GEOSAT Follow-On GDR User's Handbook

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GFO GDR User's Handbook

1.0 INTRODUCTION

1.1 Purpose

The purpose of this document is to provide a description of the GEOSAT Follow-On (GFO) Geophysical Data Record (GDR). The GDR is generated from GFO Sensor Data Records (SDRs), precise laser orbit ephemerides provided by NASA Goddard Space Flight Center and Raytheon ITSS , environmental corrections, and ancillary geophysical variables. This handbook is based in large part on the Navy IGDR User's Handbook and we would like to express our thanks and appreciation to Bruce Lunde at NAVO for developing the original HTML documentation.

1.2 Change Control

This document is not presently under document change control.

1.3 Nomenclature

An altimetry file (such as an SDR or GDR) is generally made up of a descriptive header followed by data records. The header may be comprised of ASCII text or binary data, while the data records are usually binary. The nomenclature for these items are as follows:

ITEM		DEFINITION
1. 0	Header	The first major file element. It contains general information about the file and is the first element of the file.

1.1.1	Line	A major header data item composed of ASCII text (usually terminated by a newline).
1.1.2	Record	A major header data item which may be ASCII or binary. Depending on the context, "record" may be used interchangeably with "line".
1.2	Field	A minor header data item which comprises part of a record (or line). Referencing a "field" usually requires that the corresponding record by specified.
2.0	Data Record	The second major file element. It contains unique file information and may be indexed by time or position, etc. Data records are usually binary. Depending on the context, "record" may be used interchangeably with "data record".
2.1	Field	A minor data record item. Referencing a "field" usually requires that the corresponding data record by specified.

Table 1.4-1 Altimetry File Nomenclature

When square brackets "[ ]" follow a data item they are used to indicate the item's units. For example, "SSHC [mm]" would indicate that the quantity SSHC has units of millimeters.

2.0 DATA CONTENT

2.1 General

GFO GDR filenames have the following format: gfo_cCCC_pPPP.gdr

where

"CCC" identifies the 17-day repeat cycle number and
"PPP" identifies the pass (half-revolution) number of the GDR

Each GDR is comprised of a multi-line ASCII header followed by multiple binary data records, which are made up of various fields.

Fields with bad values or missing data are set to the following values:

Data Type	Hexadecimal (base 16)	Decimal (base 10)
8 bit signed integer	7F	127
8 bit unsigned integer	FF	255
16 bit signed integer	7FFF	32767
16 bit unsigned integer	FFFF	65535
32 bit signed integer	7FFFFFFF	2147483647
32 bit unsigned	FFFFFFFF	4294967295

integer		

Table 2.1-1 Default Values for Bad or Missing Data

Flag fields whose bit values are missing or not set, contain a 0. These correspond to fields 34, 36, 48, and 49 of the Data Record.

2.2 Header

Format: Twenty lines of ASCII text terminated by linefeeds. For lines 1 through 19 a semicolon ";" marks the end of the text string.

NOTE: Records 2, 14, and 17-19 have a different definition in the NOAA GDRs and the Navy NGDRs. The format and/or units of fields 1 and 5 also differ slightly.

Description:

Record #	Record Identifier	Description	Units
1	"PASS_BEGIN_TIME = "	Time of First Record in Pass File	Seconds since 1/1/1985
2	"EQ_CROSSING_TIME_LON = "	Time and Longitude of Pass Equator Crossing	Seconds since 1/1/1985; degrees E
3	"CYCLE_NUMBER = "	17-Day Repeat Cycle Number	N/A
4	"PASS_NUMBER = "	Pass Number within Cycle	N/A
5	"PROCESSING_TIME = "	Date and Time Stamp String	N/A
6	"PROCESSING_CENTER = "	Processing Center: NOAA LSA	N/A
7	"SOFTWARE_VERSION = "	Software Version	N/A
8	"SATELLITE_ID = "	Satellite Identification: GFO	N/A
9	"DATA_RECORD_LENGTH = "	Total Length of Data Record: 184	bytes
10	"BASIC_GDR_LENGTH = "	Length of Common Portion of Data Record: 98	bytes
11	"HEIGHT_CALIBRATION_BIAS = "	Height Calibration Bias	mm
12	"ALTITUDE_BIAS_INITIAL = "	Initial Altitude Bias Correction	km
13	"ALTITUDE_BIAS_CENTER_OF_GRAVITY = "	Altitude Center of Gravity Correction	mm
14	"TIMING_BIAS_INITIAL = "	Initial Timing Bias	msec

15	"AGC_CALIBRATION_BIAS = "	AGC Calibration Bias	dB
16	"AGC_BIAS_INITIAL = "	Initial AGC Bias	dB
17	"ORBIT = "	Orbit Arc Type [poe | moe] and filename	N/A
18	"PASS_END_TIME = "	Time of Last Record in Pass File	Seconds since 1/1/1985
19	"NUMBER_GDR_RECORDS = "	Number of 1-Hz Data Records in File	N/A
20	"END_OF_HEADER "	Last Record in Header	N/A

Table 2.2-1 Header Description

Many of the fields in the GDR header are derived from (or set equal to) fields in the SDR Header.

The following sections describe the GDR header lines listed in the table above.

2.2.1 PASS_BEGIN_TIME

PASS_BEGIN_TIME [seconds] is set to the UTC time, in seconds since 1/1/1985, of the first data record in the file. This time corresponds to the midframe time of the 1-Hz average of the first record.

2.2.2 EQ_CROSSING_TIME_LON

EQ_CROSSING_TIME_LON [secs; degrees] give the time and longitude of the equator crossing point for this pass. The values are generated from the once per minute ephemeris data, interpolated to the equator crossing. The equator crossing information for each pass within each 17-day cycle are available in the equator crossing table .

2.2.3 CYCLE_NUMBER

CYCLE_NUMBER is determined from the equator crossing table, with cycle "zero" defined as the first (partial) 17-day cycle after the satellite attained its exact repeat orbit on 4/20/1998. With this definition, cycle number one, pass number one, has an equator crossing time of ~ 22:11 UTC on 5/3/1998. The first SDR data were generated during cycle one, beginning on 5/10/1998.

2.2.4 PASS_NUMBER

PASS_NUMBER is the number of half revolutions since the beginning of the current cycle, ranging from 1 to 488. These are in order of increasing equator crossing time, with all ascending passes odd-numbered, and all descending passes even-numbered. Pass number one is defined as the pass whose equator crossing longitude is the smallest east longitude in the range 0-360 degrees. This pass had an average equator crossing longitude of approximately 1.01 E. Subsequent pass numbers have equator crossing times roughly 50 minutes later than the previous pass.

2.2.5 PROCESSING_TIME

PROCESSING_TIME is the time at which the GDR was created from the input SDRs. It is comprised of a 24-byte UNIX date and time stamp, e.g. "Mon Jun 10 14:30:00 2002".

2.2.6 PROCESSING_CENTER

PROCESSING_CENTER is an alphanumeric string telling where the GDR was created, e.g. "NOAA LSA".

2.2.7 SOFTWARE_VERSION

SOFTWARE_VERSION is an alphanumeric string telling the current version of the GDR processing software.

2.2.8 SATELLITE_ID

SATELLITE_ID is an alphanumeric string telling which satellite was processed, e.g. "GFO".

2.2.9 DATA_RECORD_LENGTH

DATA_RECORD_LENGTH [bytes] is an integer representing the length in bytes of the total GDR Data Record. This is currently 184 bytes for the GFO GDRs.

2.2.10 BASIC_GDR_LENGTH

BASIC_GDR_LENGTH [bytes] is an integer representing the length in bytes of the portion of the GDR Data Record which is common between all GDR files for different satellites. This is currently 98 bytes, as defined by NAVO data processing conventions.

2.2.11 HEIGHT_CALIBRATION_BIAS

HEIGHT_CALIBRATION_BIAS [mm] is set equal to the "Height Calibration Bias" in the SDR Header (field 12).

2.2.12 ALTITUDE_BIAS_INITIAL

ALTITUDE_BIAS_INITIAL [km] is set equal to the "Altitude Bias (Initial)" in the SDR Header (field 16).

2.2.13 ALTITUDE_BIAS_CENTER_OF_GRAVITY

ALTITUDE_BIAS_CENTER_OF_GRAVITY [mm] is set equal to the "Altitude Bias based on S/C CG" in the SDR Header (field 17).

2.2.14 TIMING_BIAS_INITIAL

TIMING_BIAS_INITIAL [msec] is set equal to "Timing Bias (Initial)" in the SDR Header (field 18). All times in the GDRs have been computed by subtracting this quantity from the corresponding times in the SDRs.

2.2.15 AGC_CALIBRATION_BIAS

AGC_CALIBRATION_BIAS [dB] is set equal to the "AGC Calibration Bias" in the SDR Header (field 13).

2.2.16 AGC_BIAS_INITIAL

AGC_BIAS_INITIAL [dB] is set equal to the "AGC Bias (Initial)" in the SDR Header (field 19).

2.2.17 ORBIT

ORBIT specifies the type of laser orbit ephemeris file ("moe" = medium orbit ephemeris; "poe" = precise orbit ephemeris) and the arc date string. The arc date is of the form "ZYMMDD" where Z indicates the decade ("n" for 1990; "z" for 2000); Y indicates the year within the decade (0-9); MM is the month (01-12) and DD is the day of the month (01-31).

2.2.18 PASS_END_TIME

PASS_END_TIME [seconds] is set to the UTC time, in seconds since 1/1/1985, of the last data record in the file. This time corresponds to the midframe time of the 1-Hz average of the final record.

2.2.19 NUMBER_GDR_RECORDS

NUMBER_GDR_RECORDS gives the count of one-second average records within the GDR.

2.2.20 END_OF_HEADER

END_OF_HEADER is the text string used to demarcate the last line of the GDR Header.

2.3 Data Record

Format: Integer binary data in big-endian format.

NOTE: Records 32, 33, and 35 have a different definition in the NOAA GDRs and Navy NGDRs. Record 8 (Time Shift Midframe) does NOT have TIMING_BIAS_INITIAL subtracted from it in the NOAA GDRs, while it is subtracted in the Navy NGDRs. The order of records 74-76 have been switched from [Quality Word I, Quality Word II, Receiver Temp.] in the Navy NGDR to [Receiver Temp., Quality Word I, Quality Word II] in the NOAA GDR. This eliminates a byte-alignment problem between two-byte and four-byte integer values in the NOAA GDR.

Description:

Record #	Parameter	Units	Bytes	Position	Type	Limits/Range
1	Time Past Epoch	seconds	4	0	Unsigned Integer	0 to 2^{32}
2	Time Past Epoch Continued	µseconds	4	4	Unsigned Integer	0 to 1E6
3	Latitude	µdegrees	4	8	Integer	+/- 72E6
4	Longitude	µdegrees	4	12	Integer	0 to 360E6
5	SSH Uncorrected	millimeters	4	16	Integer	-1E6 to 1E7
6	SSH Corrected	millimeters	4	20	Integer	-1E6 to 1E7
7	Altitude	millimeters	4	24	Unsigned Integer	7E8 to 9E8
8	Time Shift Midframe	microseconds	4	28	Integer	0 to 1E6
9	SWH	centimeters	2	32	Unsigned Integer	0 to 2500
10	Sigma0	0.01 dB	2	34	Unsigned Integer	0 to 4000
11	Wind Speed	centimeters/sec	2	36	Unsigned Integer	0 to 7500
12	AGC	0.01 dB	2	38	Unsigned Integer	0 to 6400
13	Dry Troposphere	millimeters	2	40	Integer	-2500 to -2200
14	Wet Troposphere (MWR)	millimeters	2	42	Integer	-700 to 0
15	Ionosphere	millimeters	2	44	Integer	-500 to -40
16	Inverse Barometer	millimeters	2	46	Integer	+/- 500
17	Sea State Bias	millimeters	2	48	Integer	-1200 to 0

18	Solid Earth Tide	millimeters	2	50	Integer	+/- 500
19	Ocean Water Tide	millimeters	2	52	Integer	+/- 5000
20	Ocean Load Tide	millimeters	2	54	Integer	+/- 500
21	Pole Tide	millimeters	2	56	Integer	+/- 200
22	Water Depth	meters	2	58	Integer	-1 to -8000
23	Geoid Height	millimeters	4	60	Integer	+/- 1.5E6
24	Mean Sea Surface I	millimeters	4	64	Integer	+/- 1.5E6
25	Mean Sea Surface II	millimeters	4	68	Integer	+/- 1.5E6
26	SSHU STD	millimeters	2	72	Unsigned Integer	0 to 65534
27	SWH STD	centimeters	2	74	Unsigned Integer	0 to 65534
28	AGC STD	0.01 dB	2	76	Unsigned Integer	0 to 65534
29	Net Height Correction	millimeters	2	78	Integer	+/- 16767
30	Net SWH Correction	millimeters	2	80	Integer	+/- 16767
31	Net AGC Correction	0.01 dB	2	82	Integer	+/- 16767
32	1-Hz Time-Tag Deviation	1E-15 seconds	4	84	Integer	+/- 1E9
33	Attitude Squared	1E-4 degrees^2	2	88	Integer	+/- 6400
34	NOAA Flags	bit pattern	2	90	Unsigned Integer	0 or 1
35	Wet Troposphere (Model)	millimeters	2	92	Integer	-700 to 0
36	Instrument State Flags	bit pattern	1	94	Unsigned Integer	0 or 1
37	NVals SSHU	N/A	1	95	Integer	6 to 10
38	NVals SWH	N/A	1	96	Integer	6 to 10
39	NVals AGC	N/A	1	97	Integer	6 to 10
40-49	SWH High-Rate (1:10)	centimeters	2*10	98	Unsigned Integer	0 to 2500
50-59	SSHU High-Rate Differences (1:10)	millimeters	2*10	118	Integer	+/- 1E4
60-69	Altitude High-Rate Differences (1:10)	millimeters	2*10	138	Integer	+/- 1E4
70	22 GHz Brightness Temp	0.01 deg K	2	158	Unsigned Integer	0 to 27000
71	37 GHz Brightness Temp	0.01 deg K	2	160	Unsigned Integer	0 to 27000
72	RA Status Mode I	bit pattern	2	162	Unsigned Integer	0 or 1
73	RA Status Mode II	bit pattern	2	164	Unsigned Integer	0 or 1
74	Receiver Temperature	0.01 deg C	2	166	Integer	

75	Quality Word I	bit pattern	4	168	Unsigned Integer	0 or 1
76	Quality Word II	bit pattern	4	172	Unsigned Integer	0 or 1
77	Average VATT	microvolt	4	176	Integer	
78	Fitted VATT	microvolt	4	180	Integer	

Table 2.3-1 Data Record Description

Many of the fields in the GDR Data Record are derived from (or set equal to) fields from the SDR Header and SDR Data Record.

The following sections describe the GDR Data Record fields listed in the table above.

2.3.1 Time Past Epoch

Time Past Epoch [sec] is the time at the midframe expressed as the number of integer seconds since January 1, 1985, 0.0 hours UTC. Compute the actual midframe time as follows:

Time_Midframe [sec] = Time_Past_Epoch [sec] + Time_Past_Epoch_Continued [µsec] * 1E-6

2.3.2 Time Past Epoch Continued

Time Past Epoch Continued [µsec] is the fractional contribution to the total Time Past Epoch.

2.3.3 Latitude

Latitude [µdeg] is the geodetic latitude calculated at the midframe, where north is positive and south is negative. This quantity is derived from an ephemeris or Keplerian elements (refer to "ephemeris" in the Glossary).

2.3.4 Longitude

Longitude [µdeg] is the east geodetic longitude calculated at the midframe, where 0<=longitude<360. This quantity is derived from an ephemeris or Keplerian elements (refer to "ephemeris" in the Glossary).

2.3.5 SSH Uncorrected

SSH Uncorrected [mm] (SSHU) is the 1-Hz Sea Surface Height (SSH) relative to the ellipsoid, without any environmental corrections. The 1-Hz value is calculated at the midframe using the 10-Hz SSHU values. The 1-Hz value is obtained from a linear fit with iterative outlier rejection applied to the 10-Hz values.

SSHU [mm] = Satellite_Altitude - (Satellite_Range + Net_Height_Correction) ,

where

Satellite_Range is the uncorrected height of the satellite above the sea surface, obtained from the SDR parameters H(1) through H(10) (fields 7 through 16 of the SDR Data Record).

2.3.6 SSH Corrected

SSH Corrected [mm] (SSHC) is the 1-Hz Sea Surface Height (SSH) relative to the ellipsoid, with environmental corrections. The 1-Hz value is calculated at the midframe using the 10-Hz SSHC values. The 1-Hz value is obtained from a linear fit with iterative outlier rejection applied to the 10-Hz values. SSHC is calculated from SSHU (section 2.3.5).

SSHC [mm] = SSHU - Environmental_Corrections , where

Environmental_Corrections =

Ionosphere + Dry_Troposphere + Wet_Troposphere_MWR + Inverse_Barometer + Ocean_Water_Tide + Ocean_Load_Tide + Solid_Earth_Tide + Pole_Tide + Sea_State_Bias

2.3.7 Altitude

Altitude [mm] is the geodetic height of the satellite above the reference ellipsoid, calculated at the midframe. This quantity is derived from an ephemeris or Keplerian elements (refer to "ephemeris" in the Glossary).

2.3.8 Time Shift Midframe

Time Shift Midframe [μsec] is the time offset between the first high-rate (10-Hz) sample in the GDR record, and the time of the 1-Hz record (Time_Past_Epoch + 1E-6 * Time_Past_Epoch_Continued). Times of SDR Data Records pertain to the first RA data sample of the high-rate data, while times of GDR Data Records pertain to the midframe, located halfway between high-rate samples five and six. All GDR times have been corrected by subtracting TIMING_BIAS_INITIAL from the SDR times.

Time Shift Midframe is calculated from the "Ratio" parameter in the SDR Header (field 25) as follows:

Time_Shift_Midframe [μsec] = (4.5 * 0.098 * 1E6 * Ratio_{SDR})

Refer to section 2.3.32 for further details on the computation of GDR time-tagging.

2.3.9 SWH

SWH [cm] is the 1-Hz Significant Wave Height calculated at the midframe using the 10-Hz SWH's from the SDR. The 1-Hz value is obtained from a linear fit with iterative outlier rejection.

SWH [cm] = SWH_{SDR}[m] * 100

2.3.10 Sigma0

Sigma0 [0.01 dB] is set equal to the "Backscatter Coefficient" from the SDR Data Record (field 48).

2.3.11 Wind Speed

Wind Speed [cm/sec] is calculated from Sigma0 using a modified Chelton-Wentz algorithm:

Wind_Speed [cm/sec] = 100 * SUM{ a(coeff_index,i) * Sigma0**i $\}_{i=0,1,2,3,4}$

where

coeff_index = 0 for Sigma0 < 11.4

coeff_index = 1 for 11.4 <= Sigma0 < 20.2

coeff_index = 2 for Sigma0 >= 20.2

and a(coeff_index,i) is a 3x5 array with the following values:

{58.7614523 , -13.58500361, 2.239083411, -0.188532055, 0.005438225}

{366.3919346, -81.88668532, 6.890552953, -0.257760189, 0.003607894}

{0.0 , 0.0 , 0.0 , 0.0 , 0.0 }

Reference: Witter, D.L., and D.B. Chelton, A Geosat wind speed algorithm and a method for altimeter wind speed algorithm development. *J. Geophys. Res.*, **96**, 8853-8860, 1991

2.3.12 AGC

AGC [.01 dB] is the 1-Hz Automatic Gain Control calculated at the midframe using the 10-Hz AGC's from the SDR. The 1-Hz value is obtained from a linear fit with iterative outlier rejection.

$$AGC\ [0.01\ dB] = AGC_{SDR}[dB] * 100 + Net\_AGC\_Correction\ [0.01\ dB]$$

2.3.13 Dry Troposphere

Dry Troposphere [mm] is derived from the NOAA NCEP Reanalysis Project sea level pressure data set. The value is determined by bilinear interpolation in space, and linear interpolation in time, from the 6-hourly, 2.5 degree spatial grids.

$$Dry\_Troposphere\ [mm] = -2.273 * (1 + 0.0026 * \cos(2 * Latitude[radians])) * Sea\_Level\_Pressure[mbar]$$

2.3.14 Wet Troposphere (MWR)

Wet Troposphere (MWR) [mm] is the wet correction measured by the onboard microwave radiometer. It is obtained from the "Path Delay" variable in SDR Data Record (field 49) as follows:

$$Wet\_Troposphere\_MWR\ [mm] = -10 * Path\_Delay_{SDR}\ [cm]$$

2.3.15 Ionosphere

Ionosphere [mm] is the altimeter range correction derived from the total electron content (TEC) in the atmosphere. Ionosphere is obtained from the University of Bern (Switzerland) "CODE" Global Ionosphere Maps (GIM). Two-hourly GIM maps are bilinearly interpolated, after rotation in solar/magnetic coordinates, to provide a precise value based on GPS measurements.

The TEC measurements are converted to a range correction using the square of the GFO Ku-band frequency:

$$Ionosphere\ [mm] = -402.5 * TEC[10^{16}\ electrons/m^2] / f^2$$

where $f = 13.495$ is the radar frequency, in GHz, and "10^{16} electrons/m^2" is commonly referred to as a "TEC unit".

(Click on GIM in the Glossary and the GIM GFO web link in Appendix B for more information.)

2.3.16 Inverse Barometer

Inverse Barometer [mm] is calculated from the NOAA NCEP Reanalysis Project sea level pressure data set as follows:

$$Inverse\_Barometer\ [mm] = -9.948 * (Sea\_Level\_Pressure[mbar] - Mean\_Ocean\_Pressure[mbar]) ,$$

Surface_Pressure values are "local" measurements at the sub-satellite nadir location (lat/lon), determined from bilinear spatial and linear temporal interpolation ofthe 6-hourly, 2.5 degree grids. The Mean_Ocean_Pressure values are calculated for each 6-hourly grid by averaging all Sea_Level_Pressure values that are over ocean (and not land) gridpoints. The 6-hourly time series is then smoothed with a 2-day filter, and the resulting time series of Mean_Ocean_Pressure is linearly interpolated in time to the measurement time of the data record.

2.3.17 Sea State Bias

Sea State Bias [mm] (SSB) is calculated as 4.5% of SWH (see section 2.3.9):

Sea_State_Bias [mm] = -0.045 * (SWH[cm] * 10)

2.3.18 Solid Earth Tide

Solid Earth Tide [mm] is calculated as follows:

Solid_Earth_Tide [mm] = 1000 * (RH2*V2 + RH3*V3)/GRAVITY ,

where

RH2 = 0.609 , RH3 = 0.291 , and GRAVITY = 9.80 .

V2 and V3 are the second and third degree potential values (in the MKS system) from the tide-generating potential as given by Cartwright and Tayler (1971) and corrected by Cartwright and Edden (1973).

Reference: Cartwright, D.E., and A.C. Edden, Corrected tables of tidal harmonics. *Geophys. J. Roy. Soc*., **23**, 253-264, 1973.

2.3.19 Ocean Water Tide

Ocean Water Tide [mm] is calculated from the NASA Goddard Space Flight Center GOT00.2 tide model .

2.3.20 Ocean Load Tide

Ocean Load Tide [mm] is also calculated from the NASA Goddard Space Flight Center GOT00.2 tide model .

2.3.21 Pole Tide

Pole Tide [mm] is calculated as follows:

Pole_Tide [mm] = A * sin(2 * Latitude[radians]) * ((Polar_location_X - X_pole_avg) * cos(Longitude[radians]) - (Polar_location_Y - Y_pole_avg) * sin(Longitude[radians]))

where

A = -69.435 , X_pole_avg = 0.042 , and Y_pole_avg = 0.293 .

The "Polar_location_X" and "Polar_location_Y" values are the polar motion angles (in arcsec) obtained from data in the orbit ephemeris files.

(Click here for a description of the pole tide correction.)

2.3.22 Water Depth

Water Depth [m] is obtained from the NOAA/NGDC ETOPO2 two-minute topography/bathymetry data base, which is largely based on predicted bathymetry from satellite altimetry.

2.3.23 Geoid Height

Geoid Height [mm] is obtained from the joint NASA/NIMA EGM96 database.

2.3.24 Mean Sea Surface I

Mean Sea Surface I [mm] is obtained from the NASA Goddard Space Flight Center GSFC00.1 two-minute mean sea surface database.

2.3.25 Mean Sea Surface II

Mean Sea Surface II [mm] is obtained from the OSUMSS95 one-sixteenth degree database.

2.3.26 SSHU STD

SSHU STD [mm] is the standard deviation from the fit applied to the 10-Hz SSHU values (section 2.3.5).

2.3.27 SWH STD

SWH STD [cm] is the standard deviation from the fit applied to the 10-Hz SWH values (section 2.3.9).

2.3.28 AGC STD

AGC STD [0.01 dB] is the standard deviation from the fit applied to the 10-Hz AGC values (section 2.3.12).

2.3.29 Net Height Correction

Net Height Correction [mm] is calculated from fields in the SDR Header and Data Record as follows:

Net_Height_Correction [mm] =

$Attitude\_Wave\_Height\_Bias_{SDR}$ - $Height\_Calibration\_Bias_{SDR}$ + $Altitude\_Bias\_Center\_of\_Gravity_{SDR}$ - (1E6 * $Altitude\_Bias\_Initial_{SDR}$) - $FM\_Crosstalk_{SDR}$

2.3.30 Net SWH Correction

Net SWH Correction [mm] is calculated from the "SWH Bias" in the SDR Data Record (field 31) as follows:

Net_SWH_Correction [mm] = SWH_Bias_{SDR}[m] * 1000

2.3.31 Net AGC Correction

Net AGC Correction is calculated from fields in the SDR Header and Data Record as follows:

Net_AGC_Correction [0.01 dB] =

$AGC\_Temperature\_Correction_{SDR}$ + $Delta\_AGC\_Height_{SDR}$ + $AGC\_Correction\_for\_Attitude_{SDR}$ - $AGC\_Calibration\_Bias_{SDR}$

2.3.32 1-Hz Time-tag Deviation

The 1-Hz Time-tag Deviation is the difference between the actual and nominal inter-record spacing. This quantity is a function of the SDR Header variable "Ratio" (field 25), which can change within a pass, and therefore it is carried as a data variable within the GDR. The nominal value of Ratio is 0.99992E-6. The 1-Hz inter-record spacing, in seconds, is 0.98*ratio*1E6. Hence the nominal value of the 1-Hz time-tag is 0.98*0.99992 = 0.9799216 seconds. The actual 1-Hz time-tag spacing is computed from the current value of Ratio in the SDR header, and the difference between the actual and nominal values is stored as the time-tag deviation, in units of femtoseconds.

This high-precision value allows the SDR "Ratio" parameter to be reconstructed for time-tagging adjustments and calculation of the Ultra-Stable-Oscillator (USO) height correction. The USO height correction is implicitly applied during SDR generation, and is defined as:

$Delta\text{-}h_{USO}$[mm] = h_0[mm] * Delta-dt[sec] / dt[sec]

where "dt" is the 1-Hz time-tag spacing, and "Delta-dt" is the 1-Hz Time-tag Deviation.

The order of magnitude of Delta-dt/dt is 10^{-7}; with height values h_0 around 800 km, the Delta-h_{USO} term is on the order of 8 cm.

2.3.33 Attitude Squared

Attitude Squared [10^{-4} deg^2] is computed from the SDR variable Fitted_VATT, which is directly proportional to the square of attitude:

$$Attitude\_Squared\ [10^{-4}\ deg^2] = b1*b1*(Fitted\_VATT_{SDR} - b0) * 1E4$$

where b0 = 1.11, b1 = .8747

This waveform-derived estimate of spacecraft attitude[2] has a near-Gaussian distribution around the actual platform attitude, and hence can be negative when the true attitude is nearly zero (perfect nadir pointing). Hence it is desirable to store the square of attitude as a signed quantity, rather than truncating attitude estimates when a "negative square root" error would otherwise occur.

2.3.34 NOAA Flags

The NOAA Flags field currently utilizes only two flag bits. Both bit 0 and bit 1 (counting from the least-significant-bit) are based on a 2-minute landmask grid, generated from the Generic Mapping Tools (GMT) shoreline database. Bit 0 is a "wet/dry" flag (0=wet; 1=dry) while bit 1 is an ocean/non-ocean flag (0=ocean; 1=non-ocean). The four possible states for this pair of flag bits is most easily described by the following table:

Bit 1	Bit 0	Flags Value	Interpretation
0	0	0	Ocean
0	1	1	N/A ("dry ocean")
1	0	2	Lake, Inland Sea
1	1	3	Land

Table 2.3-2 NOAA Flags Description

2.3.35 Wet Troposphere (Model)

Wet Troposphere (Model) is derived from the NOAA NCEP Reanalysis Project total precipitable water data set. The value is determined by bilinear interpolation in space, and linear interpolation in time, from the 6-hourly, 2.5 degree spatial grids:

$$Wet\_Troposphere\_Model\ [mm] = -6.36 * Total\_Precipitable\_Water\ [kg/m^2]$$

2.3.36 Instrument State Flags

This field is not used at this time. It will be a bit field used to verify that the instrument state has not changed.

2.3.37 NVals SSHU

NVals SSHU is the number of high-rate values used in the calculation of the 1-Hz SSHU (section 2.3.5).

2.3.38 NVals SWH

NVals SWH is the number of high-rate values used in the calculation of the 1-Hz SWH (section 2.3.9).

2.3.39 NVals AGC

NVals AGC is the number of high-rate values used in the calculation of the 1-Hz AGC (section 2.3.12).

2.3.40-49 SWH High-Rate

SWH High-Rate is calculated from the "SWH" high-rate values in the SDR Data Record (fields 20 through 29) as follows:

$$SWH\_High\_Rate(i)\ [cm] = SWH_{SDR}(i)\ [m] * 100 + Net\_SWH\_Correction\ ,\ i=1,...,10$$

The "Net_SWH_Correction" is detailed in section 2.3.30 .

2.3.50-59 SSHU High-Rate Differences

SSHU High-Rate Differences [mm] are the differences of the high-rate SSHU values from the 1-Hz SSHU value (section 2.3.5). The original high-rate SSHU values can be reconstructed by adding them to the 1-Hz SSHU value.

2.3.60-69 Altitude High-Rate Differences

Altitude High-Rate Differences [mm] are the differences of the high-rate Altitude values from the 1-Hz Altitude value (section 2.3.7). The original high-rate Altitude values can be reconstructed by adding them to the 1-Hz Altitude value.

2.3.70 22 GHz Brightness Temp

22 GHz Brightness Temp is calculated from the "22 GHz Brightness Temp" in the SDR Data Record (field 50) as follows:

$$22\text{ GHz Brightness Temp }[0.01\text{ deg K}] = 22\text{ GHz Brightness Temp}_{SDR}[\text{deg K}] * 100$$

2.3.71 37 GHz Brightness Temp

37 GHz Brightness Temp is calculated from the "37 GHz Brightness Temp" in the SDR Data Record (field 51) as follows:

$$37\text{ GHz Brightness Temp }[0.01\text{ deg K}] = 37\text{ GHz Brightness Temp}_{SDR}[\text{deg K}] * 100$$

2.3.72 RA Status Mode I

RA Status Mode I is set equal to the "RA Status Mode I" from the SDR Data Record (field 2). This is a bit field.

2.3.73 RA Status Mode II

RA Status Mode II is set equal to the "RA Status Mode II" from the SDR Data Record (field 3). This is a bit field.

2.3.74 Receiver Temperature

Receiver Temperature is calculated from the "Receiver Temperature" in the SDR Data Record (field 54) as follows:

$$\text{Receiver Temperature }[0.01\text{ deg C}] = \text{Receiver Temperature}_{SDR}[\text{deg C}] * 100$$

2.3.75 Quality Word I

Quality Word I is set equal to the "RA Quality Test Results" from the SDR Data Record (field 4). This is a bit field.

2.3.76 Quality Word II

Quality Word II is set equal to the "WVR Quality Test Results" from the SDR Data Record (field 5). This is a bit field.

2.3.77 Average VATT

Average VATT is calculated from the "Average VATT" in the SDR Data Record (field 52) as follows:

Average VATT [microvolt] = Average $VATT_{SDR}$[volt] * 1E6

2.3.78 Fitted VATT

Fitted VATT is calculated from the "Fitted VATT" in the SDR Data Record (field 53) as follows:

Fitted VATT [microvolt] = Fitted $VATT_{SDR}$[volt] * 1E6

Glossary

[A] [C] [D] [E] [G] [I] [J] [M] [N] [O] [P] [R] [S] [T] [U] [V] [W] [Z]

µ	micro (1E-6)
-A-	
ADFC	Altimetry Data Fusion Center
AGC	Automatic Gain Control
alphanumeric	Comprised of letters and/or numbers.
Altitude	The geodetic height above the reference ellipsoid
ASCII	American Standard Code for Information Interchange
-C-	
Cal/Val	Calibration and Validation
CCAR	Colorado Center for Astrodynamics Research
CIA	Central Intelligence Agency
CNES	Centre National d'Etudes Spatiales
CRB	Change Review Board
CTRS	Conventional Terrestrial Reference System
-D-	
DBDB5	Digital Bathymetry Data Base 5 Minute Resolution
DEOS	Delft Institute for Earth-Oriented Space Research
DORIS	Doppler Orbitography and Radiolocation Integrated by Satellite
DOY	Day of Year
-E-	

ECF	Earth Centered Fixed
EGM96	Earth Gravity Model 1996
ellipsoid	A mathematical figure formed by revolving an ellipse about its minor axis (also termed an oblate spheroid). Two quantities define an ellipsoid: 1) the length of the semimajor axis, a, and 2) the flattening, f = (a - b)/a (where b is the length of the semiminor axis). The "inverse flattening" is defined as 1/f. "ellipsoid" is often used interchangeably with "reference ellipsoid". (See reference ellipsoid)
ENVISAT-1	Environmental Satellite 1
ephemerides	Plural of ephemeris
ephemeris	An orderly list of locations (positions) of a celestial object as a function of time. The locations can refer to past, present, or future (predicted) locations. GFO's NAVSPASUR (ZNSA) file consists of a list of its Keplerian orbital elements from which an ephemeris can be created. GFO's OODD file consists of a list of its geodetic postions (longitude, latitude, height above the ellipsoid) as a function of time. GFO's PODD and POE files consist of list of its Earth Centered Fixed positions (geocentric x,y,z) as a function of time.
ERM	Exact Repeat Mission
ERO	Exact Repeat Orbit
ERS-1, ERS-2	ESA Remote Sensing Satellite 1 and 2
ESA	European Space Agency (Franscati, Italy)
ESOC	European Space Operations Centre
ESRIN	European Space Research Institute
-G-	
GDR	Geophysical Data Record
GEM	Goddard Earth Model
geodetic height	The height above the reference ellipsoid, measured along the geodetic vertical at the observer's location on the earth.
geodetic vertical	The normal to the reference ellipsoid at the observer's location on the earth.
GEOSAT	Geodetic Satellite
GFO	GEOSAT Follow-On
GIM	Global Ionosphere Maps.
GIM_FL	Keyword pertaining to the final GIM product with a 72 hour lag.

GIM_ML	Keyword signifying that no GIM data was available and that JPL supplied the output from an ionospheric model.
GMT	Greenwich Mean Time (links to UTC time from NIST and USNO)
GPS	Global Positioning System (see IGS)
GSFC	Goddard Space Flight Center
-I-	
IGDR	Interim Geophysical Data Record. "Interim" refers to the fact that this data file is generated very soon after data aquistion so that interim values of some parameters (such as the orbit) must be used, until the full-precision values become available.
IGS	International GPS Service. Provider of GPS data
IRI95	International Reference Ionosphere 1995
ITOD	Inertial True of Date
-J-	
Jason-1	The follow-on satellite to TOPEX/Poseidon
JPL	Jet Propulsion Laboratory
-M-	
midframe	The midpoint (center) of an GDR Data Record, i.e. the point midway in time between the fifth and six samples of the high-rate data.
MOE	Medium Orbit Ephemeris. Created by GSFC.
MOESLR	MOE data obtained from SLR data.
MSS	Mean Sea-Surface
-N-	
N/A	Not Applicable
NASA	National Aeronautics and Space Administration
NAVO	Naval Oceanographic Office
NAVOCEANO	Naval Oceanographic Office
NAVSOC	Naval Satellite Operations Center (Pt. Mugu, CA)
NAVSPACECOM	Naval Space Command
NAVSPASUR	Naval Space Surveillance System (now NAVSPACECOM). For historical reasons the satellite orbital elements obtained from NAVSPASUR were referred to as "NAVSPASUR elements or files". NAVSPOC now provides these elements (see also ZNSA).
NAVSPOC	Naval Space Command Operations Center (Dahlgren, VA). Provides Keplerian orbital elements for satellites of interest to the Navy.

GDR	Navy Interim Geophysical Data Record (see IGDR)
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NOGAPS	Navy Operational Global Atmospheric Prediction System
NORAD	North American Aerospace Defense Command
Nvals	Number of Values

-O-

OODD	Operational Orbit Determination Data. Created by NAVSOC.
OOE	Operational Orbit Ephemeris
OOESLR	OOE data obtained from SLR data.
Orbit	Depending on the context this may refer to a satellite's 1) path in space, 2) ephemeris , or 3) altitude.
OSUMSS95	Ohio State University Mean Sea-Surface 1995

-P-

POC	Payload Operations Center
PODD	Precision Orbit Determination Data. Created NAVSOC.
PODPS	Precision Orbit Determination Production System
POE	Precision Orbit Ephemeris. Created by GSFC.
POESLR	POE data obtained from SLR data.

-R-

RA — Radar Altimeter

reference ellipsoid — An ellipsoid created/used for geodesic measurement purposes (i.e. locating or positioning points on the surface of the Earth).

In satellite geodesy, a reference ellipsoid can be thought of as a low order ("smooth") approximation to the shape of the Earth (or to the Earth's equipotential gravity surface which most closely matches mean sea-level), where the semimajor axis is taken to lie along the rotation axis of the Earth.

The table below lists the parameters of the reference ellipsoids used for several satellites:

Satellite	Semimajor Axis [meters]	Inverse Flattening (1/f)
ERS-1 , ERS-2	6378137.0	298.257
GFO	6378136.3	298.257
TOPEX/Poseidon	6378136.3	298.257

Click here for information on the TOPEX/Poseidon reference ellipsoid.

(See ellipsoid)

REV — Revolution

-S-

SDR — Sensor Data Record
- * Link to GFO SDR Header format
- * Link to GFO SDR Data Record format
- * Link to GFO SDR Data Record description

Seasat-A — Sea Satellite (link to Seasat page at JPL)

Sigma0 — Backscatter Coefficient

SLR — Satellite Laser Ranging

SSB — Sea State Bias

SSH — Sea-surface Height (relative to the reference ellipsoid)

SSHC — Sea-surface Height Corrected

SSHR — Sea-surface Height Residual (relative to a reference surface). An example of this type of residual would be "SSHR = SSHC - MSS".

SSHU — Sea-surface Height Uncorrected

STD — Standard Deviation

SWH — Significant Wave Height

SWS — Surface Wind Speed

-T-

TEC — Total Electron Content

TLE — Two Line Element. A list of Keplerian orbital elements formatted as two lines of alphanumeric text.

TOPEX — Ocean Topography Experiment

-U-

USNO — United States Naval Observatory

UTC — Universal Time Coordinated (links to UTC time from NIST and USNO)

-V-

VATT — Voltage Proportional to Attitude

-W-

WDBII — World Data Bank II. A one-minute resolution landmask based on the CIA World Vector Shoreline.

WS	Wind Speed
WSC	War Fighting Support Center
WVR	Water Vapor Radiometer
WVS	World Vector Shoreline
-Z-	
ZNSA	A set of Keplerian orbital elements from NAVSPOC (see also NAVSPASUR).

APPENDIX A : Computing Times of High-Rate Data

To compute the 10 high-rate times for any of the high-rate data (from timing information available in the GDR) proceed as follows:

Define the variables:

TIME_MID = time at the midframe of the data record
TIME_INC = time increment (separation) of high-rate data points
TIME_10HZ(I) = array of high-rate times (size=10)

Set their values:

TIME_MID = Time_Past_Epoch + Time_Past_Epoch_Continued * 1E-6

(Using fields 1 and 2 of the Data Record from section 2.3)

TIME_INC = Time_Shift_Midframe/4.5

This equation reduces to TIME_INC = 0.098 * 1E6 * $Ratio_{SDR}$ (see section 2.3.8))

```
DO I = 1,10

   TIME_10HZ(I) = TIME_MID + TIME_INC*(I-5.5)

ENDDO
```

APPENDIX B : GEOSAT Follow-On Web Links

1.0 GFO Home Pages

Navy
http://gfo.bmpcoe.org/gfo/default.htm

Navy SDR
http://gfo.bmpcoe.org/Gfo/Data_val/Cal_formats/sdr_format.htm

Navy NGDR
http://gfo.bmpcoe.org/Gfo/Data_val/Cal_formats/gdr_format.htm

Ball Aerospace

http://www.ball.com/aerospace/gfohome.html

NASA JPL Quicklook
http://msl.jpl.nasa.gov/QuickLooks/gfoQL.html

NASA WFF
http://gfo.wff.nasa.gov/

NOAA
http://ibis.grdl.noaa.gov/SAT/gdrs/gfo.html

2.0 GFO Applications

CCAR GFO Precision Orbit Determination
http://www-ccar.Colorado.EDU/research/gps/html/gps_gfo.html

NASA GFO Satellite Laser Ranging
http://www-csbe.atsc.allied.com/slr/gfo.htm

University of Bern CODE GIM Ionosphere Maps
http://www.cx.unibe.ch/aiub/ionosphere.html

NRL Real Time Ocean Environment
http://www7300.nrlssc.navy.mil/altimetry/

OSU GFO Data and Orbit Verification (UNDER CONSTRUCTION)
http://www.geodesy.eng.ohio-state.edu/gfo.html

3.0 GFO Related Sites

NASA GSFC /OSU /NIMA GEOSAT Orbit Error Predictions with Different Gravity Models
http://cddisa.gsfc.nasa.gov/926/egm96/orberr.html

APPENDIX C : Equator Crossing Table

eqc_tabl_utc.txt

Email comments or suggestions to John Lillibridge: John.Lillibridge@noaa.gov