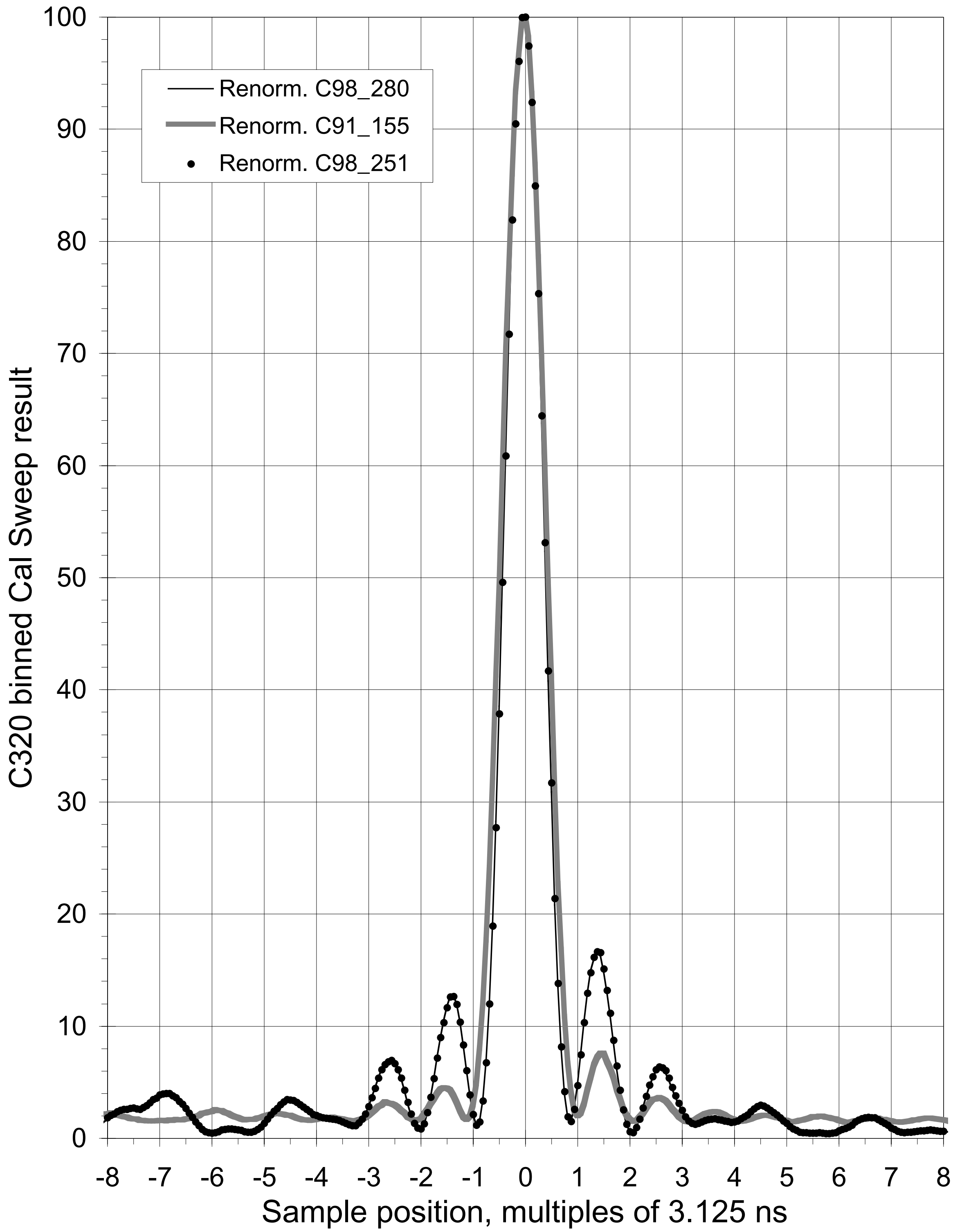

Figure 3-18 TOPEX C320 Cal Sweep PTR Comparison

for Ku- and C-band. The theoretical PTR for TOPEX is $[\mathrm{sinc}(x)]^2$, where x is the sample position relative to the center and the function sinc(x) is

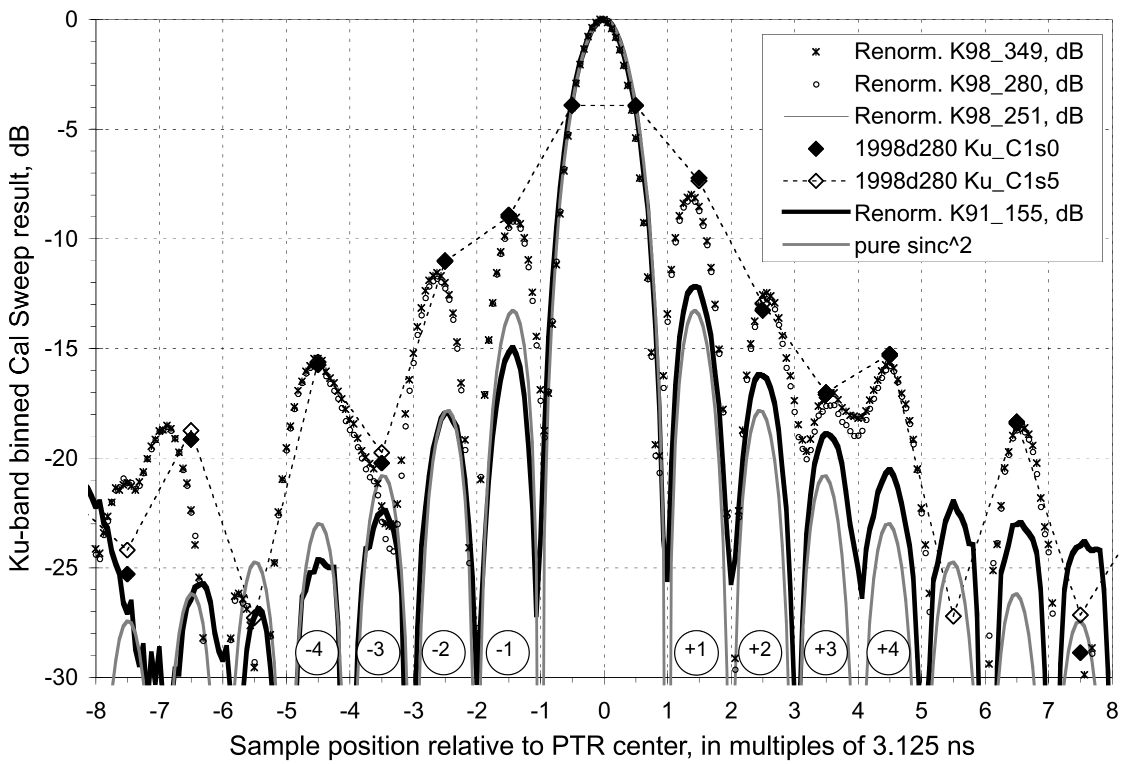

Figure 3-19 TOPEX Ku-Band Cal Sweep PTR Comparisons (labels shown for first four sidelobes each side of central peak)

$$\mathrm{sinc}(x) = [\sin(\pi x)] \;/\; [\pi x].$$

This theoretical PTR, labeled "pure sinc^2" is also plotted in Figure 3-19 and Figure 3-20. The noise baseline is more apparent in the C-band Figure 3-20. This baseline is a function of the AGC level set for the CalSweep, and the AGC freeze value was not as well chosen for the 1991CalSweep. For later discussion it is useful to establish a sidelobe numbering scheme, based on the location of the sinc^2 sidelobes relative to the central peak. The first sidelobe above the main lobe will be designated as the +1 sidelobe, the second as the +2 sidelobe, and so forth. Sidelobes below the main lobe will be designated as -1, -2, etc. For the first four sidelobes at either side of the main lobe, these labels are shown by numbers within circles near the x-axes in Figure 3-19 and Figure 3-20.

In examining Figure 3-19 and Figure 3-20, it is important to remember that these waveform-based data come from a system with a 8-bit telemetry word for the waveform data, and that the dynamic range that can be represented by an 8-bit unsigned integer is only about 24 dB. There might be several more dB available as the comb of waveform samples moves away from the PTR peak being centered in one of the waveform samples, but that waveform sampler will only move down about 4dB from the peak before the next sampler starts moving up the peak. Any numbers below -25 dB in Figure 3-19 and Figure 3-20 should be viewed with scepticism.

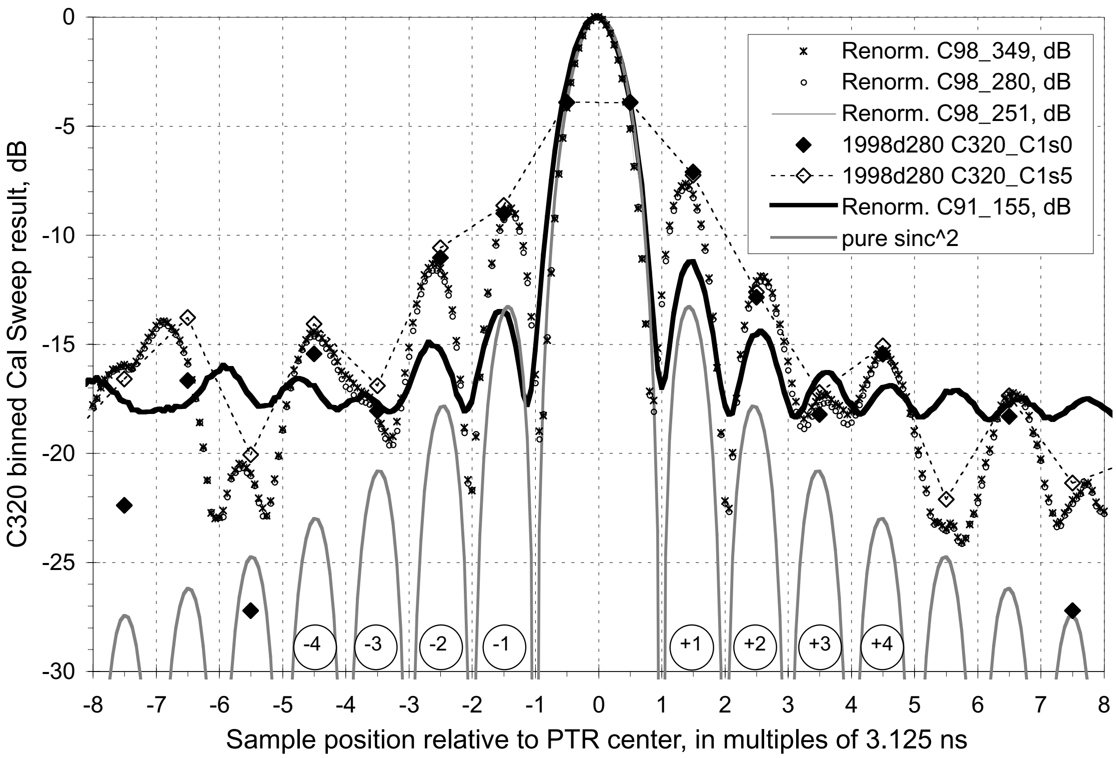

Figure 3-20 TOPEX C320 Cal Sweep PTR Comparisons (labels shown for first four sidelobes each side of central peak)

From Figure 3-19 and Figure 3-20, here is an oversimplified, first-order-only characterization of the 1998 TOPEX PTR changes relative to the (1991) preflight PTR:

- The PTR changes are symmetric relative to the central lobe;
- The Ku-band and the C-band PTRs have the same changes;
- Sidelobes +/-1, +/-2, +/-3, +/-4, and +/-6 are higher;
- The null between sidelobes +3 and +4 (and between -3 and -4) has disappeared;
- Sidelobes +/-5 have disappeared; and
- The CalSweep results probably have little meaning outside sidelobes +/-6.

The first two assertions above can be argued with. Some asymmetry is apparently present, and the Ku- and C-band agreement is not complete. But this list is a starting point for a search for possible explanations of the PTR changes.

To this point, only the CalSweep results have been described. In hindsight, it is clear having no CalSweep data between 1991 and 1998 creates considerable difficulty in understanding what changed and when. [For Side B operations, a CalSweep is now routinely being executed every three months.] The waveform results from the normal (twice-daily) CAL-1 can perhaps supply some information for this problem. Until recognition of the SWH drift in middle 1998, only the AGC and range information from the normal CAL-1 had been monitored. The normal CAL-1 waveform will have only two samples on the PTR main lobe, and samples at the approximate peaks of the sidelobes. The 1998 day 280 CAL-1 waveform data are also shown by diamond symbols in Figure 3-19 and Figure 3-20, again renormalized to a PTR peak value of 1.00. The normal CAL-1 mode has a series of steps in the AGC level, each step being 2 dB down from the preceding step. CAL-1 step 5 has been used for the range and AGC monitoring, because the power seen by the altimeter in CAL-1 step 5 is approximately the same as in normal over-ocean tracking.

CAL-1 step 0 and CAL-1 step 5 in Figure 3-19 and Figure 3-20 are in relatively good agreement although they differ by 8 dB in AGC attenuator setting. A dotted line connects the individual CAL-1 step 5 points in Figure 3-19 and Figure 3-20 to make these points easier to find in these somewhat cluttered figures. The 1998 day 280 CAL-1 results agree fairly well with the 1998 CalSweep results in Figure 3-19 and Figure 3-20. Although not shown on these figures, the 1991 CAL-1 results are in fair agreement with the 1991 CalSweep results. This suggests that the entire-mission CAL-1 waveforms can be used to study the time evolution of the PTR between 1991 and 1998.

Figure 3-21 shows the time evolution of the first five Ku CAL-1 step 5 sidelobes

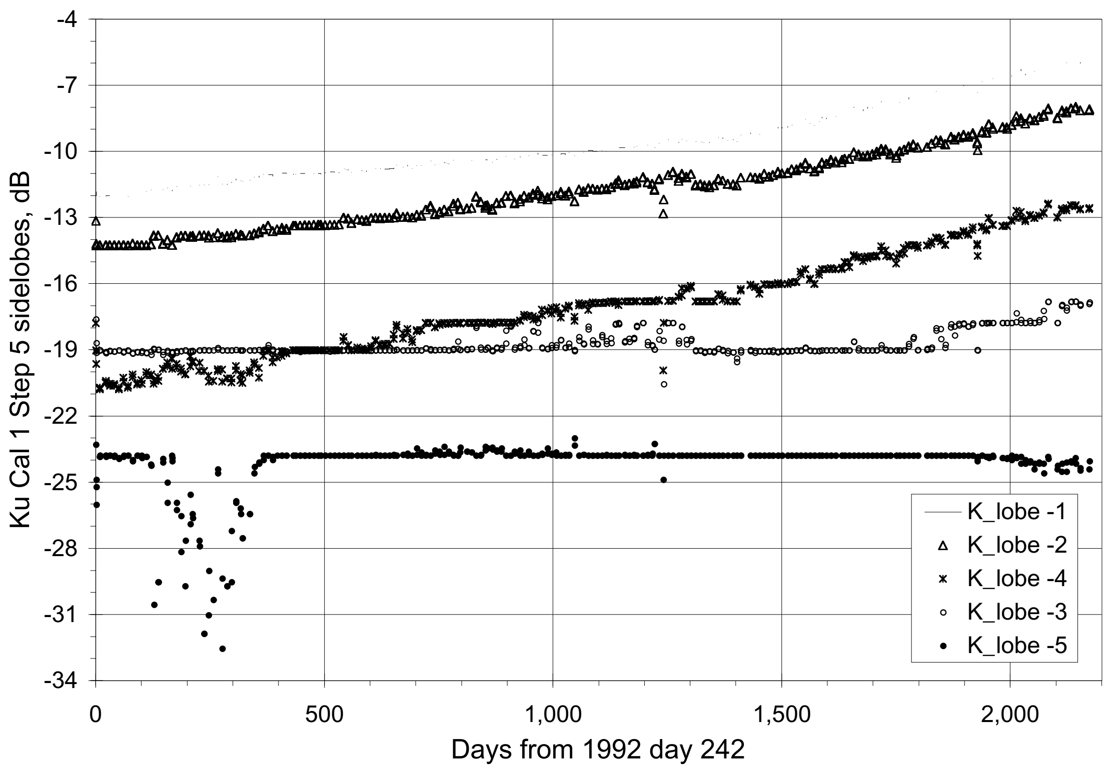

Figure 3-21 Ku PTR Lower Sidelobes Relative to Peak Value

below the central PTR lobe, and Figure 3-22 shows the same information for the five corresponding Ku sidelobes above the central lobe. Figure 3-23 and Figure 3-24 show the time evolution of the first five C-band sidelobes below and above the C-band PTR

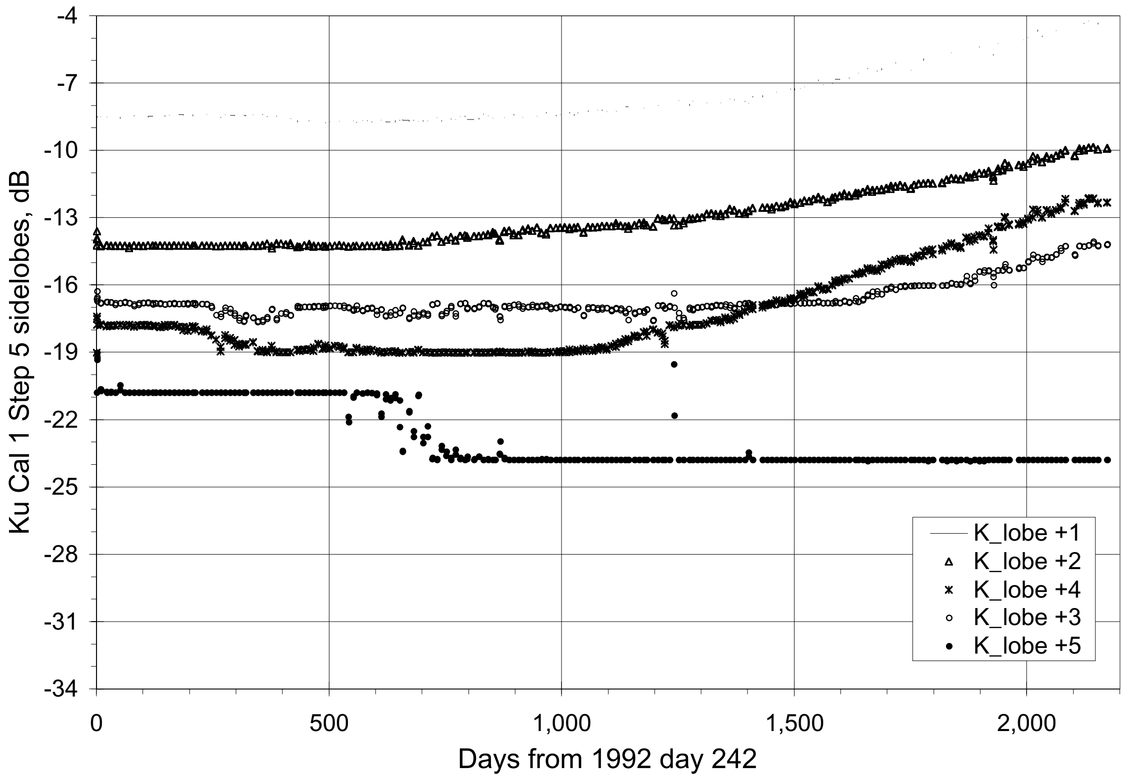

Figure 3-22 Ku PTR Upper Sidelobes Relative to Peak Value

central lobe. Figure 3-21 and Figure 3-22 are similar, but not identical and the PTR asymmetry again is visible. As a first approximation the trend lines in Figure 3-21 and Figure 3-22 are straight lines, and a straight line in a dB vs. time plot implies exponential growth in the linear domain.

3.3.4 Modeling to Estimate SWH and Range Errors for PTR Models Based on CalSweep and CAL-1

As we started to learn about the Side A PTR changes, we hoped that there would be a relatively simple correction procedure produced by the following steps:

- Produce a time-dependent (or cycle-dependent) model PTR by using CalSweep results for details and using normal CAL-1 waveform history to establish the time dependence;
- Run a detailed TOPEX altimeter simulation with the time-dependent model PTR to predict altimeter response to a range of SWH and attitude values;
- Compare simulation results from time-dependent model PTR to those with ideal sinc^2 PTR; and
- Express differences as a function of the GDR SWH and gate index values.

We hoped that the SWH correction for PTR change would be straightforward, and that the range correction for PTR change would have two separate components: i) there would be a change in altimeter-estimated range solely as a result of the PTR

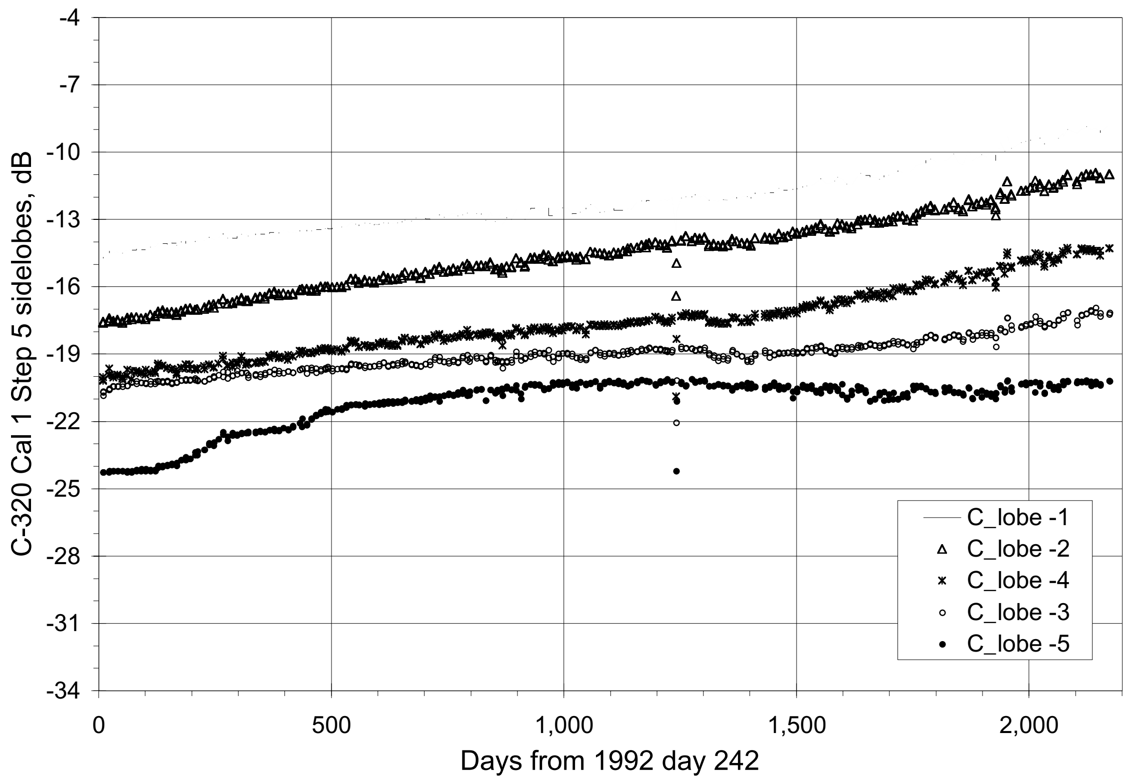

Figure 3-23 C320 PTR Lower Sidelobes Relative to Peak Value

change; and ii) there would be a change in the electromagnetic bias (EMB) correction to range as a result of the SWH error arising from PTR change, since the EMB range correction is a function of SWH.

Three different time-dependent PTR models were tried in the simulation efforts just sketched. These PTR models are referred to as the Sept98 model, the Nov98 model, and the Jan99 model, with the labels obviously referring to the approximate date of the particular modeling effort. In all three model PTRs, there were values given to the first 20 sidelobes at both sides of the central lobe, and all other sidelobes were assumed to have zero values. All of these models assume that the PTR sampled in the TOPEX calibration mode is the correct PTR to be using at the normal, over-ocean track point.

The Sept98 PTR model was based on only a comparison of a 1993 and a 1998 set of normal CAL-1 waveforms. This model was developed before we had obtained any 1998 CalSweep data. The time-dependence of the PTR sidelobes was assumed to be linear in the dB vs. time realm, which implies exponential growth in the absolute power realm. The sinc^2 sidelobes were each multiplied by a different amplitude factor scaling the common time dependence, but the PTR central lobe was left undisturbed. Figure 3-25 shows the Sept98 PTR model for data cycles 000, 050,..., 250, together with a pure sinc^2 function for comparison. Figure 3-26 shows, for several different data cycles, the simulation prediction of the additive SWH correction needed if the actual PTR were described by the Sept98 model. Notice that the x-axis

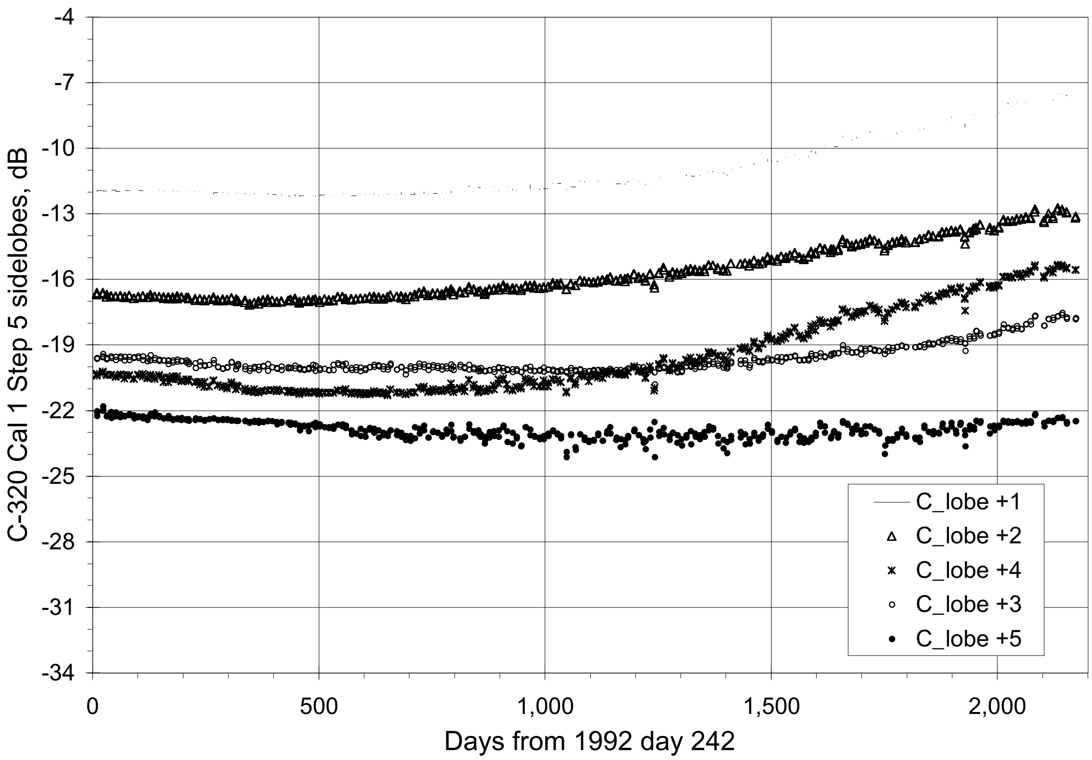

Figure 3-24 C-320 PTR Upper Sidelobes Relative to Peak Value

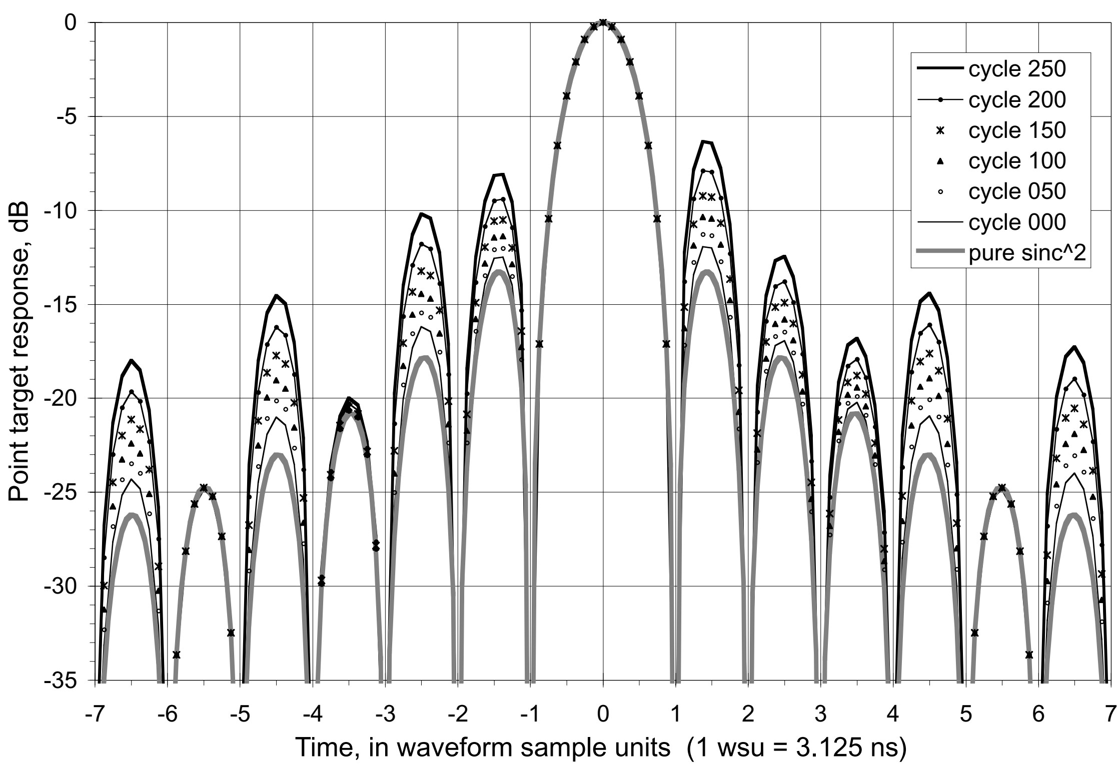

Figure 3-25 TOPEX Sept98 Model PTR

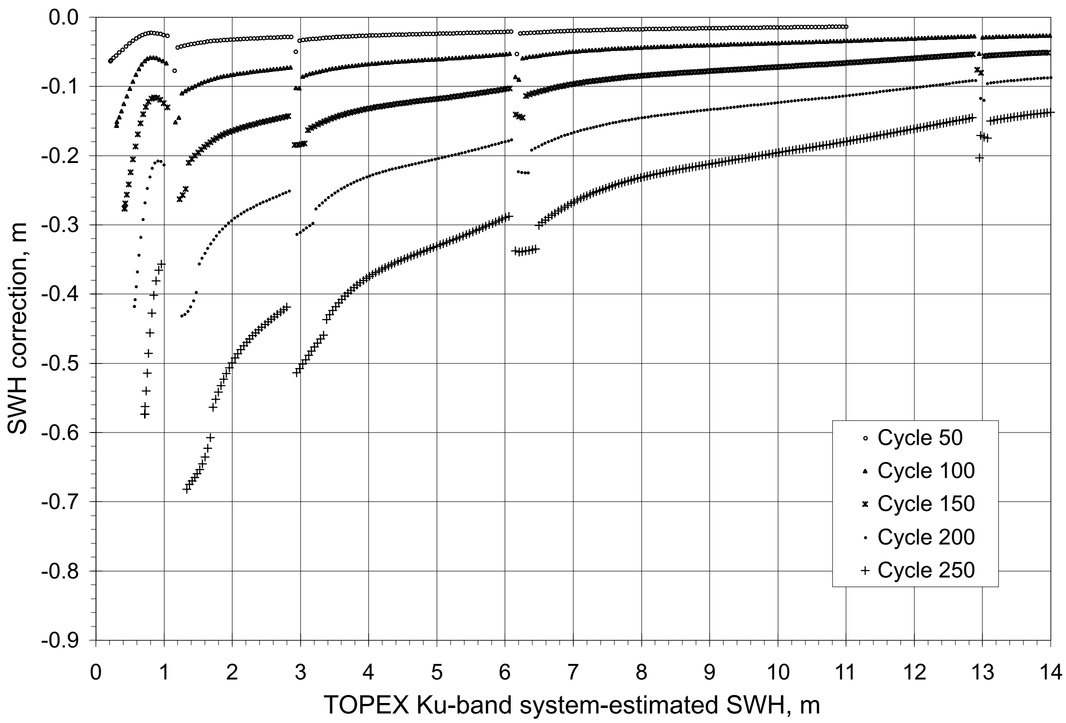

Figure 3-26 TOPEX SWH Additive Correction Relative to Cycle 1

in Figure 3-26, and in several of the subsequent plots, is the system-estimated SWH. By system-estimated SWH we mean the SWH value that would have appeared on the TOPEX GDR after the current ground processing (which is based on a pure sinc^2 PTR). The SWH corrections in Figure 3-26 are negative, since the PTR change leads to system-estimated SWH values which are larger than the true SWH.

Figure 3-27 shows the additive range correction for PTR shape effects alone from the Sept98 PTR model, and Figure 3-28 shows the final range corrections. Notice that these figures show range correction relative to cycle 001 since it is the change in range estimation which is of greatest concern. To get the Figure 3-28 results, based on the Figure 3-26 and Figure 3-27 results, it was necessary to use an empirical relationship between TOPEX SWH and sigma0 estimates so that the EMB correction could be expressed as a function solely of SWH. In practice, the EMB would have to be recalculated point-by-point for the TOPEX sigma0 and corrected SWH, and shows only a "typical" net range correction. However, Figure 3-28 was encouraging in its suggestion that the net range error was generally within one centimeter for cycles up to 250 for a PTR described by the Sept98 model. The correction results from the Sept98 PTR model were presented at the October 1998 TOPEX Science Working Team (SWT) meeting in Keystone, Colorado.

Shortly after the October 1998 SWT meeting, we began incorporating the newly available 1998 TOPEX CalSweep information into a new Nov98 PTR model. The Nov98 PTR model was based on Cal Sweep data for the central lobe and first five sidelobes on either side of the central lobe (where the lobe numbering is for the

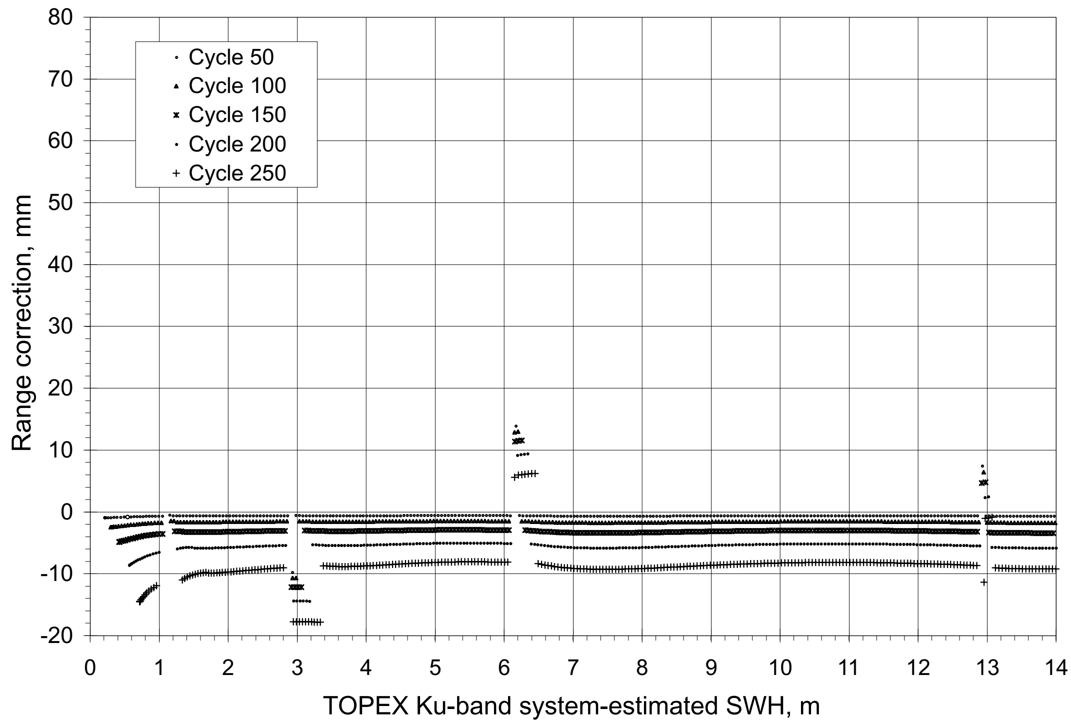

Figure 3-27 TOPEX Additive Range Correction Relative to Cycle 1 for PTR Shape Change Alone

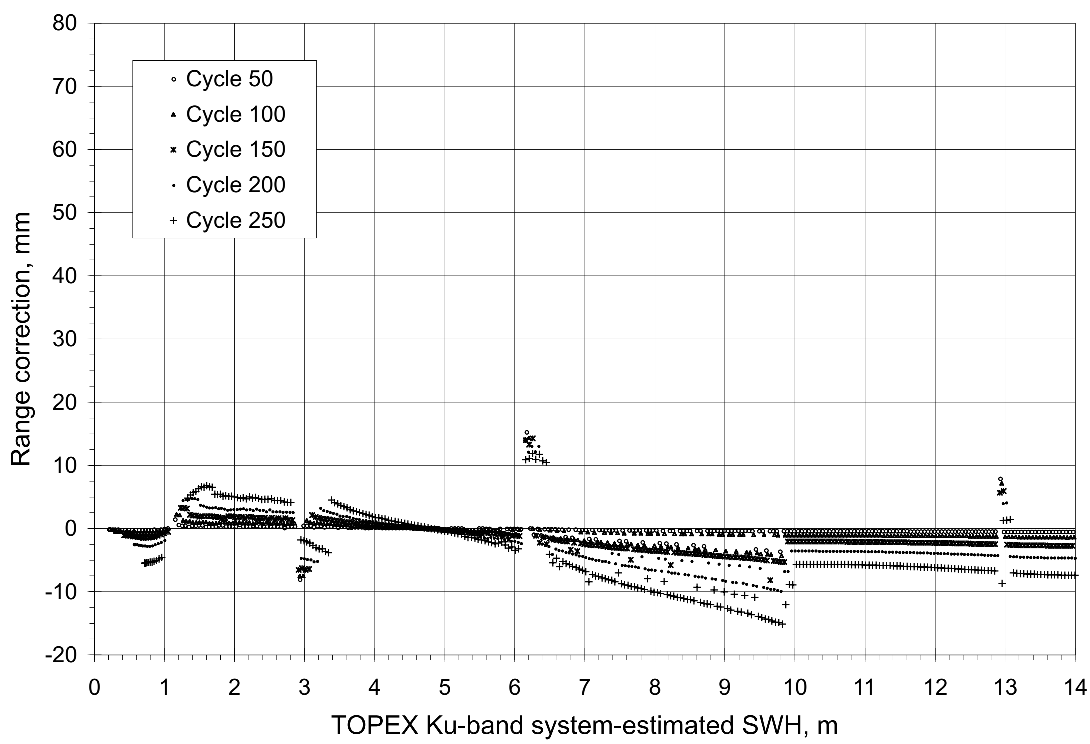

Figure 3-28 TOPEX Additive Range Correction Relative to Cycle 1 for Both PTR Shape Change and EM Bias Change

assumed underlying sinc^2 function). The 1998 Cal Sweep and the 1991 Cal Sweep were renormalized to have the same maximum values. Then the Cal Sweep Difference (1998 minus1991) was formed, and this difference is shown in Figure 3-29. Call-

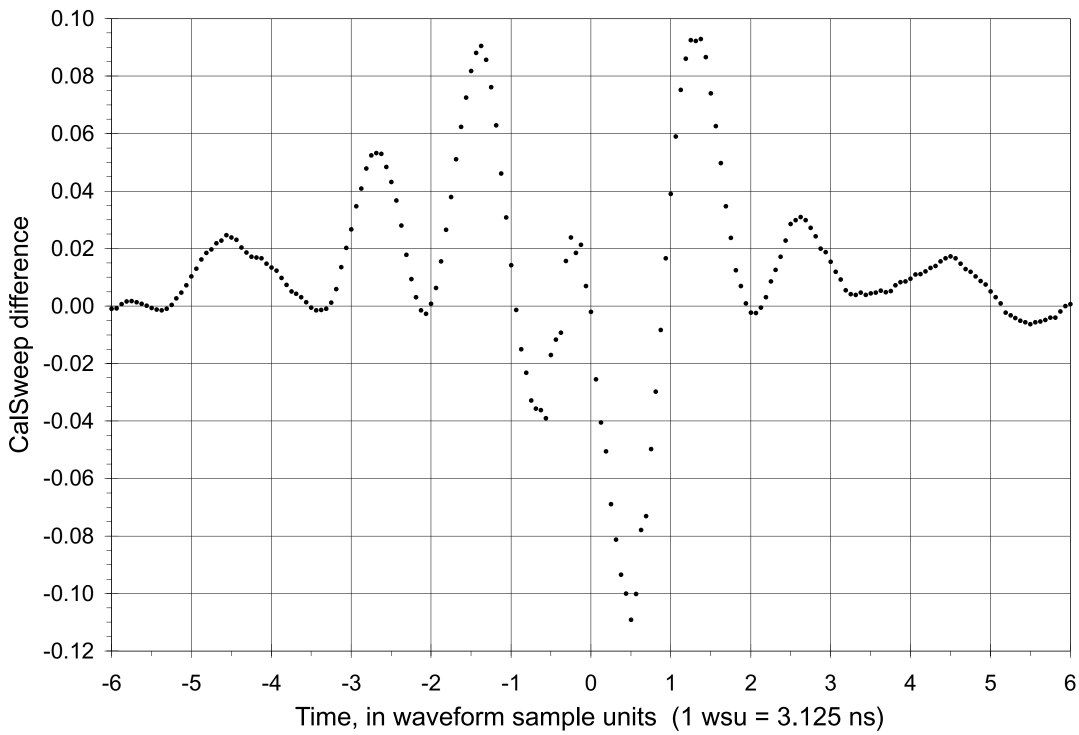

Figure 3-29 CalSweep Difference, 1998 Day280 Minus 1991 Day155

ing this difference D, and calling the 1991 renormalized Cal Sweep result B, then and for any time t the model Cal Sweep function M(t) is assumed to be given by M(t) = B + f(t)*D. Assume that at any time t the f(t) is a simple scalar multiplier. The time-dependence of f(t) is found from the average time growth of the first two sidelobes each side of the central lobe, with C- and Ku-band sidelobe growth averaged together. The time factor multiplier f(t) is shown in Figure 3-30. This approach will build in a change in the central lobe as well, and the central lobe looks slightly narrower in the 1998 Cal Sweep than in the 1991 Cal Sweep. This Nov98 PTR model used only the first five sidelobes to each side of the main lobe for the time-dependent model, used the ideal sinc^2 function for sidelobes 6 through 20, and set all remaining sidelobes to zero.

Figure 3-31 shows the Nov98 model PTR, and also the pure sinc^2 function. The SWH correction from the Nov98 model is plotted in Figure 3-32. Comparing Figure 3-32 to Figure 3-26 shows that the SWH corrections from the Sept98 and the Nov98 models are not identical, but not that different. The Nov98PTR model’s range corrections for PTR shape alone are shown in Figure 3-33, where it is seen that the Nov98 does however have considerably larger range corrections for the PTR shape effect than did the Sept98 model whose range corrections for PTR shape alone were shown

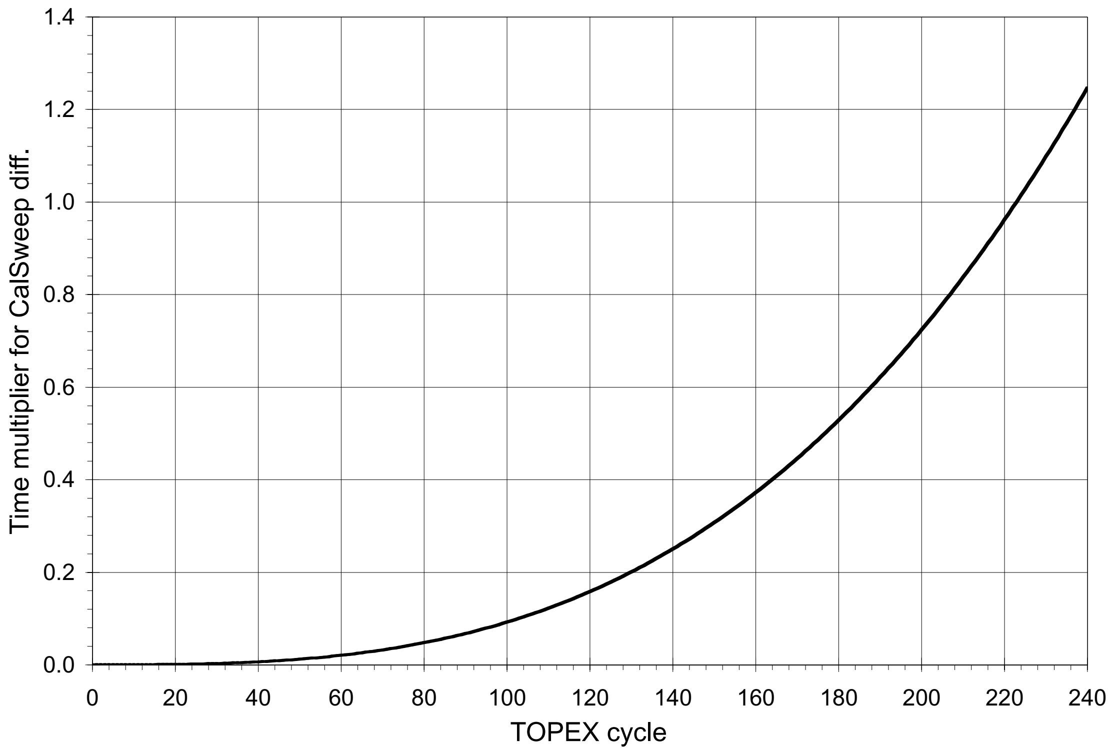

Figure 3-30 Nov98 Model PTR Time Factor Multiplier

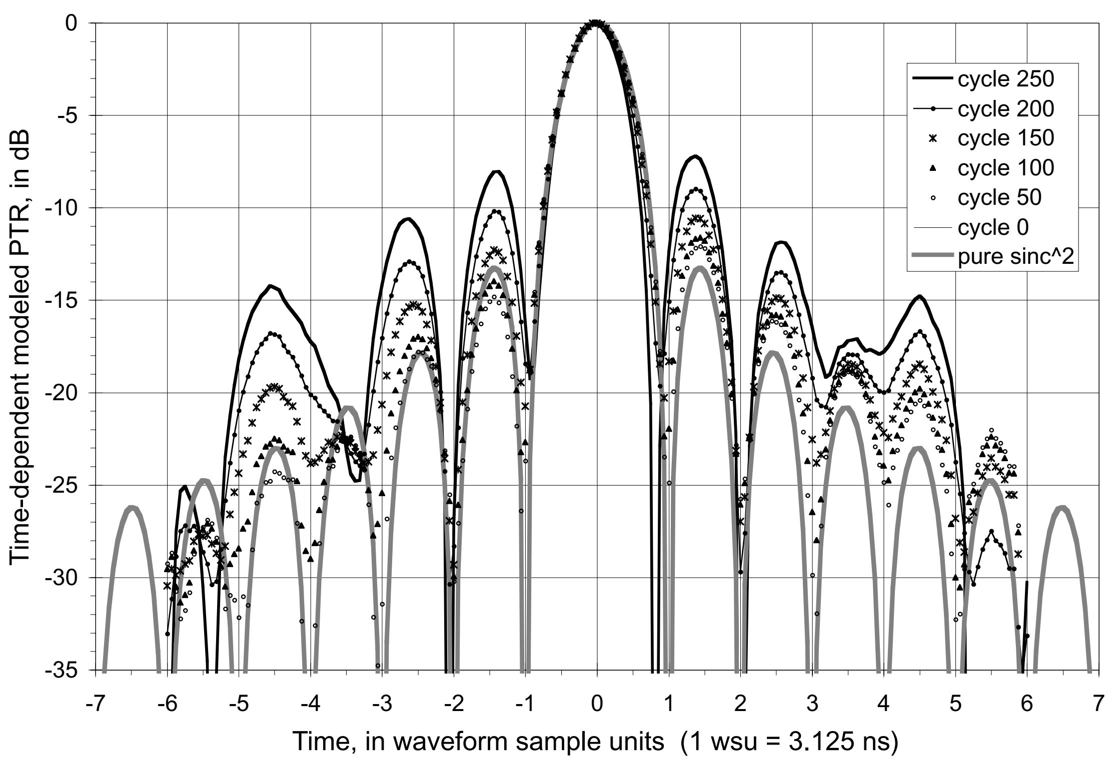

Figure 3-31 Nov98 Model PTR for Cycles 0, 50, 100,...,250

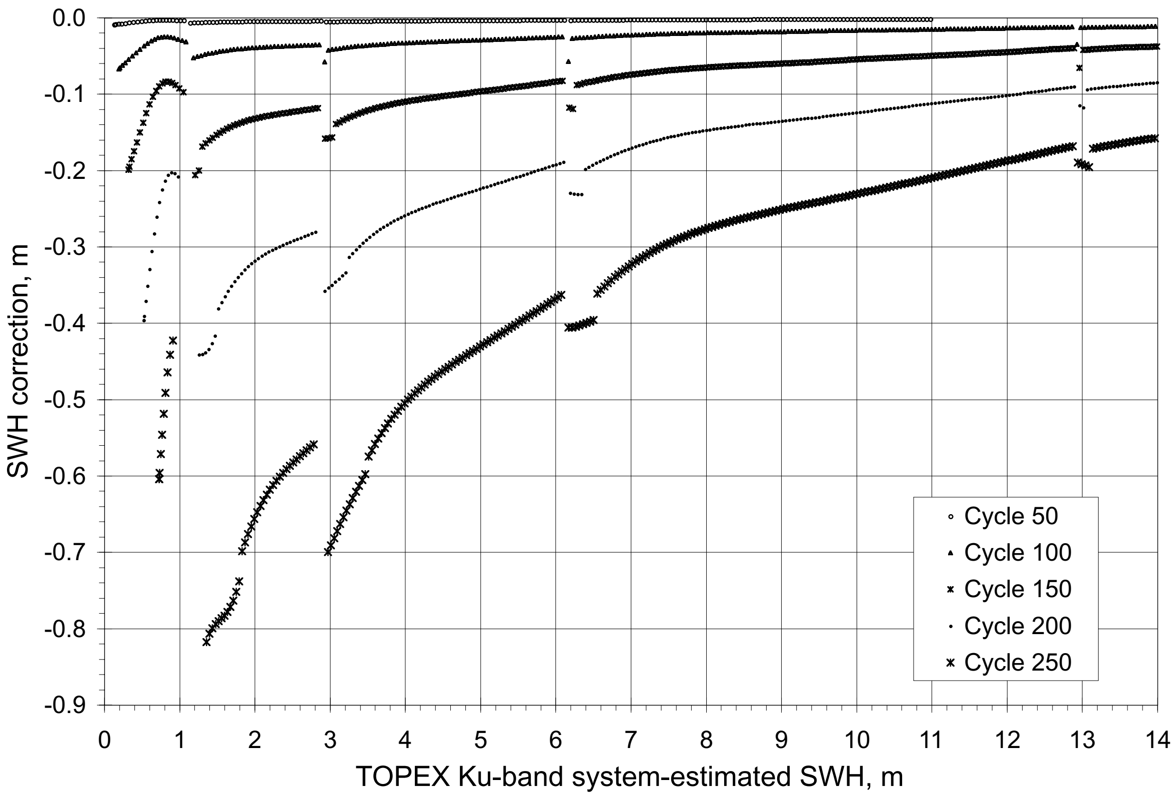

Figure 3-32 TOPEX SWH Additive Correction Relative to Cycle 1

in Figure 3-27. Figure 3-34 shows the combined range corrections for the Nov98 PTR model, again using an empirical sigma0 to SWH relationship to estimate EMB correction. Comparison of Figure 3-34 to Figure 3-28 shows that the Nov98 PTR model led to considerably larger net range corrections than did the Sept98 PTR model. The results from the Nov98 PTR model were presented in a poster session at the AGU 1998 Fall Meeting in San Francisco. Various discussions with other investigators indicated that the Nov98 range change predictions were too large, and would have shown up in some of the TOPEX/buoy comparisons that are being done at other institutions.

One more model function was tried, the Jan99 model PTR in which the PTR central lobe was assumed to be a pure sinc^2 function, and all other sidelobes of this model were the same as the Nov98 PTR model. The SWH correction curve from the Jan99 model was about the same as from the Nov98 model. The Jan99 model's range corrections were only slightly smaller than those from the Nov98 model.

3.3.5 Jensen Model of PTR and Consequences of this PTR Model

Responding to the need to understand possible sources and implications of apparent anomalies in the PTR, Jensen constructed and exercised a numerical simulation of the altimeter [Jensen, 1998]. Jensen found that corruption of the circularity of the baseband chirp could produce features at least partially similar to those seen in CalSweep. The corruption of the circularity can be characterized by a phase change

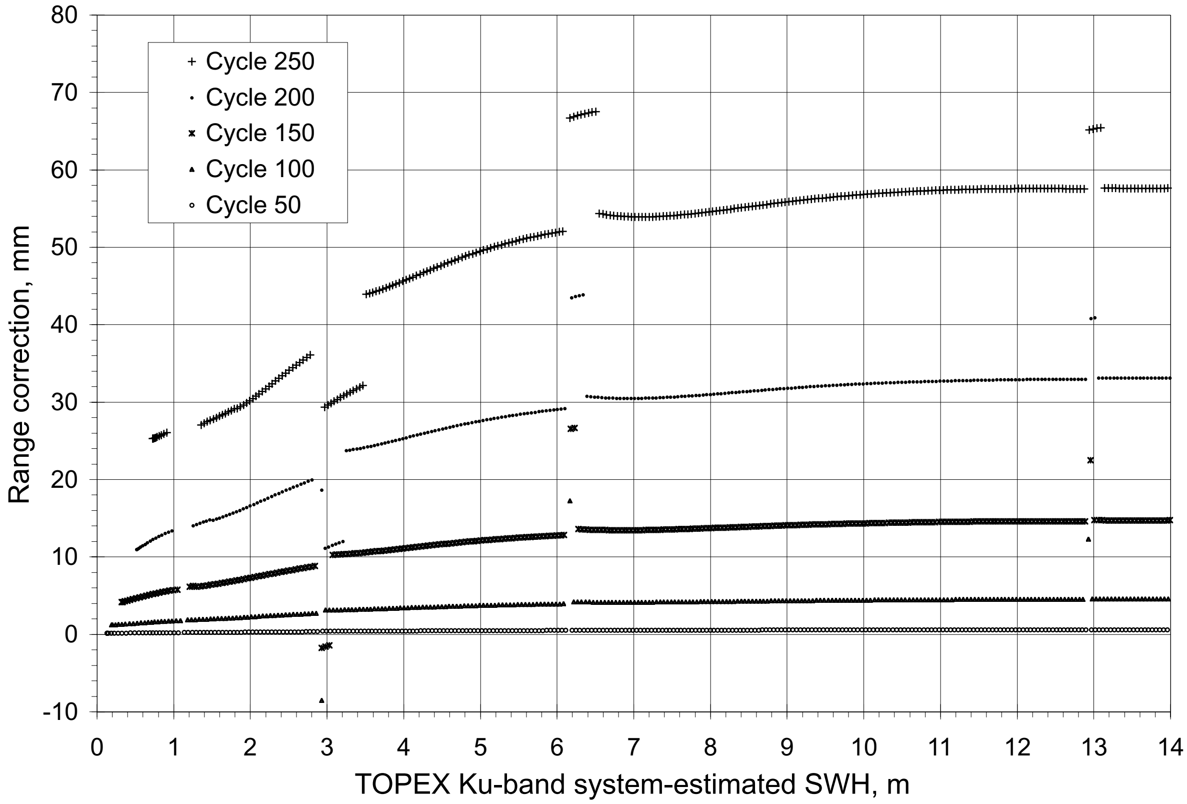

Figure 3-33 TOPEX Ku-band Additive Range Correction Relative to Cycle 1 for PTR Shape Change Along

(in degrees) of one of the local oscillator signals in the single sideband mixer of the altimeter's chirp generator. As the phase change is increased from zero, there are two consequences: i) the sidelobes of the PTR are changed from those of the ideal sinc^2; and ii) the amplitude of the mean return waveform is increased in the zero-frequency region (around waveform sample number 64 in the TOPEX set of 128 on-board waveform samples). Jensen found that a phase change of about 15 degrees produced an approximate match to the PTR sidelobes in the CalSweep mode. A phase change of 9 degrees, however, produced a better match to the observed mean return waveform.

A considerably more disquieting result of Jensen's work was that the PTR shape changed as a function of where the PTR was located within the digital filter bank. In its calibration modes the TOPEX altimeter centers the PTR between samples 78 and 79 in the total set of 128 waveform samples, but in its normal ocean tracking mode the altimeter positions the mean return between samples 32 and 33.

Jensen supplied modeled PTR values for the following four cases.

Phase Error	Center Waveform Sample Number	Model Designation

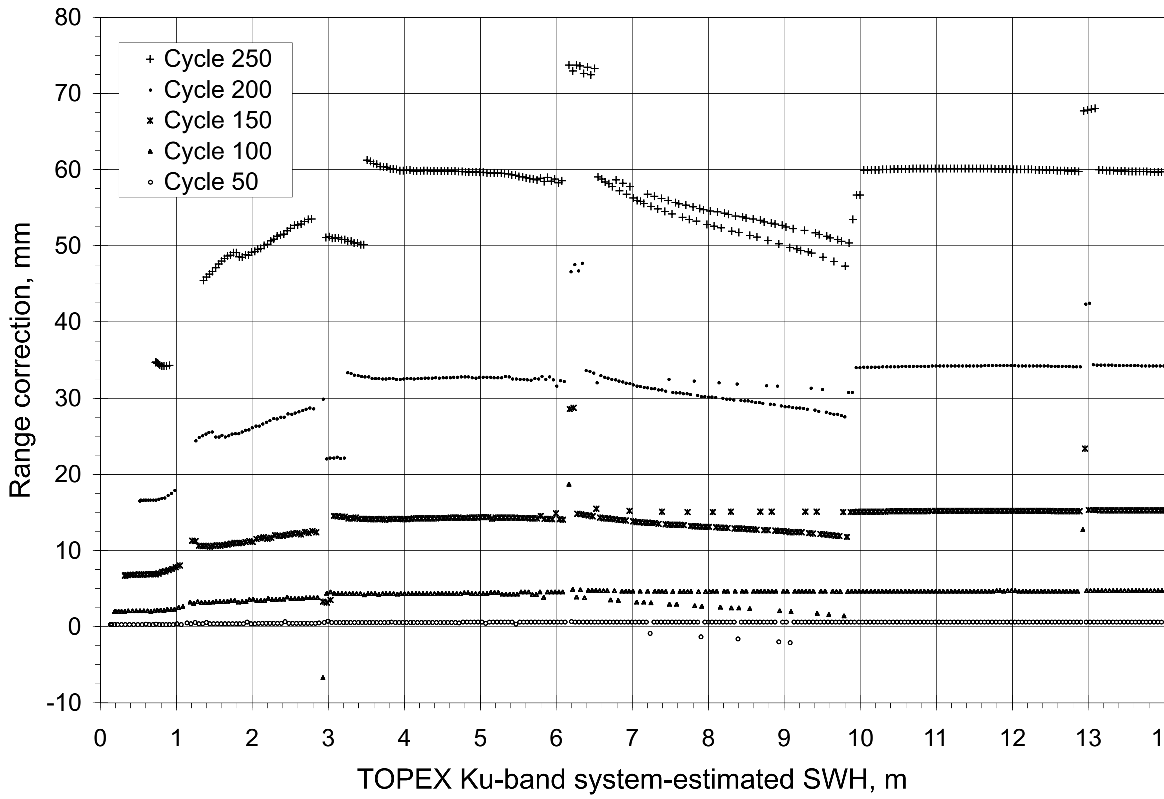

Figure 3-34 TOPEX Ku-band Additive Range Correction Relative to Cycle 1 for Both PTR Shape Change and EM Bias Change

09	78.5	J-ph09_ctr78.5
15	78.5	J_ph15_ctr78.5
09	32.5	J_ph09_ctr32.5
15	32.5	J_ph15_ctr32.5

The "model designation" above is the legend to be used in the next several figures which show plots of the two different Jensen model PTRs centered at waveform sample 78.5 together with a late Side A CalSweep PTR estimate, and then the model PTR change as model PTR position is changed from waveform sample 78.5 to sample 32.5. Then the SWH and range consequences will be shown for these Jensen PTR models.

Figure 3-35 shows the Jensen model PTR for 9 degrees phase change together with the CalSweep result from 1998 day 280 and the ideal sinc^2 PTR. Only the central lobe and nine sidelobes to one side of the PTR are plotted. The Jensen model PTR is symmetric about sample 78.5 whereas the CalSweep results are actually slightly asymmetric, but we’re not ready yet to bring the asymmetry into the Jensen modeling. Figure 3-36 shows the Jensen model PTR for 15 degrees phase difference, plotting this together with the 1999 day 208 CalSweep and the ideal sinc^2. The 15 degree phase model in Figure 3-36 seems to have a qualitatively better agreement with the

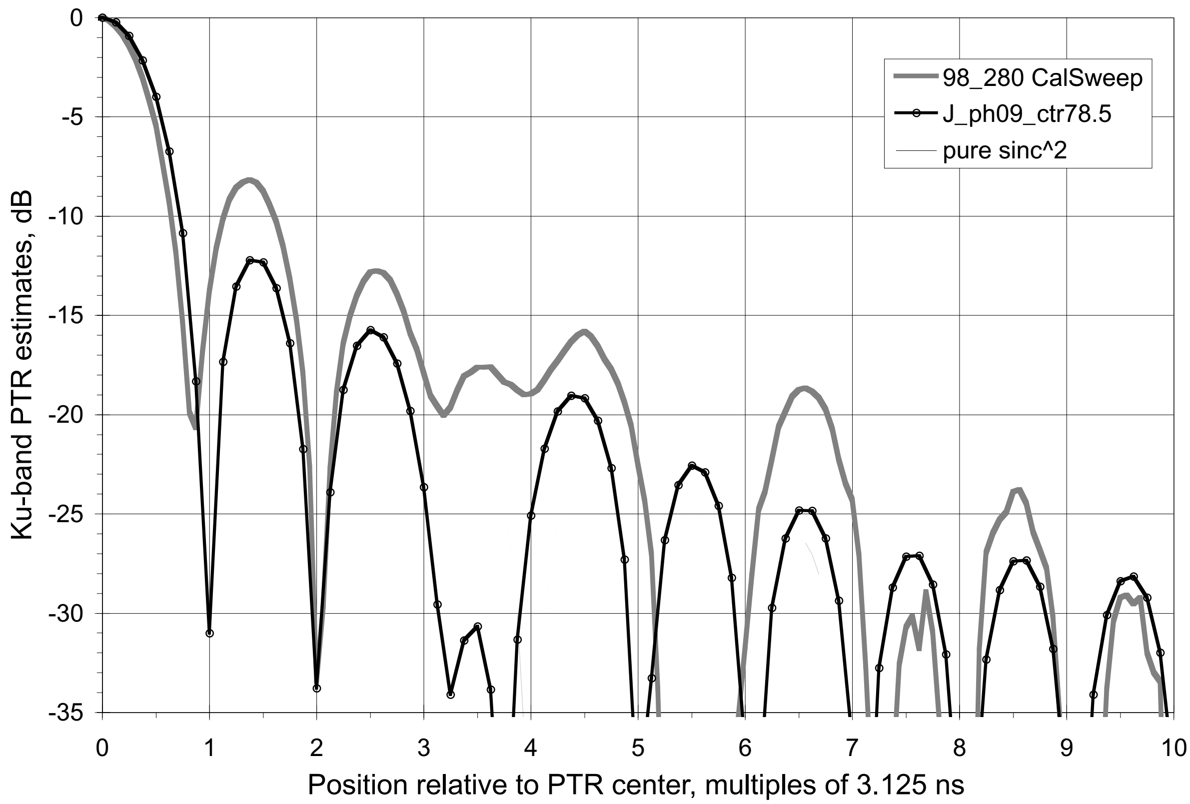

Figure 3-35 CalSweep Comparison for Jensen Model Phase Error of 9 Degrees

CalSweep than does the 9 degree phase model of Figure 3-35, although neither the 9 degree nor the 15 degree phase model reproduce the disappearance of the fifth side-lobe (centered at the abcissa value 5.5 in Figure 3-35 and Figure 3-36).

Figure 3-37 shows the change in the Jensen 9 degree phase model PTR as it is shifted from sample 78.5 to sample 32.5. The first several sidelobes of the 9 degree model become much more regular for the model PTR centered at sample 32.5 than when centered at sample 78.5, although these sidelobes still are bit higher than the sinc^2. Now however the 9 degree model centered at sample 32.5 shows a significant change out at sidelobes 6, 7, and 8. Figure 3-38 shows the change in the Jensen 15 degree phase model PTR as it is shifted from sample 78.5 to sample 32.5, and again the ideal sinc^2 PTR is also shown. There is qualitatively the same behavior as in Figure 3-37, but the magnitudes of departure from sinc^2 are larger for the 15 degree phase model than for the 9 degree phase model.

Figure 3-39 through Figure 3-41 show the corrections that would be needed for a TOPEX altimeter for the Jensen PTR cases centered at waveform sample 32.5. Figure 3-39 shows the SWH error as a function of the system-estimated SWH. For the 9 degree phase model, the SWH error is almost constant at around 0.2 m. For the 15 degree phase model, the error is a function of system-estimated SWH and the magnitude of the error is 1 m or greater for system-estimated SWH of 3 m or higher. This is too large, not at all consistent with the observed SWH estimate increase of only a few tenths of a meter, so 15 degrees is too large a phase error.

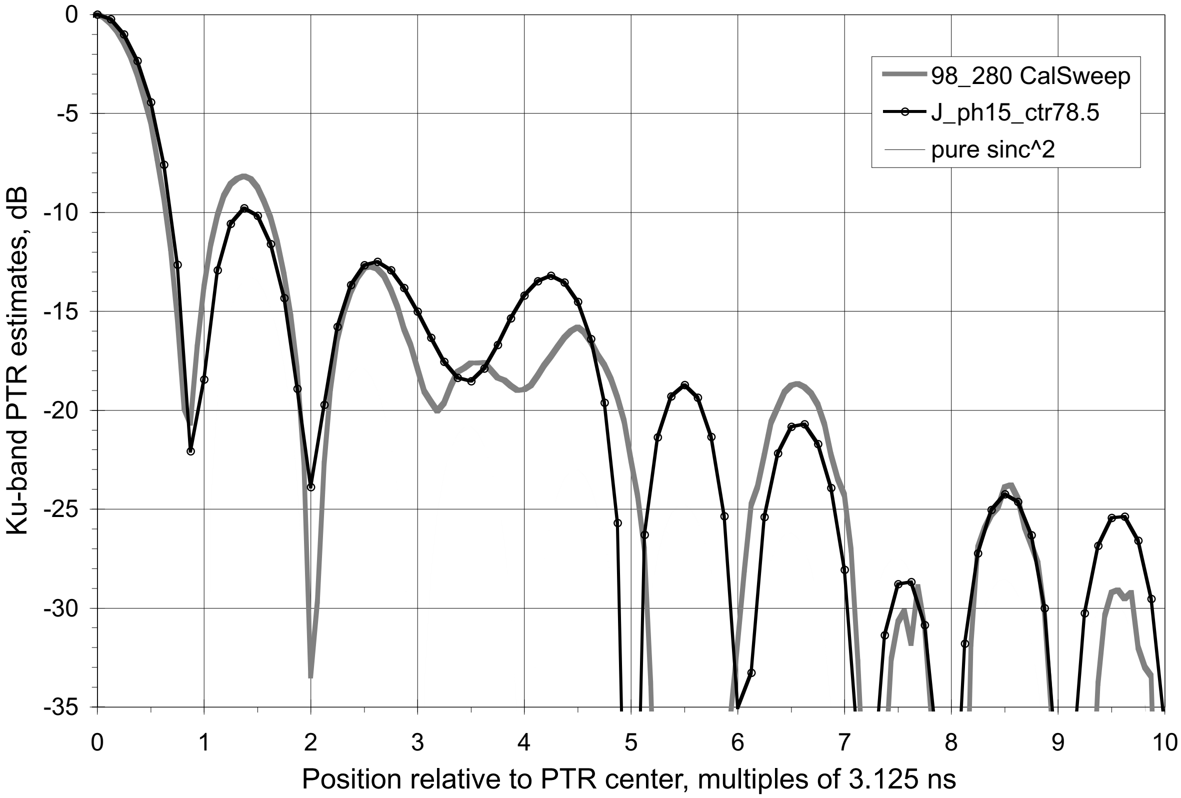

Figure 3-36 CalSweep Comparison for Jensen Model Phase Error of 15 Degrees

Figure 3-40 shows the range error arising from the shape alone of Jensen model PTR, and Figure 3-41 shows the combined range errors from PTR shape and from EMB error. The combined range error magnitude for the 9 degree phase model is still within 1 cm over the entire SWH range 0 to 14 m. The 15 degree phase model shows range error magnitudes within 2 cm for system-estimated SWH from 0 to 6 m. Most of the TOPEX over-ocean data will be within the range 0 - 5 m (true) SWH, but there will be a non-negligible amount of data at higher SWH values. The conspicuous breaks or discontinuities in Figure 3-40 and Figure 3-41 arise from the gate index boundaries, and gate index 4 has range errors of +/- 4 cm in Figure 3-41.

In summary, we have tried to show the SWH and range error consequences of a PTR having the shape described in [Jensen, 1998]. A 15 degree phase error shows at least some of the features seen in the 1998 day 208 CalSweep and, to the eye at least, is a better match to the CalSweep than is the 9 degree phase model. But the SWH errors from the 15 degree phase PTR are too large. Also, as Jensen pointed out, the 9 degree model is a better match to the observed mean return in its zero frequency region (around waveform sample 64, or telemetry sample 48) than is the 15 degree model. Neither the 9 degree nor the 15 degree model, centered at sample 78.5, can match the disappearance of the fifth sidelobe above the central lobe of the PTR as seen in the CalSweep results. Jensen's modeling study indicated that the PTR would change shape as it was moved from sample 78.5 to sample 32.5. The TOPEX calibration mode (both CalSweep and normal CAL-1) can only assess the PTR at sample 78.5, and only

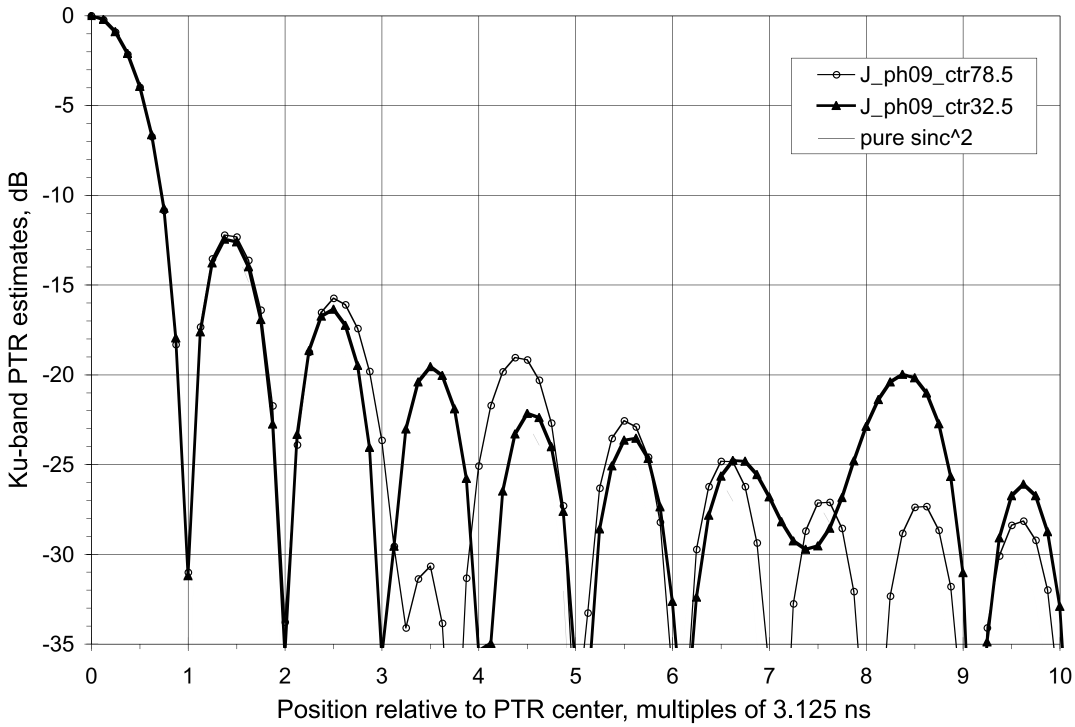

Figure 3-37 Effect of Shifting PTR Position in Jensen Model with 9 Degree Phase Error

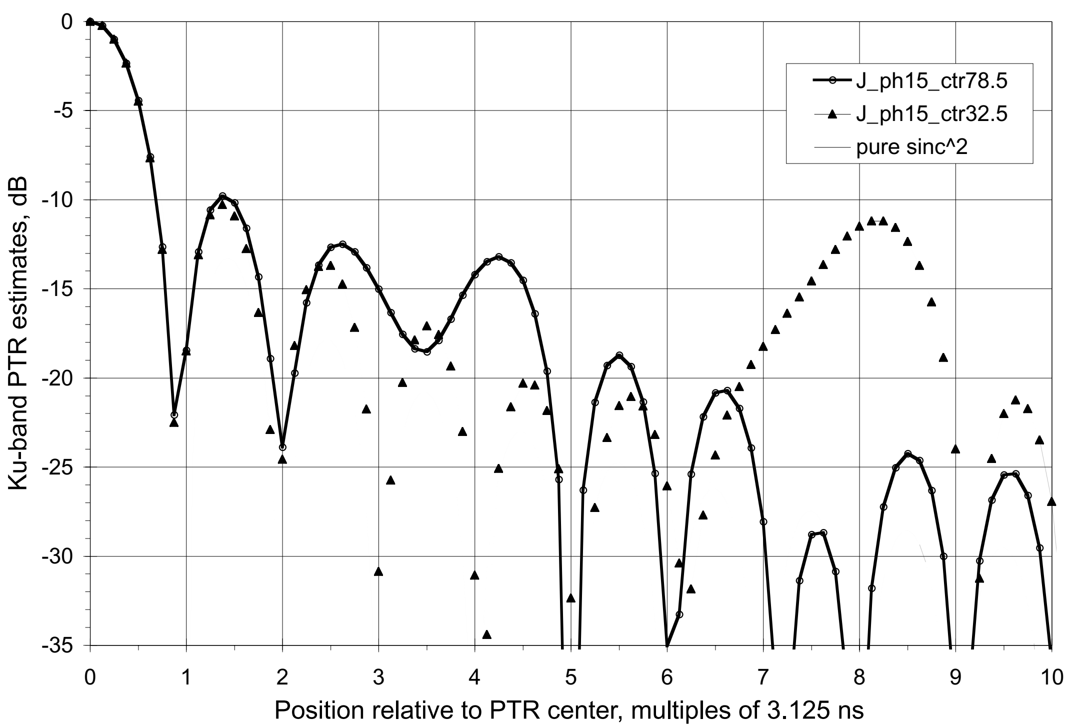

Figure 3-38 Effect of Shifting PTR Position in Jensen Model with 15 Degree Phase Error

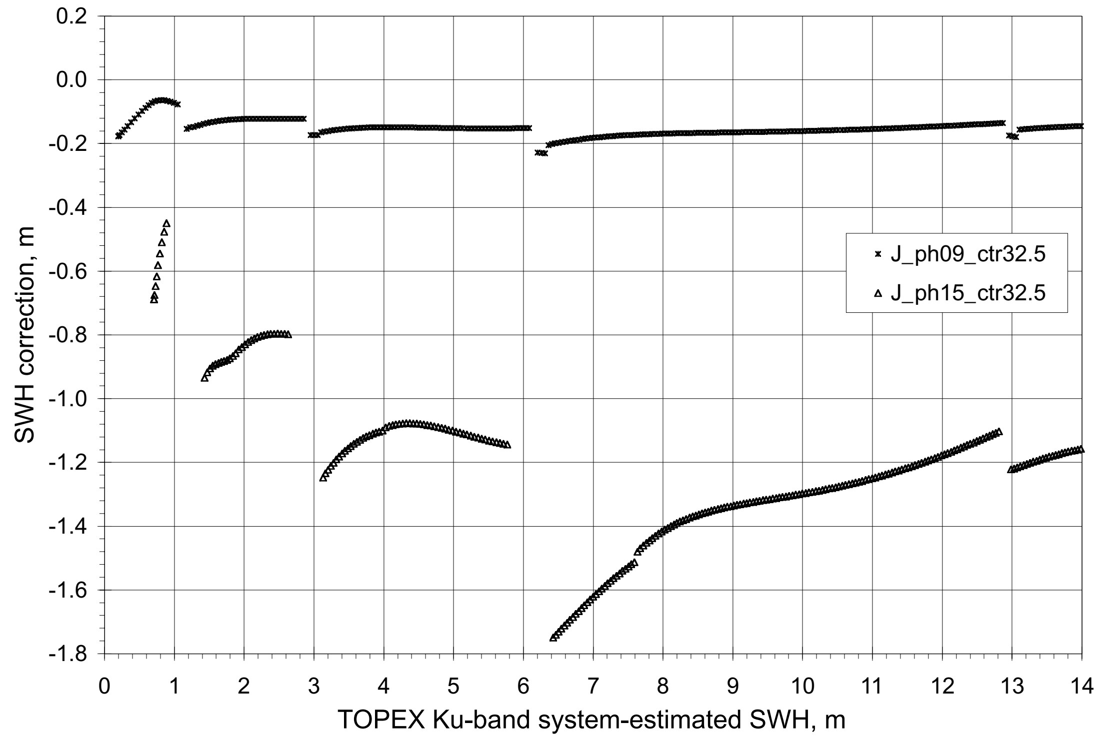

Figure 3-39 SWH Correction Relative to Ideal Sinc^2 for Jensen Model PTRs at Sample 32.5

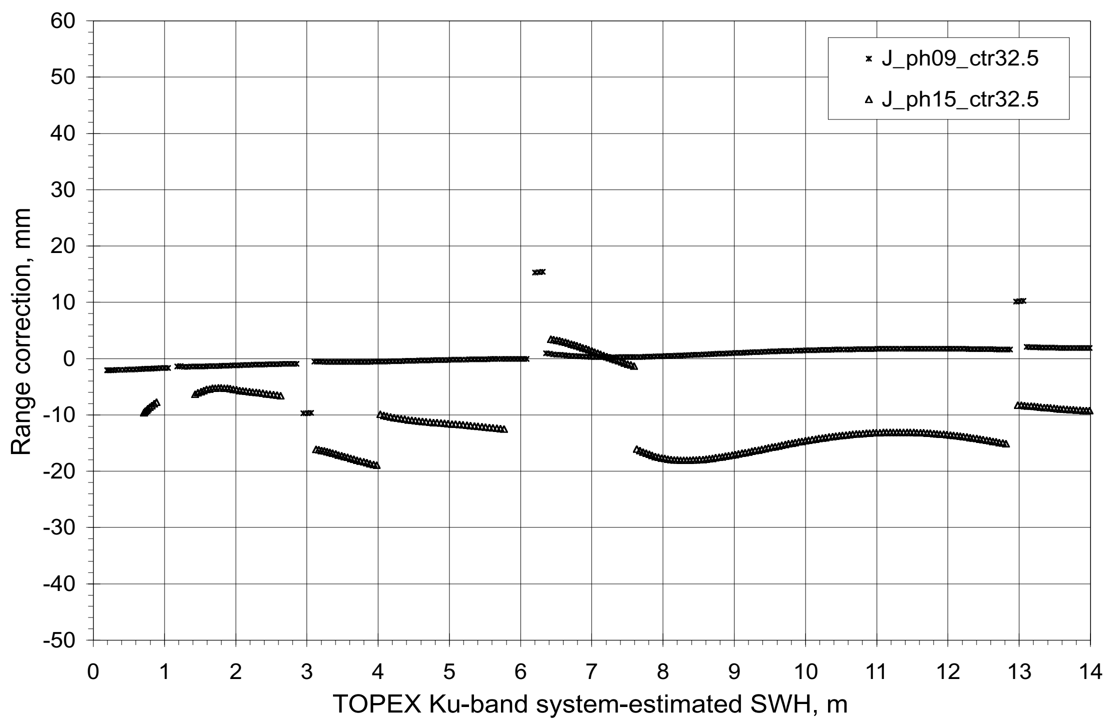

Figure 3-40 Range Correction Relative to Sinc^2 for Model PTR Shape Change Alone, PTRs at Sample 32.5

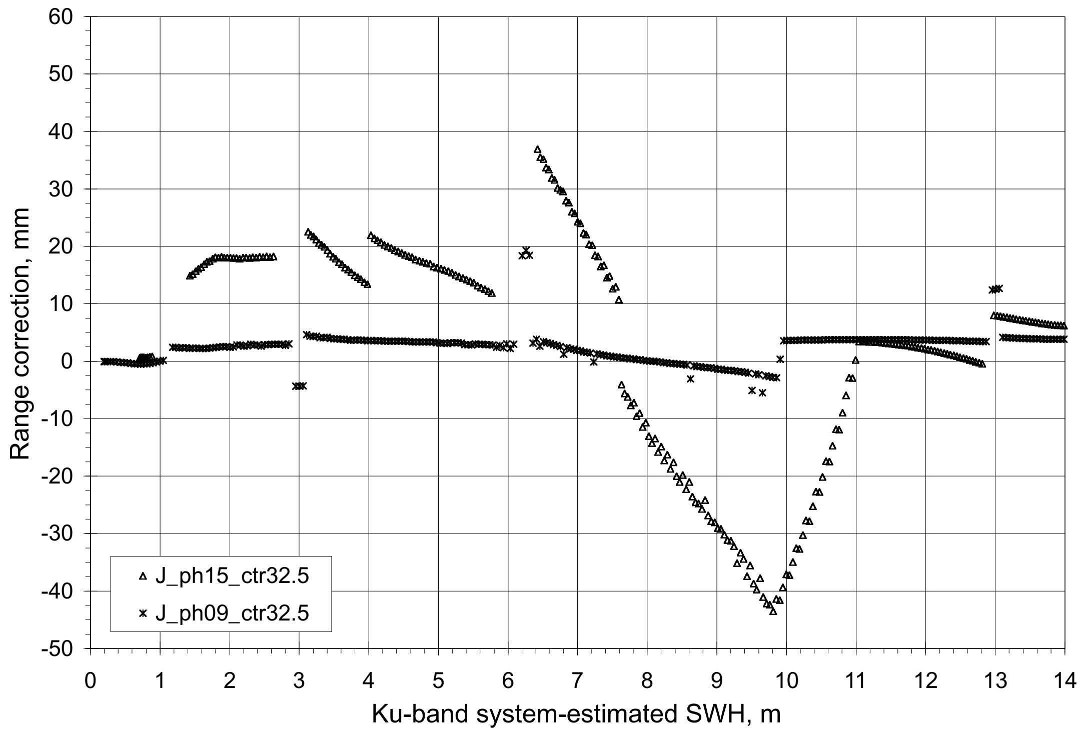

Figure 3-41 Range Correction Relative to Sinc^2 for Both PTR Shape Change and EM Bias Change and EM Bias Change, PTRs at Sample 32.5

modeling efforts like Jensen's will get from the CalSweep data at sample 78.5 to the effective PTR seen at sample 32.5 in normal TOPEX tracking operation. Phase error values between 9 and 15 degrees need to be explored, and perhaps the net SWH error can be used to help guess at a "reasonable" phase error. Once a model is found that is a reasonable match for observations in late 1998, then a time dependence will need to be built into the model to describe the Side A PTR evolution from late 1992 to early 1999. And somehow there will have to be a decision how much asymmetry to build in to the model PTR, since the CalSweep results are not completely symmetric about the central PTR lobe.

3.3.6 Summary of PTR Change Discussion

The apparent drift in TOPEX Side A SWH estimation was the first indication of a change in the TOPEX effective PTR at the track point. The SWH cycle averages showed that the TOPEX drift starts to become apparent somewhere around cycle 160, and that by cycle 235 the SWH error had probably started to exceed 10% of the SWH.These SWH data were described, as was a small "shoulder" evident in the leading edge region of the TOPEX over-ocean waveform in later cycles.The PTR information available from both CalSweep and from normal CAL-1 waveforms was then described.

We described efforts to build time-dependent PTR models and to predict SWH and range corrections resulting from these models.These efforts were not successful, but are described here as part of the history of PTR investigations and because part of this work was presented at the October 1998 SWT meeting in Keystone, CO, and another part was presented at the AGU Fall 1998 meeting in San Francisco, CA.

Finally we reviewed some modeling efforts by J. R. Jensen which predicted that the TOPEX PTR shape would depend on its position within the digital filter bank.This prediction creates a huge problem for efforts to predict SWH and range errors from PTR changes, because the TOPEX calibration mode (both CalSweep and normal CAL-1) positions the center of the PTR at waveform sample 78.5 while the normal over-ocean tracking positions the PTR at waveform sample 32.5. We have used the Jensen position-dependent PTR model, and assessed the SWH and range errors by the same type of TOPEX simulation used for the Sept98, Nov98, and Jan99 PTR models.

There is no final answer yet in this problem of PTR changes and their consequences. Because we cannot directly sample the PTR at its track-point (waveform sample 32.5) for TOPEX on-orbit, it seems clear that we will have to rely on Jensen's modeling to transfer calibration mode PTR information to the track-point where it is really needed. Jensen is now doing further investigation into more detailed, more realistic modeling of the PTR changes.We have only been able here to sketch the current status of the analysis of PTR changes.

Section 4

Engineering Assessment Synopsis

4.1 Performance Overview

On February 10, 1999, after six-and-a-half years of very successful on-orbit operations, Side A of the NASA Radar Altimeter on the TOPEX/POSEIDON spacecraft was turned off; its Point Target Response (PTR) had changed slightly over time, affecting measurement consistency. Side B is now the operational altimeter; however, Side A could be turned back on if needed.

Side A performance significantly surpassed all its pre-launch specifications, including its length of service; its design lifetime was three years, with a goal of five years. The primary pre-launch specification for the altimeter was to monitor and maintain range calibration to the +1.5 cm level. Based on the published results of TOPEX science investigators, unprecedented range measurement accuracy has been achieved with this altimeter data set. With our analysis techniques, we believe that we have achieved range calibration (i.e., internal range consistency) at the one-centimeter level, and have made meaningful inroads towards the sub-centimeter level.

We are continuing our NASA Radar Altimeter performance assessment on a daily basis, now with Side B, and are continuing to develop improved analysis techniques. Our performance assessment techniques are relevant not only for the NASA Radar Altimeter, but are very applicable to other spaceborne altimeters as well.

Section 5

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