SDR FORMAT, CONTENTS, AND ALGORITHMS

This section provides an SDR Data Format Table that lists each parameter in the SDR, an SDR Parameter Table that defines each parameter, an SDR Algorithm Table that describes the algorithm used to produce each parameter, and tables of the Altimeter Constants and the Radiometer Algorithm and Constants.

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1.0 SDR Data Format Table

Each SDR includes a header and multiple data records.

The file name has the form: "sdryyddd_hh_mm_ss_xxxxx.dat" where xxxxx = number_of_records.

The first line in the file is ASCII text.

The Header includes an ASCII string (42 bytes long) followed by a binary portion (744 bytes long).

Each binary Data Record is 256 bytes long. Two Quality Words define the status of the data. The two RA Status words and known flag problems are described under the Altimeter File Description

1.1 SDR Data Record Format

The Gate Index contains the gate index of all ten RA frames. The index is 3 bits in length with the first frame's index starting at bit 0 (rightmost), 2nd frame starting bit position 3, etc.

Item	Parameter	Units	Bytes/Type	Limits/Range
1	Frame UTC	Seconds	8 - Dbl	0-86400.0
2	RA Status Mode I	Bit Pattern	2 - Int	N/A
3	RA Status Mode II	Bit Pattern	2 - Int	N/A
4	RA Quality Test Results	Bit Pattern	4 - Int	N/A
5	WVR Quality Test Results	Bit Pattern	4 - Int	N/A
6	Gate Index	Bit Pattern	4 - Uns Int	N/A
7	H(1)	mm	8 - Dbl	TBD
8	H(2)	mm	8 - Dbl	TBD
..	..	..	..	…
16	H(10)	mm	8 - Dbl	TBD
17	H_Rate	m/sec	4 - Flt	TBD
18	Height Word STD	mm	4 - Flt	TBD
19	FM Crosstalk	mm	4 - Flt	TBD
20	SWH(1)	m	4 - Flt	0-20
21	SWH(2)	m	4 - Flt	0-20
..	..	..	..	….
29	SWH(10)	m	4 - Flt	0-20
30	SWH STD	m	4 - Flt	TBD
31	SWH Bias (Off-nadir, SWH)	m	4 - Flt	TBD
32	AGC(1)	dB	4 - Flt	0-64

33	AGC(2)	dB	4 - Flt	0-64
..	..	..	..	….
41	AGC(10)	dB	4 - Flt	0-64
42	AGC STD	dB	4 - Flt	0-64
43	AGC Temperature Correction	dB	4 - Flt	TBD
44	Delta AGC Height	dB	4 - Flt	TBD
45	AGC Correction for Attitude	dB	4 - Flt	TBD
46	Attitude Wave Height Bias	mm	4 - Flt	TBD
47	Off-nadir Angle	deg	4 - Flt	0-5
48	Backscatter Coefficient	dB	4 - Flt	TBD
49	Path Delay	cm	4 - Flt	TBD
50	22 GHz Brightness Temp	K	4 - Flt	TBD
51	37 GHz Brightness Temp	K	4 - Flt	TBD
52	Average VATT	volt	4 - Flt	0-2
53	Fitted VATT	volt	4 - Flt	0-2
54	Receiver Temperature	deg C	4 - Flt	TBD

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1.2 Quality Word Format

Quality Word #1

Data Element Identifier (bit)	Data Description	Type	Units of Measure	Limits/ Range	Size (bits)
31-MSB	RA data frame 1 missing	int	N/A	0,1	1
30	RA data frame 2 missing	int	N/A	0,1	1
29	RA data frame 3 missing	int	N/A	0,1	1
28	RA data frame 4 missing	int	N/A	0,1	1
27	RA data frame 5 missing	int	N/A	0,1	1
26	RA data frame 6 missing	int	N/A	0,1	1
25	RA data frame 7 missing	int	N/A	0,1	1
24	RA data frame 8 missing	int	N/A	0,1	1
23	RA data frame 9 missing	int	N/A	0,1	1
22	RA data frame 10 missing	int	N/A	0,1	1
21	height STD error	int	N/A	0,1	1
20	AGC STD error	int	N/A	0,1	1
19	SWH STD error	int	N/A	0,1	1
18	off nadir error	int	N/A	0,1	1
17	trs 1 temperature error	int	N/A	0,1	1
16	trs 2 temperature error	int	N/A	0,1	1
15	rcvr 1 temperature error	int	N/A	0,1	1
14	rcvr 2 temperature error	int	N/A	0,1	1
13	dfb temperature error	int	N/A	0,1	1
12	hgt bounds error	int	N/A	0,1	1
11	AGC bounds error	int	N/A	0,1	1

10	SWH bounds error	int	N/A	0,1	1
9	rate error	int	N/A	0,1	1
8	spare	int	N/A	0	1
7	no smoothed VATT	int	N/A	0,1	1
6	VATT estimate error	int	N/A	0,1	1
5	rcvr temperature error	int	N/A	0,1	1
4	backscatter error	int	N/A	0,1	1
3	RA not in fine track	int	N/A	0,1	1
2	record is zero filled	int	N/A	0,1	1
1	spare	int	N/A	0	1
0-LSB	spare	int	N/A	0	1

Quality Word #2

Note: A value of 1 in bit 31 signifies either a configuration change, the RA is not in the fine track mode, or an error has occurred.

Data Element Identifier	Data Description	Type	Units of Measure	Limits/ Range	Size (bits)
31-MSB	RA configuration changed	int	N/A	0,1	1
30	0 - RA #1; 1 - RA #2	int	N/A	0,1	1
29	0 - SSPA #1; 1 - SSPA #2	int	N/A	0,1	1
28	spare	int	N/A	0	1
27	spare	int	N/A	0	1
26	spare	int	N/A	0	1
25	spare	int	N/A	0	1
24	spare	int	N/A	0	1
23	spare	int	N/A	0	1
22	spare	int	N/A	0	1
21	spare	int	N/A	0	1
20	spare	int	N/A	0	1
19	spare	int	N/A	0	1
18	spare	int	N/A	0	1
17	spare	int	N/A	0	1
16	spare	int	N/A	0	1
15	22 GHz temp out of bounds	int	N/A	0,1	1
14	37 GHz temp out of bounds	int	N/A	0,1	1
13	possible rain	int	N/A	0,1	1
12	probable rain	int	N/A	0,1	1
11	land contamination	int	N/A	0,1	1
10	sun glint	int	N/A	0,1	1
9	WVR latch up	int	N/A	0,1	1
8	WVR interpolated	int	N/A	0,1	1
7	WVR data missing	int	N/A	0,1	1
6	spare	int	N/A	0	1
5	spare	int	N/A	0	1
4	spare	int	N/A	0	1

3	spare	int	N/A	0	1
2	spare	int	N/A	0	1
1	spare	int	N/A	0	1
0-LSB	spare	int	N/A	0	1

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1.3 SDR Header Format

The Generic File Header is a '\n' terminated ASCII string. All fields after the Generic File Header are binary.
Note: Item 2 (Filename) appears in the form "sdryydddhhmmssxxxxx.dat" where xxxxx = number_of_records.

Item	Parameter	Units	Bytes/Type	Limits/Range
1	Generic File Header	N/A	42 - Char[]	N/A
2	Filename	Filename	40 - Char[]	Legal UNIX name
3	Number of SDR Records	Record number	4 - Int	0-62449
4	Start Time Year (time of 1st RA data sample)	Year	4 - Int	00-99
5	Start Time Day of Year (time of 1st RA data sample)	Day of Year	4 - Int	1-366
6	Start Time Hour (time of 1st RA data sample)	Hour	4 - Int	0-23
7	Start Time Minutes (time of 1st RA data sample)	Minutes	4 - Int	0-59
8	Start Time Seconds (time of 1st RA data sample)	Seconds	4 - Int	0-59
9	SDR Start UTC	Seconds	8-Dbl	0-86400.0
10	SDR Stop UTC	Seconds	8 - Dbl	0-86400.0
11	Number of CAL Mode Ops	N/A	4 - Int	0-15
12	Height Calibration Bias	mm	4 - Flt	0.0
13	AGC Calibration Bias	dB	4 - Flt	0.0
14	Waveform Sampler Gate Calibration (1-64)	0.0001 (no units)	256 - Flt	0-2
15	Waveform sampler Gate Calibration from Cal Table (1-64)	0.0001 (no units)	256 - Flt	0-2
16	Altitude Bias (initial)	km	4 - Flt	E3
17	Altitude Bias based on S/C CG	mm	4 - Flt	0-10E4
18	Time Bias (Initial)	Seconds	4 - Flt	+/-0.1
19	AGC Bias (Initial)	dB	4 - Flt	TBD
20	UTC Year (scc file time for VTCW to UTC conversion)	years	4 - Int	00-99
21	UTC Day (scc file time for VTCW to UTC conversion)	days	4 - Int	1-366
22	PAD	N/A	4 - Char	N/A
23	UTC Seconds (scc file time for VTCW to UTC conversion)	seconds	8 - Dbl	0-86400.0

24	VTCW Value	ticks	8 - Dbl	N/A
25	Ratio	sec per VTCW tick	8 - Dbl	N/A
26	Velocity of Light	m/sec	8- Dbl	2.99792458E8
27	AGC Limit Upper Bound	dB	4 - Flt	0-64
28	AGC Limit Lower Bound	dB	4 - Flt	0-64
29	H Limit Upper Bound	km	4 - Flt	825.0
30	H Limit Lower Bound	km	4 - Flt	775.0
31	Hgt Rate Limit	m/sec	4-Flt	40.0
32	Off- Nadir Upper Bound	deg	4 - Flt	0-0.8
33	SWH Limit Upper Bound	m	4 - Flt	0-20
34	SWH Limit Lower Bound	m	4 - Flt	0-20
35	Rcvr Temp Upper Bound	deg C	4 - Flt	50.0
36	Rcvr Temp Lower Bound	deg C	4 - Flt	10.0
37	Rad Temp 22 GHz Lower Limit	K	2 - Int	105 (TOPEX)
38	Rad Temp 22 GHz Upper Limit	K	2 - Int	240 (TOPEX)
39	Rad Temp 37 GHz Lower Limit	K	2 - Int	130 (TOPEX)
40	Rad Temp 37 GHz Upper Limit	K	2 - Int	260 (TOPEX)
41	Possible Rain Lower Limit (37 GHz)	K	2 - Int	200 (TOPEX)
42	Possible Rain Upper Limit (37 GHz)	K	2 - Int	230 (TOPEX)
43	Probable Rain Limits (37 GHz) Lower Limit	K	2 - Int	230 (TOPEX)
44	Probable Rain Limits (37 GHz) Upper Limit	K	2 - Int	260 (TOPEX)
45	Land Contamination - Lower Limit	K	2 - Int	260
46	Sun Glint - Lower Limit	K	2 - Int	300
47	AGC STD Reason Limit	dB	4 - Flt	TBD
48	Height Word STD Reason Limit	mm	4 - Flt	TBD
49	Height Rate STD Reason Limit	m/sec	4 - Flt	TBD
50	SWH STD Reason Limit	m	4 - Flt	TBD
51	Rcvr Cal Temp	deg C	4- Flt	TBD

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2.0 SDR Parameter Definition Table

Item	Parameter	Definition
2	RA Status Mode I	See RA Status Mode I Table.
3	RA Stat. Mode II	See RA Status Mode II Table.
4	Quality Word I	See Quality Word I Table.
5	Quality Word II	See Quality Word II Table.
6	Gate Index	The Gate Index contains the gate index of all 10 RA frames
7 - 16	H(1) - H(10)	Sea surface height determined on-board the spacecraft at a 10 per second rate (no corrections).
17	H_Rate	Height rate averaged at 1 per second rate (no corrections).

18	Height Word STD	Standard deviation from a linear fit to the 10 per second sea height values. Only non-rejected values are used with a minimum of 6 points required.
19	FM Crosstalk	The computed FM Crosstalk correction for the height data - see the CalValDR Algorithm Table.
20-29	SWH(1)-SWH(10)	Significant Wave Height determined on board the spacecraft at a 10 per second rate (no corrections).
30	SWH STD	Standard deviation of the 10 per second SWH values.
31	SWH Bias	The computed attitude/SWH correction for the SWH - see the CalValDR Algoritm Table.
32-41	AGC(1) - AGC(10)	Automatic Gain Control determined on board the spacecraft at a 10 per second rate.
42	AGC STD	Standard deviation of the 10 per second automatic gain control values. Only non-rejected values with a minimum of 6 good points required.
43	AGC Temperature Correction	The measured temperature of the altimeter receiver is used to derive this correction to the AGC for receiver gain changes.
44	Delta AGC Height	Computed delta height correction for the AGC - see the CalValDR Algorithm Table.
45	AGC Correction for Attitude	Computed correction for the AGC to account for satellite off nadir angle. - see the CalValDR Algorithm Table.
46	Attitude Wave Height Bias	The computed correction for the height to correct for the attitude/SWH effect. - see the CalValDR Algorithm Table.
47	Off-nadir Angle	The altimeter's determination of satellite off nadir angle based on VATT. - see the CalValDR Algorithm Table.
48	Backscatter Coefficient	Backscatter coefficient computed from AGC, applying corrections for satellite height, receiver temperature, attitude/SWH effect, onboard calibration, and prelaunch calibration. - see the CalValDR Algorithm Table.
49	Path Delay	Altimeter path delay as determined by the Water Vapor Radiometer using Ruf's Algorithm. - see the CalValDR Algorithm Table.
50	22 GHz Brightness Temperature	Brightness temperature as measured by the Water Vapor Radiometer (no corrections).
51	37 GHz Brightness Temperature	Brightness temperature as determined by the Water Vapor Radiometer (no corrections).
52	Average VATT	Voltage proportional to ATTitude - see the CalValDR Algorithm Table.
53	Fitted VATT	Fit to the VATT - see the SDR Algorithm Table and the CAL/VAL/QC Plan.
54	Receiver Temperature	The measured receiver temperature that is used to correct the AGC value.

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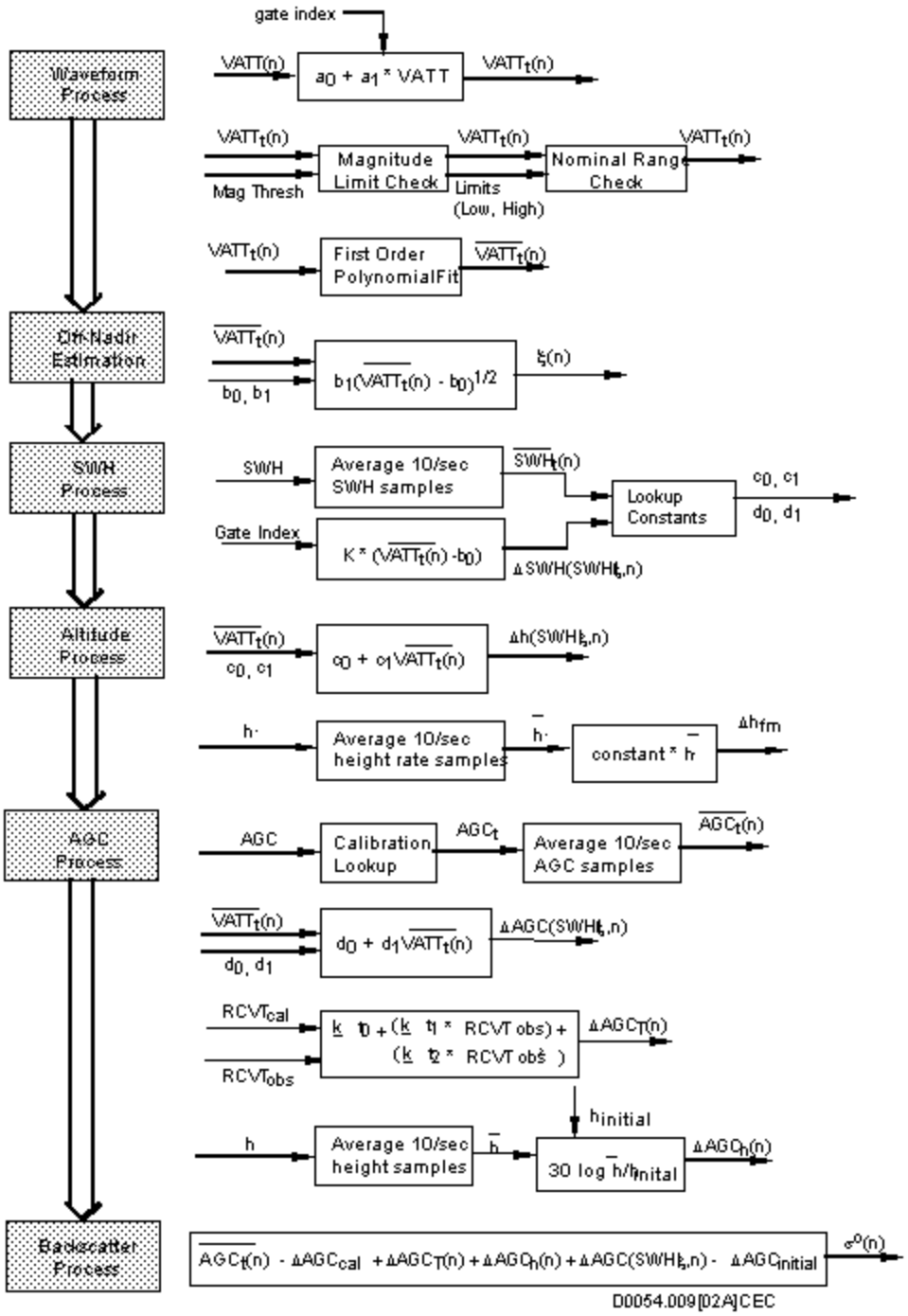
3.0 SDR Algorithm Table

This table describes the processing algorithms that have been applied to produce the corrections in the SDR data fields. The Calibration Constants (constants listed in each algorithm) are in ASCII files external to the SDR program. The files are included here after this table. The Cal/Val/QC Plan describes the updating of the Calibration Constants based on prelaunch and on-orbit data. The limits are included here after the constants table.



Algorithm	Definition
Algo 1: Fitted VATT	The altimeter H, SWH, and AGC measurements must be corrected to account for the impact of spacecraft attitude control error. The spacecraft off-nadir attitude excursions cause the slope of the plateau region of the return waveform to decrease. The altimeter detects this change in slope and generates a parameter named Voltage proportional to ATTitude (VATT) that is the primary input to these corrections. The altimeter outputs raw VATT samples at a 10.2 Hz rate. This algorithm averages and then edits the values and then performs a first order polynomial fit to provide a smooth VATT sample at a nominal 1 Hz rate (0.98 sec interval) for later corrections.
Step 1 - VATT Average	If the altimeter data frame is GOOD, the 10 10/sec VATT samples are averaged to produce one VATT[i] for the ith data frame. The resulting Average VATT is in the SDR record produced.

Step 2 - Gate Index Correction	The VATT[i] is next normalized to account for the gate index in use. The equation is: VATT[i] = a0[gate_index] + a1[gate_index]*VATT[i]. The normalized VATT[i] is not in the SDR.
Step 3 - VATT[i] Rate (Magnitude) Test	The difference between the current and proceeding VATT[i] is formed and if the magnitude exceeds a preset threshold, the current sample is not passed to the fit routine. This test discards samples caused by land, rain cells, etc. that cause an abrupt change in the waveform. The threshold is ra_limits.thr(0).
Step 4 - Nominal Range Test	A test is now applied to reject all VATT[i] samples that do not fall within a nominal range (ra_limits.vatt_low to ra_limits.vatt_high. Samples that fall below the lower limit are indicative of a specular or near specular ocean return.
Step 5 - Height Rate Test	A test is now applied to reject VATT[i] samples when the measured height rate is below a threshold (ra_limits.hgt_rate_limit, indicating that the measurement is unreliable due to lack of digital filter bank averaging. (NOT DONE ON GFO)
Step 6 - Track Mask Test	A test is now applied to reject VATT[i] samples when the altimeter mode does not satisfy "fine track" criterion (320 MHz chirp, low variability, track algo, AGC from AGC gate, EML height error not exceeded, precision EML tracking). These masks are hard wired in the code. If the mode does not satisfy the mask, all records are zero filled. (NOT DONE ON GFO)
Step 7 - Least Squares Fit	A first order polynomial fit routine (from the GEOSAT ICD) is now applied to the sample points that remain in order to determine Fitted_VATT[i] for each 1 sec data frame. The fitted VATT is written to the SDR record produced. The fit routine operates on a sliding 1 minute data span. The nominal case is to estimate a central value from data over +/- 30 seconds (62 VATT[i] values). Points that deviate from the linear fit by more than 3 times the standard deviation about the fit are rejected and the remaining points are fitted again. If the number of points falls below the prescribed count (15), but above 4, the fit is used and a quality flag is set. If the number of points to fit falls below 4, the fit is not used and an extrapolation using the most recent fit constants is performed.
.	.
Algo 2: Off-Nadir Angle	The Fitted_VATT[i] is used to estimate the satellite off-nadir angle at a 1 per second rate using the algorithm: off_nadir_angle[i]= b1*SQRT(Fitted_VATT[i] - b0). The resulting off nadir angle is in the CalValDR produced. The constants are ra_constants.b0 and ra_constants.b1. If noise causes the argument of the SQRT to be negative, the off nadir angle for that frame is set to zero.
.	.
Algo 3: SWH bias (Correction for Attitude, SWH)	The Fitted_VATT[i] is used to derive a one per second satellite off-nadir angle correction to the altimeter SWH measurement. The algorithm for the SWH correction is given by: SWH_bias_attitude= K[gate_index]*(Fitted_VATT[i] - b0). The resulting SWH bias correction is in the CalValDR produced. The constants are ra_constants.b0 and ra_constants.k[gate_index]. If (Fitted_VATT[i] - b0) = 0, then SWH_bias_attitude=0.
.	.
Algo 4: Height Correction for Attitude and Sea State (Attitude Waveht Bias)	The Fitted_VATT[i] and SWH are used to derive a one per second correction to the altimeter height measurement. The algorithm for the Height correction is given by: H_bias= c0[gate_index][Corrected_SWH] +Fitted_VATT[i]*c1[gate_index][Corrected_SWH]. The resulting H bias correction is in the CalValDR produced. The Corrected_SWH is determined from the SWH by first averaging the 10 10/sec SWH values and then correcting the ave_SWH by the SWH_bias from step 3 above.
.	.
Algo 5: AGC Correction for Attitude and Sea State	The Fitted_VATT[i] and SWH are used to derive a one per second correction to the altimeter SWH measurement. The algorithm for the Height correction is given by: AGC_bias= d0[gate_index][Corrected_SWH] +Fitted_VATT[i]*d1[gate_index][Corrected_SWH] The resulting AGC bias correction is in the CalValDR produced.
.	.

Algo 6: Height Correction for FM Crosstalk	A one second average of the altimeter 10/sec height rate measurements is used to derive a correction to the height measurement for the range/Doppler crosstalk effect of linear FM waveforms. The algorithm for the height correction is given by the equation: H_crosstalk_bias= (46.9/107.4)*ave_height_rate. The resulting H_crosstalk_ bias correction is in the SDR record produced.
.	.
Algo 7: AGC Correction for Height Variation (Delta AGC Height)	A one second average of the altimeter 10/sec height measurements is used to derive a correction to the AGC for the variation in height. The algorithm for the correction is given by: AGC_height_bias= 30 log (ave_height/initial_height). The resulting AGC_height_ bias correction is in the SDR record produced.
.	.
Algo 8: AGC Correction for Receiver Temp	The measured temperature of the altimeter receiver is used to derive a correction to the AGC for receiver gain changes. The algorithm for the correction is given by: AGC_temperature_correction= k_t0+(k_t1*Rcvr_T)+(k_t2*Rcvr_T**2). The resulting correction: AGC Temperature_Correction is in the SDR record produced. The default receiver temperature is defined in the ra_constants table.
.	.
Algo 9: AGC Calibration Lookup	A long term AGC drift correction, AGC_cal_bias, is derived by off-line analysis of altimeter calibrate mode data. The correction is included in the SDR header.
.	.
Algo 10: AGC Initial Offset	An initial offset is selected during ground testing to convert AGC measurements to backscatter coefficient measurements. The correction is included in the SDR header.
.	.
Algo 11: ave_AGC	A frame of 10 10/sec AGC values is averaged to produce ave_AGC at a one per second rate.
.	.
Algo 12: Backscattr Coefficient	The backscatter coefficient is computed using the algorithm: Backscatter coefficient= ave_AGC - AGC_cal_bias + AGC_temperature_correction + AGC_height_bias + AGC_attitude_bias - AGC_initial_offset and written into the CalValDR produced.

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3.1 Altimeter Constants

Note that there are 4 different altimeter configurations: ra1/sspa1, ra1/sspa2, ra2/sspa1, and ra2/sspa2. The pre-launch constants for all four configurations are set as noted in the table below.

		SDR Correction Constants					
Gate Index	H-1/3 Range	c0	c1	d0	d1	a0	a1
1	<.625	10.45463	-6.45929	-6.94208	6.33180		
1	.625 to .9375	11.00605	-6.80099	-6.95484	6.34192	-0.00076	1.00043
1	>.9375	11.85432	-7.31417	-6.94917	6.33611		
2	<1.79688	13.42933	-8.31773	-6.92383	6.32317		
2	1.79688 to 2.42188	16.33199	-10.11647	-6.91872	6.31642	-0.00596	1.00333

2	>2.42188	19.62077	-12.17858	-6.93596	6.32775		
3	<4.21875	27.17765	-16.94702	-6.85119	6.27887		
3	4.21875 to 5.39063	32.68521	-20.48797	-6.86089	6.28241	-0.02259	1.01274
3	>5.39063	38.76554	-24.40598	-6.88596	6.29777		
4	<8.98438	51.40449	-32.83095	-6.67721	6.17054		
4	8.98438 to 11.5625	64.14288	-41.48602	-6.71310	6.18890	-0.06190	1.03602
4	>11.5625	77.35845	-50.72013	-6.75978	6.21537		
5	<17.10938	97.06467	-66.76093	-6.45979	6.01777		
5	>=17.10938	113.59410	-79.80987	-6.50140	6.03712	-0.12730	1.07908

b0 = 1.1419
b1 = 0.8747

number_VATT_pt = 62
good_pt_thres = 62
min_VATT_samples = 30

h_initial = -0.019893 mm

AGC_initial = ~~33.0 dB~~ ***31.86 dB*** ***This parameter changed 25 Feb 00***

k = { 0.0 0.0 0.0 0.0 0.0}

default_recv_temp = 30.0

g0 = 46.38069
g1 = 107.4

trs_1_coeff = 0.2
trs_2_coeff = 0.2

recv1_coeff = 0.2
recv2_coeff = 0.2

dfb_coeff = 0.2

recv_1 k_t0 = ~~3.6191~~ ***-5.5301*** ***Note: These parameters were changed on 25 Feb 00***
recv_1 k_t1 = ~~-0.0865~~ ***0.1323*** ***for both pdp_ra1_ssp a1 and pdp_ra1_ssp a2***
recv_1 k_t2 = ~~0.0~~ ***0.0***

recv_1 cal_temp = 41.8

recv_2 k_t0 = 1.8282
recv_2 k_t1 = -0.0436
recv_2 k_t2 = 0.0

recv_2 cal_temp = 41.9

Altimeter limits table ----------

Note: The format of the data is very critical. There must be a space between each label or number.

For example:
pd_a0 = 123.45 is correct pd_a0=123.4 is incorrect and will be ignored

Document Last Changed: June 12, 1998, Changed by: Ball

agc_upper_bound = 64.0
agc_lower_bound = 0.1

hgt_upper_bound = 825.0 km
hgt_lower_bound = 775.0 km

off_nadir_upper_bound = 0.8

swh_lower_bound = 0.01 m
swh_upper_bound = 20.00 m

rcvr_temp_upper_bound = 50.0
rcvr_temp_lower_bound = 10.0

vatt_low = 1.0
vatt_high = 2.2

agc_reason = 10.0

hgt_word_reason = 50.0
hgt_rate_reason = 200.0

swh_reason = 5.0

rcv_cal_temp = 20.0

trs_1_low_limit = 10.0
trs_1_high_limit = 50.0
trs_2_low_limit = 10.0
trs_2_high_limit = 50.0

recv_temp_1_low_limit = 10.0
recv_temp_1_high_limit = 50.0
recv_temp_2_low_limit = 10.0
recv_temp_2_high_limit = 50.0

dfb_temp_low_limit = 10.0
dfb_temp_high_limit = 50.0

thr0 = 0.15

hgt_rate_limit = 40.0

range_correct_low = { 0.62500 1.79688 4.21875 8.98438 17.10938 }
range_correct_high = { 0.93750 2.42188 5.39063 11.5625 17.10938 }

bck_scat_low = 7.0
bck_scat_high = 14.0

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3.2 Radiometer Algorithm and Constants

GEOSAT Follow-On Water Vapor Radiometer
Path Delay Retrieval Algorithm

Christopher S. Ruf
The Pennsylvania State University
Version 16 May 1995

BACKGROUND:

The wet tropospheric path delay correction to the altimeter range measurement (henceforth referred to as the path delay) can be expressed to first order as a linear combination of the WVR brightness temperatures

(1) PD = c0_global + c1_global*TB22 + c2_global*TB37

where PD is the path delay and TBff is the brightness temperature at frequency ff. The retrieval coefficients ci,global are found by regression analysis using a large set of radiosonde profiles of the atmosphere. The residual error in this regression fit is improved by stratifying the database into subsets of the path delay and the cloud liquid water content. The cloud liquid water content, LIQ, is also estimated by a linear combination of TBs

(2) LIQ = c0_liq + c1_liq*TB22 + c2_liq*TB37

where the retrieval coefficients ci,liq are found by regression analysis of a large ensemble of radiosonde profiles, similar to the above coefficients. The retrieval coefficients can be expanded into sub-groups appropriate for different ranges of the path delay and liquid. The stratified path delay retrieval then becomes

(3) PD2 = c0(PD,LIQ) + c1(PD,LIQ)*TB22 + c2(PD,LIQ)*TB37

where PD is a first guess at the path delay (made by using (1) with coefficients ci_global derived from a global distribution of path delays), LIQ is the liquid water estimate made using (2), and the coefficients ci(j,k) are derived from appropriate subsets of distributions of the path delay and liquid water content. The residual error in this stratified regression fit can be further improved slightly, and the dependence of the bias in the fit on ocean surface wind speed can be reduced significantly, by removing the windspeed dependent bias

(4) PD3 = PD2 + ëPD(WS)

where ëPD is a tabulated list of PD bias corrections vs. windspeed, WS. WS is determined from å0, the normalized radar cross section measured by the radar altimeter via a look-up table.

SOFTWARE IMPLEMENTATION:

A number of tables of retrieval coefficients are needed in order to implement this algorithm. The values for ci_global and ci_liq and for ci(j,k) are given below. The index i = 0,1,2 represents the offset, TB22, and TB37 coefficients, respectively. The index j = 1,2,3,4 represents the path delay stratification, where

j = 1 for 0 <= PD < 10 cm
j = 2 for 10 <= PD < 20 cm
j = 3 for 20 <= PD < 30 cm
j = 4 for 30 <= PD cm

and the index k = 1 or 2 represents the liquid stratification, where

k = 1 for 0 <= LIQ < 100 microns (i.e. clear skies)
k = 2 for 100 <= LIQ microns (i.e. cloudy skies)

A table of windspeed dependent path delay bias corrections, ëPD in (4), is also given below. This table has 7 entries, for the windspeed ranges

1 for 0 <= WS < 7 m/s
2 for 7 <= WS < 10 m/s
3 for 10 <= WS < 13 m/s
4 for 13 <= WS < 16 m/s
5 for 16 <= WS < 19 m/s
6 for 19 <= WS < 22 m/s

7 for 22 <= WS

Finally, a look-up table relating altimeter å0 to WS is provided. This table is extracted from Witter and Chelton, J. Geophys. Res., 96, 8853-8860, 1991. In using this look-up table, extrapolation beyond the values listed for å0 is as follows: for å0>19.6 dB assume WS=0 and for å0<7.0 dB assume WS>=22 m/s. Weighted averaging of the path delay will be used to smooth the behavior of PD2 at the transition points in the stratification with respect to path delay. No weighted averaging is used for the cloud liquid stratification or for the windspeed dependent bias correction. Let PD be the value retrieved by (1) and LIQ be the value retrieved by (2). There are two different cases to consider in the weighted average. If either PD >= 35 cm or PD < 5 cm, then the value for PD2 given by (3) is exact. Otherwise, define PDL as the odd multiple of 5 below or equal to PD and PDU as (PDL + 10). A weighted average of the PD2 values returned by (3) using the PDL and the PDU stratification levels is used, as defined by

(5) PD2 = PD2L + ((PD2U-PD2L)/10)*(PD - PDL)

where PD2L = PD2(PDL,LIQ) and PD2U = PD2(PDU,LIQ). Finally, the windspeed dependent bias correction is made, according to (4), and PD3 is the final path delay correction.

TABLES:

The following tables list the values needed to implement this algorithm.

RESIDUAL ERROR ANALYSIS:

The quality of fit between this PD retrieval and the true PD is determined using an ensemble of 29,172 radiosonde atmospheric profiles from 28 open ocean launch sites distributed over the globe during 1992-1994. The RMS difference between the retrieved and true PD, assuming no noise in the TBs or in å0, is 0.64 cm. This is the intrinsic error in the algorithm. The RMS error, assuming realistic errors of +/-1.0 K in the TBs and +/-0.5 dB in å0, is 0.77 cm.

GFO WVR WET PATH DELAY RETRIEVAL ALGORITHM COEFFICIENTS:

Table 1. Global and stratified PD and Liquid from TB

Bin	c0	c1	c2
_global	-43.513	0.422	-0.090
_liq	-2271.387	-5.980	20.831
0<=PD<10; LIQ<100	-25.939	0.281	-0.059
10<=PD<20; LIQ<100	-53.544	0.321	0.082
20<=PD<30; LIQ<100	-63.882	0.381	0.081
30<=PD; LIQ<100	-49.351	0.226	0.193
0<=PD<10; LIQ>=100	-12.147	0.246	-0.111
10<=PD<20; LIQ>=100	-32.252	0.413	-0.151
20<=PD<30; LIQ>=100	-47.306	0.474	-0.128
30<=PD; LIQ>=100	-43.773	0.443	-0.106

Table 2. Wind speed dependent wet path delay retrieval bias corrections

Bin (m/s)	0-7	7-10	10-13	13-16	16-19	19-22	>22
Bias (cm)	0.22850	0.03592	-0.38714	-0.81554	-1.18394	-1.35222	-2.07217

Table 3. Modified Chelton-Wentz altimeter RCS vs. wind

sig0 (dB)	windspeed (m/s)

7.0	21.373
7.2	20.781
7.4	20.189
7.6	19.579
7.8	18.958
8.0	18.321
8.2	17.662
8.4	16.979
8.6	16.276
8.8	15.555
9.0	14.821
9.2	14.075
9.4	13.316
9.6	12.545
9.8	11.763
10.0	10.970
10.2	10.169
10.4	9.361
10.6	8.546
10.8	7.739
11.0	6.975
11.2	6.279
11.4	5.642
11.6	5.051
11.8	4.509
12.0	4.021
12.2	3.582
12.4	3.196
12.6	2.871
12.8	2.595
13.0	2.342
13.2	2.113
13.4	1.927
13.6	1.777
13.8	1.641
14.0	1.505
14.2	1.370
14.4	1.238
14.6	1.120
14.8	1.031
15.0	0.970
15.2	0.925
15.4	0.883
15.6	0.842
15.8	0.800
16.0	0.759

16.2	0.718
16.4	0.676
16.6	0.635
16.8	0.593
17.0	0.552
17.2	0.510
17.4	0.469
17.6	0.427
17.8	0.385
18.0	0.344
18.2	0.302
18.4	0.261
18.6	0.219
18.8	0.177
19.0	0.136
19.2	0.094
19.4	0.053
19.6	0.012

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