CALIPSO Lidar Level 0 Data Description Document
Version 1.00

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Introduction

The Lidar Level 0 (L0) data product translates a matched set of three 90-minute (full orbit) L0 binary files into a single HDF file containing the lidar measurements and health and status data from all three channels; 532 nm parallel, 532 nm perpendicular, and 1064 nm.

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Additional Documentation

- CALIPSO Data Management Team: CALIPSO Data Products Catalog, PC-SCI-503, Release 5.00.
- Hostetler, C. A., Z. Liu, J. Reagan, M. A. Vaughan, D. M., Winker, M. Osborn, W. A. Hunt, K. A. Powell, and C. Trepte, 2006: CALIOP Algorithm Theoretical Basis Document: Calibration and Level 1 Data Products, PC-SCI-201.01, https://ntrs.nasa.gov/citations/20250006623.

Scientific Data Sets: Measurement Altitudes

Lidar_Data_Altitudes

Units: km

Format: Float_32

Description: Altitudes (above mean sea level) that specify the vertical midpoints of the 583 range bins in the profile measurements downlinked from the CALIPSO satellite.

Region_6_Altitude

Region_5_Altitude

Region_4_Altitude

Region_3_Altitude

Region_2_Altitude

Region_1_Altitude

Units: km

Format: Float_32

Description: Region 1-6 altitude ranges. The first element is the altitude top and the second is the altitude base.

Region_5_Altitude_Index

Region_4_Altitude_Index

Region_3_Altitude_Index

Region_2_Altitude_Index

Region_1_Altitude_Index

Units: No Units

Format: UInt_16

Description: Region 1-5 altitude index ranges. The first element is the altitude top index and the second is the altitude base index.

Range_To_Mean_Sea_Level

Units: km

Format: Float_32

Description: Satellite altitude above mean sea level.

Backscatter_Start_Altitude

Units: km

Format: Float_32

Description: The altitude above mean sea level at which the backscatter region begins.

Scientific Data Sets: Time and Position

Profile_Time

Units: TAI seconds

Format: Float_64

Valid Range: 4.203E8, 9.623E8

Description: Reports the International Atomic Time (TAI) in elapsed seconds from January 1, 1993.

Profile_UTC_Time

Units: yymmdd.ffffffff

Format: Float_64

Valid Range: 60428.0…230701.0

Description: Reports the Coordinated Universal Time (UTC); format = yymmdd.ffffffff, where yy is a two digit data acquisition year number (06 to 23), mm is a month number (01 to 12), dd is a day number (1 to 31), and ffffffff is the elapsed fraction of the data acquisition day.

Day_Night_Flag

Units: No Units

Format: Int_8

Valid Range: 0, 1

Range Value: 0 = day; 1 = night

Description: As CALIPSO approaches the terminator, the lidar is automatically reconfigured to adapt to changing lighting conditions that directly impact signal-to-noise (SNR) levels. These changes occur at Sun-Earth-Satellite (SES) angles of 95° (day to night) and 265° (night to day), corresponding to changes in lighting conditions at an altitude of ~24 km above mean sea level. 0 indicates daytime conditions, 1 indicates nighttime.

Profile_ID

Units: No Units

Format: Int_32

Valid Range: 1,228630

Description: Unique profile identifier generated sequentially for each single-shot profile record. Profile IDs are unique within each granule but not unique over multiple granules.

Latitude

Units: degrees_north

Format: Float_32

Valid Range: -90.0, 90.0

Fill Value: -9999.0

Description: Geodetic latitude of the laser footprint on the Earth's surface.

Longitude

Units: degrees_east

Format: Float_32

Valid Range: -180.0, 180.0

Fill Value: -9999.0

Description: Longitude of the laser footprint on the Earth's surface.

Scientific Data Sets: Lidar Operating Mode

Frame_Number

Units: No Units

Format: Int_16

Valid Range: 1, 11

Description: The number of current frame (5 km horizontal segment = 15 consecutive laser pulses) within the sequence of 11 frames within a Payload Data Acquisition Cycle (PDAC). A PDAC specifies the minimum time interval over which each of the three CALIPSO instruments (CALIOP, IIR, and WFC) can collect an integer number of measurements (165 laser pulses, ~55 km along track).

Lidar_Mode

Units: No Units

Format: Int_16

Valid Range: 1, 6

Description: Lidar operations mode, as defined in Table 2.

Table 1: interpretation of the lidar operations mode values

Value	Operations Mode
1	Safe
2	Standby
3	autonomous data collection
4	built in test system (BITS)
5	special operations
6	Diagnostic

Lidar_Submode

Units: No Units

Format: Int_16

Valid Range: 1, 25

Description: Lidar operations sub-mode, as defined in Table 3.

Table 2: interpretation of the lidar operations submode values

Value	Operations Submode		Value	Operations Submode
1	safe		14	baseline measurement
2	warm-up		15	polarization calibration
3	standby		16	extended background measurement
4	normal		17	boresight alignment
5	BITS profile #1, no background		18	manual boresight operation
6	BITS profile #2, no background		19	boresight search
7	BITS profile #3, no background		20	build on-board baseline profiles
8	BITS profile #4, no background		21	baseline corrected high gain channel
9	BITS profile #1, with background		22	baseline corrected low gain channel
10	BITS profile #2, with background		23	uncorrected high gain channel
11	BITS profile #3, with background		24	uncorrected low gain channel
12	BITS profile #4, with background		25	diagnostic

Value	Operations Submode		Value	Operations Submode
13	no baseline removal		26–32	unused

Laser_Energy_Monitor_532

Units: J

Format: Float_32

Typical Range: 0.003…0.135

Description: 532 nm laser energy measured for each laser pulse by a dedicated onboard laser energy monitor.

Laser_Energy_Monitor_1064

Units: J

Format: Float_32

Typical Range: 0.038…0.12

Description: 1064 nm laser energy measured for each laser pulse by a dedicated onboard laser energy monitor.

Parallel_Amplifier_Gain_532

Perpendicular_Amplifier_Gain_532

Units: V/V

Format: Float_32

Typical Range: 26.0…178.0

Description: Gain of the variable gain amplifier for the 532 nm parallel and perpendicular channels. The nighttime gains are substantially higher than the daytime gains.

Amplifier_Gain_1064_High

Amplifier_Gain_1064_Low

Units: V/V

Format: Float_32

Typical Range: 102.0…195.0

Description: Gain of the high and low gain amplifiers for the 1064 nm perpendicular channel.

Off_Nadir_Angle

Units: degrees

Format: Float_32

Description: Angle of the lidar viewing vector relative to nadir pointing; the off-nadir angle was fixed at 0.3 degrees at launch/first-light and permanently changed to 3.0 degrees after November 28, 2007.

There is some jitter in the off-nadir angle. The mean value for the 51,719,250 good laser profiles acquired during October 2014 is 2.9827° ± 0.0128°, with minimum and maximum values of, respectively, 2.9348° and 3.0274°. There is also a very small number of granules in which pointing angle experiments are conducted, and during these events the off-nadir angles can be as large as 30° or more. Appendix 1 lists all granules containing off-nadir angles that vary by more than ±0.5° from the nominal values.

Scientific Data Sets: Signal Quality

High_Gain_ADC_Offset_532_Par

Low_Gain_ADC_Offset_532_Par

Units: No Units

Format: UInt_16

Description: High and low gain analog to digital offset settings for the 532 nm parallel channel.

High_Gain_ADC_Offset_532_Per

Low_Gain_ADC_Offset_532_Per

Units: No Units

Format: UInt_16

Description: High and low gain analog to digital offset settings for the 532 nm perpendicular channel.

High_Gain_ADC_Offset_1064

Low_Gain_ADC_Offset_1064

Units: No Units

Format: UInt_16

Description: High and low gain analog to digital offset settings for the 1064 nm channel.

Parallel_Background_Monitor_532

Perpendicular_Background_Monitor_532

Units: counts

Format: Float_32

Typical Range: 120.0…6000.0

Description: Magnitudes of the background signals, in science digitizer counts, for, respectively, the 532 nm parallel and 532 nm perpendicular channels. Background signals are measured for each laser pulse at very high altitudes (97-112 km), where laser backscatter from atmospheric constituents is essentially zero. Background signals include such things as detector dark current and background radiation signals (e.g., from daytime sunlight). CALIPSO lidar signals measured onboard the satellite include both an atmospheric backscatter component and a background contribution, with the background signal being subtracted during the onboard data processing prior to data downlink.

Region_6_Low_Gain_Raw_Mean_532_Par

Region_6_Low_Gain_Raw_Mean_532_Per

Region_6_Low_Gain_Raw_Mean_1064

Units: counts

Format: Float_32

Description: The mean of 15000 samples of raw data collected on the 532 nm parallel, 532 nm perpendicular, and 1064 nm low gain channels within region 6 (high) of the defined backscatter regions.

Region_6_Low_Gain_Frame_RMS_Noise_532_Par

Region_6_Low_Gain_Frame_RMS_Noise_532_Per

Region_6_Low_Gain_Frame_RMS_Noise_1064

Units: counts

Format: Float_32

Description: The root-mean-square (RMS) noise of 15000 samples of raw data collected on the 532 nm parallel, 532 nm perpendicular, and 1064 nm low gain channels within region 6 (high) of the defined backscatter regions.

Region_6_Low_Gain_Overflows_532_Par

Region_6_Low_Gain_Overflows_532_Per

Region_6_Low_Gain_Overflows_1064

Units: No Units

Format: UInt_16

Description: The number of overflows in 15000 samples of raw data collected on the 532 nm parallel, 532 nm perpendicular, and 1064 nm low gain channels within region 6 (high) of the defined backscatter regions.

Region_6_Low_Gain_Underflows_532_Par

Region_6_Low_Gain_Underflows_532_Per

Region_6_Low_Gain_Underflows_1064

Units: No Units

Format: UInt_16

Description: The number of underflows in 15000 samples of raw data collected on the 532 nm parallel, 532 nm perpendicular, and 1064 nm low gain channels within region 6 (high) of the defined backscatter regions.

Region_2_Low_Gain_Overflows_532_Par

Region_2_Low_Gain_Overflows_532_Per

Region_2_Low_Gain_Overflows_1064

Units: No Units

Format: UInt_16

Description: The number of overflows in 8700 samples in Normal Processing or 9900 samples in Atmospheric Test Processing of raw data collected on the 532 nm parallel, 532 nm perpendicular, and 1064 nm low gain channels within region 2 of the defined backscatter regions.

Region_1_Low_Gain_Overflows_532_Par

Region_1_Low_Gain_Overflows_532_Per

Region_1_Low_Gain_Overflows_1064

Units: No Units

Format: UInt_16

Description: The number of overflows in 1500 samples in Normal Processing or 9900 samples in Atmospheric Test Processing of raw data collected on the 532 nm parallel, 532 nm perpendicular, and 1064 nm low gain channels within region 1 of the defined backscatter regions.

Region_0_Low_Gain_Raw_Mean_532_Par

Region_0_Low_Gain_Raw_Mean_532_Per

Region_0_Low_Gain_Raw_Mean_1064

Units: counts

Format: Float_32

Description: The mean of 7500 samples in Normal Processing or 15000 samples in Atmospheric Test Processing of raw data collected on the 532 nm parallel, 532 nm perpendicular, and 1064 nm low gain channels within region 0 (low) of the defined backscatter regions.

Region_6_High_Gain_Raw_Mean_532_Par

Region_6_High_Gain_Raw_Mean_532_Per

Region_6_High_Gain_Raw_Mean_1064

Units: counts

Format: Float_32

Description: The mean of 15000 samples of raw data collected on the 532 nm parallel, 532 nm perpendicular, and 1064 nm high gain channels within region 6 (high) of the defined backscatter regions.

Region_6_High_Gain_Frame_RMS_Noise_532_Par

Region_6_High_Gain_Frame_RMS_Noise_532_Per

Region_6_High_Gain_Frame_RMS_Noise_1064

Units: counts

Format: Float_32

Description: The root-mean-square (RMS) noise of 15000 samples of raw data collected on the 532 nm parallel, 532 nm perpendicular, and 1064 nm high gain channels within region 6 (high) of the defined backscatter regions.

Region_6_High_Gain_Overflows_532_Par

Region_6_High_Gain_Overflows_532_Per

Region_6_High_Gain_Overflows_1064

Units: No Units

Format: UInt_16

Description: The number of overflows in 15000 samples of raw data collected on the 532 nm parallel, 532 nm perpendicular, and 1064 nm high gain channels within region 6 (high) of the defined backscatter regions.

Region_6_High_Gain_Underflows_532_Par

Region_6_High_Gain_Underflows_532_Per

Region_6_High_Gain_Underflows_1064

Units: No Units

Format: UInt_16

Description: The number of underflows in 15000 samples of raw data collected on the 532 nm parallel, 532 nm perpendicular, and 1064 nm high gain channels within region 6 (high) of the defined backscatter regions.

Region_3_High_Gain_Overflows_532_Par

Region_3_High_Gain_Overflows_532_Per

Region_3_High_Gain_Overflows_1064

Units: No Units

Format: UInt_16

Description: The number of overflows in 12000 samples in Normal Processing or 7200 samples in Atmospheric Test Processing of raw data collected on the 532 nm parallel, 532 nm perpendicular, and 1064 nm high gain channels within region 3 of the defined backscatter regions.

Region_2_High_Gain_Overflows_532_Par

Region_2_High_Gain_Overflows_532_Per

Region_2_High_Gain_Overflows_1064

Units: No Units

Format: UInt_16

Description: The number of overflows in 8700 samples in Normal Processing or 9900 samples in Atmospheric Test Processing of raw data collected on the 532 nm parallel, 532 nm perpendicular, and 1064 nm high gain channels within region 2 of the defined backscatter regions.

Region_6_Merged_Background_Mean_532_Par

Region_6_Merged_Background_Mean_532_Per

Region_6_Merged_Background_Mean_1064

Units: counts

Format: Float_32

Description: The mean of 15000 samples of data after baseline removal, offset removal, merging and scaling, and residual offset removal, collected on the 532 nm parallel, 532 nm perpendicular, and 1064 nm combined gain channel within region 6 (high) of the defined backscatter regions.

Region_6_Merged_Shot_RMS_Noise_532_Par

Region_6_Merged_Shot_RMS_Noise_532_Per

Region_6_Merged_Shot_RMS_Noise_1064

Units: counts

Format: Float_32

Description: The root-mean-square (RMS) noise of 15000 samples of data after baseline removal, offset removal, merging and scaling, and residual offset removal, collected on the 532 nm parallel, 532 nm perpendicular, and 1064 nm combined gain channel within region 6 (high) of the defined backscatter regions.

Region_0_Merged_Background_Mean_532_Par

Region_0_Merged_Background_Mean_532_Per

Region_0_Merged_Background_Mean_1064

Units: counts

Format: Float_32

Description: The mean of 7500 samples in Normal Processing or 15000 samples in Atmospheric Test Processing of data after baseline removal, offset removal, merging and scaling, and residual offset removal, collected on the 532 nm parallel, 532 nm perpendicular, and 1064 nm combined gain channel within region 0 (low) of the defined backscatter regions.

Scientific Data Sets: Merge and Scale Coefficients

Gain_Coeff_A_532_Par

Gain_Coeff_A_532_Per

Gain_Coeff_A_1064

Units: No Units

Format: Float_32

Description: The 532 nm parallel, 532 nm perpendicular, and 1064 nm gain coefficient A used by the combined gain channel algorithm for this frame of data.

Gain_Coeff_B_532_Par

Gain_Coeff_B_532_Per

Gain_Coeff_B_1064

Units: No Units

Format: Float_32

Description: The 532 nm parallel, 532 nm perpendicular, and 1064 nm gain coefficient B used by the combined gain channel algorithm for this frame of data.

Gain_Coeff_C_532_Par

Gain_Coeff_C_532_Per

Gain_Coeff_C_1064

Units: No Units

Format: Float_32

Description: The 532 nm parallel, 532 nm perpendicular, and 1064 nm gain coefficient C used by the combined gain channel algorithm for this frame of data.

Gain_Coeff_D_532_Par

Gain_Coeff_D_532_Per

Gain_Coeff_D_1064

Units: No Units

Format: Float_32

Description: The 532 nm parallel, 532 nm perpendicular, and 1064 nm gain coefficient D used by the combined gain channel algorithm for this frame of data.

Scientific Data Sets: Backscatter Profiles

Backscatter_532_Parallel_Averaged

Backscatter_532_Perpendicular_Averaged

Backscatter_1064_Averaged

Units: counts

Format: Float_32

Description: The 532 nm parallel, 532 nm perpendicular, and 1064 nm raw backscatter measurements.

Scientific Data Sets: Quality Assurance

QC_Flag

Units: No Units

Format: UInt_32

Valid Range: 1, 16777215

Description: An unsigned 32-bit integer which each bit indicating a specific error condition, as defined in Table 1.

Prior to being downlinked, CALIPSO lidar data are averaged on-board the satellite using a variable averaging scheme. Regions 1 and 2 contain single shot data (albeit at different vertical resolutions). In regions 3, 4, and 5, the downlinked data have been averaged to horizontal resolutions of, respectively, 3 shots, 5 shots, and 15 shots. The level 1 processing constructs Pseudo Single Shot Profiles (PSSP) by replicating the data from regions 3, 4, and 5, and then stacking data arrays from the different averaging regions. The QC flags, as shown in Tables 1 are computed for each one of these pseudo single shot profiles.

Table 3: interpretation of the bits in the CALIOP QC Flag

Bit(s)	Interpretation
1	532 nm parallel channel missing
2	532 nm perpendicular channel missing
3	1064 nm channel missing
4	Not geolocated
5	Single shot 532 laser energy below calibration threshold (<0.01 J; near zero energy)
6	Single shot 1064 laser energy below calibration threshold (< 0.0408 J; near zero energy)

Bit(s)	Interpretation
7	Historical value used for the depolarization gain ratio
8	Historical calibration constant used, 532 nm parallel channel
9	Historical calibration constant used, 532 nm perpendicular channel
10	Historical calibration constant used, 1064 nm channel
11	Averaged calibration constant used, 532 nm parallel channel
12	Averaged calibration constant used, 532 nm perpendicular channel
13	Single shot 532 laser energy below data quality threshold (< 0.05 J; low energy)
14	Single shot 1064 laser energy below data quality threshold (< 0.05 J; low energy)
15	Near zero 532 nm laser energy profile included in region 3 average
16	Near zero 1064 nm laser energy profile included in region 3 average
17	Near zero 532 nm laser energy profile included in region 4 average
18	Near zero 1064 nm laser energy profile included in region 4 average
19	Near zero 532 nm laser energy profile included in region 5 average
20	Low 532 nm laser energy profile included in region 3 average
21	Low 1064 nm laser energy profile included in region 3 average
22	Low 532 nm laser energy profile included in region 4 average
23	Low 532 nm laser energy profile included in region 4 average
24	Low 532 nm laser energy profile included in region 5 average
25–32	Spare

Quality_Flags_532_Par

Quality_Flags_532_Per

Quality_Flags_1064

Units: No Units

Format: UInt_16

Description: 532 nm parallel and perpendicular and 1064 nm channel quality assurance flags; most significant bit = 15.

Table 4: 532nm and 1064nm quality assurance flag interpretations

Bit	Interpretation	Values
15	Configuration Suspect	True = 1, False = 0
14	Shutter Position Unconfirmed	True = 1, False = 0
13	High Gain Upper FIFO Empty	Empty = 0, Not Empty = 1 (nominal state = empty)
12	High Gain Lower FIFO Empty	Empty = 0, Not Empty = 1 (nominal state = empty)
11	Low Gain Upper FIFO Empty	Empty = 0, Not Empty = 1 (nominal state = empty)
10	Low Gain Lower FIFO Empty	Empty = 0, Not Empty = 1 (nominal state = empty)
09	Remove Baseline Algorithm Failed	True = 1, False = 0
08	Dynamic Gain Used	True = 1, False = 0 (nominal state = false)
07	Gain Calculation Status	Successful = 1, Unsuccessful = 0
06	Suspect Filter Wait Time	True = 1, False = 0
05	Suspect Old Table Data	True = 1, False = 0
04	Suspect GPS Data Points Ignored	True = 1, False = 0
03	Suspect Filter Performance	True = 1, False = 0
02	Suspect Old GPS Data	True = 1, False = 0

Bit	Interpretation	Values
01	Suspect No Geolocation Solution	True = 1, False = 0
00	Suspect Attitude	True = 1, False = 0

Metadata Parameter Descriptions

Product_ID

An 80-byte character string containing the product name. For the L0 data, this parameter is “L0_LIDAR”.

Date_Time_at_Granule_Start

A 27-byte character string that specifies the granule start date and time. The format is yyyy-mm-ddThh:mm:ss.ffffffZ.

Date_Time_at_Granule_End

A 27-byte character string that specifies the granule end date and time. The format is yyyy-mm-ddThh:mm:ss.ffffffZ.

Date_Time_of_Production

A 27-byte character string that specifies the granule production. The format is yyyy-mm-ddThh:mm:ss.ffffffZ.

Initial_Subsatellite_Latitude

This field reports the first subsatellite latitude of the granule.

Initial_Subsatellite_Longitude

This field reports the first subsatellite longitude the granule.

Final_Subsatellite_Latitude

This field reports the last subsatellite latitude of the granule.

Final_Subsatellite_Longitude

This field reports the last subsatellite longitude the granule.

Orbit_Number_at_Granule_Start

Orbit_Number_at_Granule_Stop

Orbit_Number_Change_Time

Orbit Number consists of three fields that define the number of revolutions by the CALIPSO spacecraft around the Earth. This number is incremented each time the spacecraft passes the equator on the ascending node. To maintain consistency between the CALIPSO and CloudSat orbit parameters, the Orbit Number is keyed to the CloudSat orbit 2121 at 23:00:47 on 2006/09/20. Because the CALIPSO data granules are organized according to the day and night conditions, based on fixed Sun-Earth-Satellite angles, day/night boundaries do not coincide with transition points for defining orbit number. As such, three parameters are needed to describe the orbit number for each granule as:

- **Orbit Number at Granule Start:** orbit number at the granule start time.
- **Orbit Number at Granule End:** orbit number at the granule stop time.
- **Orbit Number Change Time:** time at which the orbit number changes in the granule.

Path_Number_at_Granule_Start

Path_Number_at_Granule_Stop

Path_Number_Change_Time

Path Number consists of three fields that define an index ranging from 1-233 that references orbits to the Worldwide Reference System (WRS). This global grid system was developed to support scene identification for LandSat imagery. Since the A-Train is maintained to the WRS grid within +/- 10 km, the Path Number provides a

convenient index to support data searches, instead of having to define complex latitude and longitude regions along the orbit track. The Path Number is incremented after the maximum latitude in the orbit is attained and changes by a value of 16 between successive orbits. Because the CALIPSO data granules are organized according to the day and night conditions, based on fixed Sun-Earth-Satellite angles, day/night boundaries do not coincide with transition points for defining path number. As such, three parameters are needed to describe the path number for each granule as:

- **Path Number at Granule Start:** path number at the granule start time.
- **Path Number at Granule End:** path number at the granule stop time.
- **Path Number Change Time:** time at which the path number changes in the granule.

Data Release Information

Table 5: dates, versions, and production strategy for all CALIPSO lidar level 0 data releases

Lidar Level 0: Full Orbit			
Release Date	**Version**	**Data Date Range**	**Production Strategy**
August 2024	1.00	June 13, 2006 to June 30, 2023	Standard

References

Hunt, W. H, D. M. Winker, M. A. Vaughan, K. A. Powell, P. L. Lucker, and C. Weimer, 2009: CALIPSO Lidar Description and Performance Assessment, *J. Atmos. Oceanic Technol.*, **26**, 1214–1228, https://doi.org/10.1175/2009JTECHA1223.1.

Appendix 1: Granules Containing Unusual Off-Nadir Angles

Table 6: During the mission, CALIOP conducted an intermittent series of measurements to characterize ocean surface backscatter at high off-nadir angles. This table lists the start time, measurement duration, and minimum and maximum off-nadir angles for each measurement. Granules containing these data are not part of the standard lidar level 1b data set.

Start Date/Time	duration (min)	θ_{min}	θ_{max}
2014-01-28@11:05:59 UTC	4.383	N/A	N/A
2014-07-17@13:36:28 UTC	52.217	N/A	N/A
2015-09-23@10:55:03 UTC	48.375	3.000	20.000
2015-10-07@12:45:12 UTC	45.120	3.000	20.000
2015-10-21@11:17:13 UTC	44.252	3.087	29.997
2015-11-04@13:07:06 UTC	41.335	3.077	30.036
2015-11-18@11:39:15 UTC	43.418	3.042	30.063
2015-12-02@11:51:04 UTC	42.668	3.013	30.090
2015-12-16@12:03:01 UTC	42.335	3.013	30.107
2016-01-13@12:29:05 UTC	41.585	2.981	30.109
2016-01-27@14:20:06 UTC	41.252	2.985	30.109
2016-03-30@13:44:06 UTC	40.918	3.011	30.108
2016-04-13@13:58:04 UTC	42.668	2.995	30.104
2016-04-27@14:13:11 UTC	43.252	3.151	29.985
2016-05-11@12:48:05 UTC	42.668	3.146	29.953
2016-05-25@14:39:07 UTC	41.585	3.164	29.944

Start Date/Time	duration (min)	θ_{min}	θ_{max}
2016-06-08@11:34:13 UTC	41.502	3.162	29.939
2007-08-21@20:42:00 UTC	41.085	3.181	29.943
2007-11-28@20:19:12 UTC	41.502	3.167	29.945
2016-06-22@13:25:14 UTC	42.502	3.175	29.945
2016-07-13@10:25:06 UTC	41.585	3.161	29.943
2016-07-27@04:02:12 UTC	41.252	3.181	29.936
2016-08-10@04:13:00 UTC	41.418	3.182	29.941
2016-08-24@04:24:05 UTC	41.418	3.165	29.944
2016-09-07@02:56:15 UTC	41.085	3.147	29.997
2016-09-21@03:07:03 UTC	41.585	3.147	29.997
2016-10-19@03:29:05 UTC	40.168	3.096	30.062
2016-11-09@03:44:03 UTC	41.585	3.027	30.096
2016-11-30@04:02:03 UTC	40.418	3.021	30.108
2016-12-14@04:14:09 UTC	40.252	3.022	30.107
2017-01-11@03:00:08 UTC	41.085	3.024	30.105
2017-01-25@11:28:10 UTC	41.085	3.022	14.104
2017-02-08@13:20:12 UTC	41.502	2.031	14.091
2017-02-22@11:55:06 UTC	41.002	3.064	14.069
2017-03-08@12:09:04 UTC	41.502	3.088	10.036
2017-03-22@12:23:11 UTC	41.585	3.118	10.004
2017-04-19@12:51:07 UTC	41.585	3.152	9.948
2017-05-03@13:04:04 UTC	41.002	3.165	9.948
2017-05-17@11:39:15 UTC	41.085	3.159	9.947
2017-05-23@07:45:59 UTC	42.667	3.185	45.611
2018-11-28@10:07:06 UTC	56.085	N/A	N/A
2019-05-03@13:53:02 UTC	41.252	3.164	44.940
2020-05-27@20:47:45 UTC	44.280	2.973	27.323