University of Texas
Center for Space Research
ICESat/GLAS Document:

Summary of Laser Profile Array (LPA)
Parameter Estimation

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Version 1.0, October 2006
Initial document created for Science Team on the SCF web site.

Version 2.0, August 2011
Reformat document.
Add Tables 1-5.
Embed LPA plots into the document.
Use GLA parameter names in text.
Include notes about low-energy campaigns L2c, L2d, L2e, and L2f.

Summary

The Laser Profile Array (LPA) data for ICESat are delivered in the GLA04-01 Level 1A data product. LPA images are recorded at 40 Hz. The LPA image is a far-field projection of the laser spot measured onboard the satellite and is used to approximately represent the laser spot footprint size and shape on the ground.

The elliptical parameters of the LPA laser image are determined by using the SOURCE EXTRACTOR algorithm (http://terapix.iap.fr/soft/sextractor/). The major (and minor) axis length of the LPA image obtained by this algorithm represents twice the maximum (and minimum) spatial RMS (one sigma) of the laser image along each direction; three (3) times these algorithm values are reasonably close to the true measurements of the LPA image and this scaling is applied. One LPA pixel represents 3.388 arcseconds, and the total LPA image size is on the order of tens of arcseconds.

Six characteristics of each LPA footprint are computed: major axis, eccentricity, orientation, maximum intensity, total intensity, and number of pixels used. GLA product parameter names are given in *italics*.
- Major Axis (*i_tpmajoraxis_avg*): the ground projection of the LPA image considering the distance from ICESat to the Earth's surface, resolved in units of meters
- Eccentricity (*i_tpeccentricity_avg*): computed according to $e^2 = 1 - b^2/a^2$, where the major axis is *a* and the minor axis is *b*
- Orientation (*i_tpazimuth_avg*): computed as the angle between the major axis and the LPA x-axis; the ground laser orientation from North (CW) (distributed within GLA Level 2 products) is obtained from the geometrical relationships between the GLAS frame, the LPA frame, and ICESat orbit at the measurement time
- Maximum Intensity: the intensity of each LPA pixel is recorded, with the maximum within each image identified to apply a $1/e^2$ cut-off criterion (where here *e* means the natural logarithm)
- Number of Pixels Used: the number of LPA pixels used within a $1/e^2$ cut-off criterion, indicative of the total area of the footprint
- Total Intensity (*i_tpintensity_avg*): the sum of the intensity values within a $1/e^2$ criterion; imagined as the volume of a footprint-intensity 3D curve, it represents the total energy hitting the ground

Tables

Tables 1 and 2 list the campaign-averaged LPA characteristics (± standard deviation), computed as the average of the daily means plotted in the figures, inclusive of any discontinuities in the time series (see Table 5). Tables 3 and 4 list the campaign-averaged standard error (± standard deviation) of each of the six LPA characteristics computed as the average of the daily error bars. Table 5 lists anomalies observed in the LPA characteristic time series shown in the figures. Note that no table or figures are included for data after L2c day 160 (including L2d, L2e, and L2f) due to the inability to resolve LPA characteristics at very low energy.

Table 1: Mean LPA characteristics ± standard deviation averaged over each campaign: major axis, eccentricity, and orientation.

	Major Axis (meter)	Eccentricity	Orientation (degree)
L1	148.60±9.77	0.920±0.017	126.89±1.10
L2a	99.93±8.65	0.881±0.010	127.20±1.63
L2b	89.52±4.93	0.822±0.045	119.74±10.05
L2c	88.37±19.12	0.892±0.044	82.01±8.85
L3a	55.79±0.43	0.567±0.043	77.35±15.21
L3b	79.53±11.55	0.753±0.051	99.57±19.95
L3c	55.41±1.84	0.633±0.034	117.80±3.62
L3d	52.04±1.06	0.523±0.009	122.16±2.98
L3e	52.31±1.60	0.483±0.040	113.25±5.75
L3f	51.20±1.63	0.480±0.023	100.81±9.98
L3g	53.41±1.51	0.510±0.037	107.43±3.08
L3h	55.61±0.48	0.521±0.019	95.63±8.80
L3i	57.28±0.57	0.590±0.013	93.99±2.08
L3j	58.66±1.52	0.575±0.036	110.27±3.78
L3k	51.99±1.12	0.611±0.036	116.41±1.88

Table 2: Mean LPA characteristics ± standard deviation averaged over each campaign: total intensity, maximum intensity, and number of pixels used.

	Total Intensity	Maximum Intensity	Number of Pixels
L1	531.71±57.97	106.34±5.81	53.68±3.36
L2a	632.01±88.86	144.28±19.21	32.38±4.48
L2b	369.48±109.54	114.16±16.37	31.51±4.37
L2c	54.14±58.23	73.65±4.08	16.05±10.26
L3a	356.08±14.70	140.03±2.71	17.80±0.71
L3b	356.52±21.21	125.32±9.65	26.48±4.97
L3c	223.37±1.16	115.30±1.77	16.75±1.50
L3d	247.59±2.90	123.29±0.50	15.63±0.23
L3e	201.12±33.28	111.69±7.97	16.78±0.81
L3f	122.44±5.09	95.93±0.96	16.18±0.43
L3g	126.63±9.30	95.07±1.96	17.49±0.78
L3h	103.76±9.18	90.03±2.25	18.91±0.38
L3i	86.17±7.99	85.84±2.17	18.59±0.25
L3j	85.54±9.73	83.94±2.47	20.15±1.28
L3k	45.34±6.16	79.71±0.29	15.11±1.45

Table 3: Mean LPA standard error ± standard deviation averaged over each campaign: major axis, eccentricity, and orientation.

	Major Axis (meter)	Eccentricity	Orientation (degree)
L1	2.23±0.77	0.00037±0.00192	1.21±0.28
L2a	1.77±1.06	0.01057±0.00412	1.48±1.00
L2b	2.38±3.33	0.01452±0.01121	2.19±1.10
L2c	11.02±9.83	0.06045±0.03273	8.19±5.02
L3a	1.17±0.30	0.07857±0.01353	18.15±4.18
L3b	4.48±2.91	0.03912±0.01583	5.09±4.28
L3c	2.50±0.93	0.03212±0.00992	7.33±0.37
L3d	1.05±0.12	0.04061±0.00899	7.78±1.38
L3e	1.44±0.35	0.07273±0.03185	13.50±6.12
L3f	2.80±1.43	0.11469±0.02436	20.60±3.54
L3g	2.00±0.20	0.08219±0.01621	16.74±6.18
L3h	2.94±0.26	0.11344±0.00745	16.10±4.01
L3i	2.81±0.39	0.09273±0.01126	10.38±1.63
L3j	2.11±0.31	0.05094±0.01329	7.68±1.50
L3k	3.04±0.30	0.07071±0.00997	10.30±0.85

Table 4: Mean LPA standard error ± standard deviation averaged over each campaign: total intensity, maximum intensity, and number of pixels used.

	Total Intensity	Maximum Intensity	Number of Pixels
L1	27.19±3.81	1.93±0.22	2.22±0.75
L2a	39.40±13.44	5.39±1.47	2.00±0.51
L2b	40.62±34.17	3.94±2.53	2.96±6.65
L2c	19.36±28.78	1.28±1.13	10.28±15.21
L3a	23.36±8.49	4.68±1.89	1.48±0.21
L3b	15.56±4.16	3.56±1.78	1.83±1.00
L3c	9.70±3.88	2.98±0.37	2.00±0.95
L3d	14.81±2.25	3.97±0.58	1.13±0.10
L3e	17.61±3.44	4.56±0.59	1.20±0.19
L3f	19.31±21.26	3.52±0.29	1.57±1.57
L3g	16.81±3.60	3.31±0.49	1.23±0.12
L3h	13.45±0.77	2.60±0.34	1.42±0.10
L3i	10.23±1.73	2.16±0.27	1.50±0.36
L3j	5.64±1.65	0.92±0.29	1.69±0.72
L3k	8.60±1.77	1.27±0.17	1.42±0.17

Table 5. Anomalies observed in the time series plots of LPA characteristics.

Campaign	Day of year/Year	Comments
L2a	286/2003	Footprint parameters changed in response to onboard temperature changes
	302/2003	
	313/2003	
L2b	50/2004	Slight jump, unknown cause
L2c	160/2004	Due to the decreasing energy of L2, the LPA cannot be used to detect the footprint beyond L2c day 160/2004
L2d	All/2008	
L2e	All/2009	
L2f	All/2009	
L3a	281/2003	Slight jump, unknown cause
	293/2003	
L3b	54/2004	Major axis jumps to ~90 m for the remainder of the campaign, unknown cause
L3f	171/2006	Higher RMS for one day, unknown cause

Figures

For each campaign, two figures (six plots) are generated that show the evolution of the six LPA characteristics. The first figure contains plots of orientation, major axis and eccentricity, and the second contains plots of total intensity, maximum intensity, and the number of pixels used. Each plot point is a daily average and the errors bars are the standard deviation.
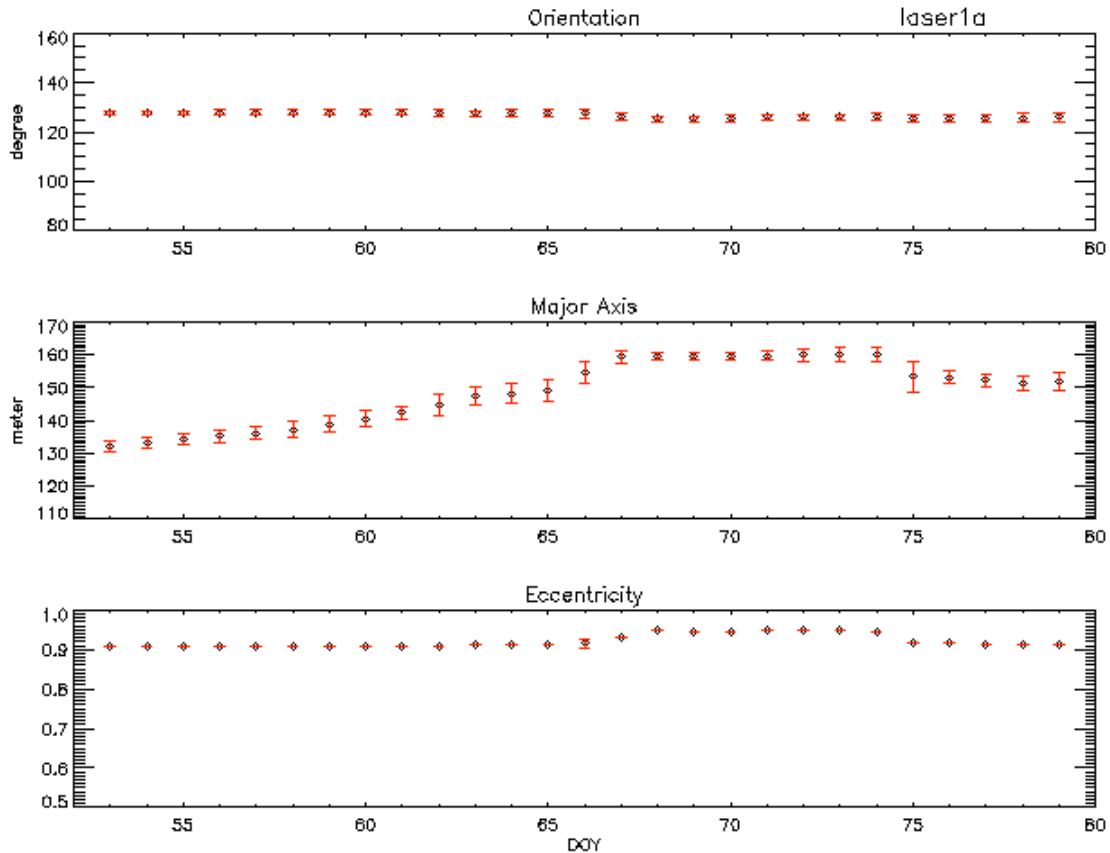
Figure 1. Campaign L1a LPA orientation, major axis and eccentricity.
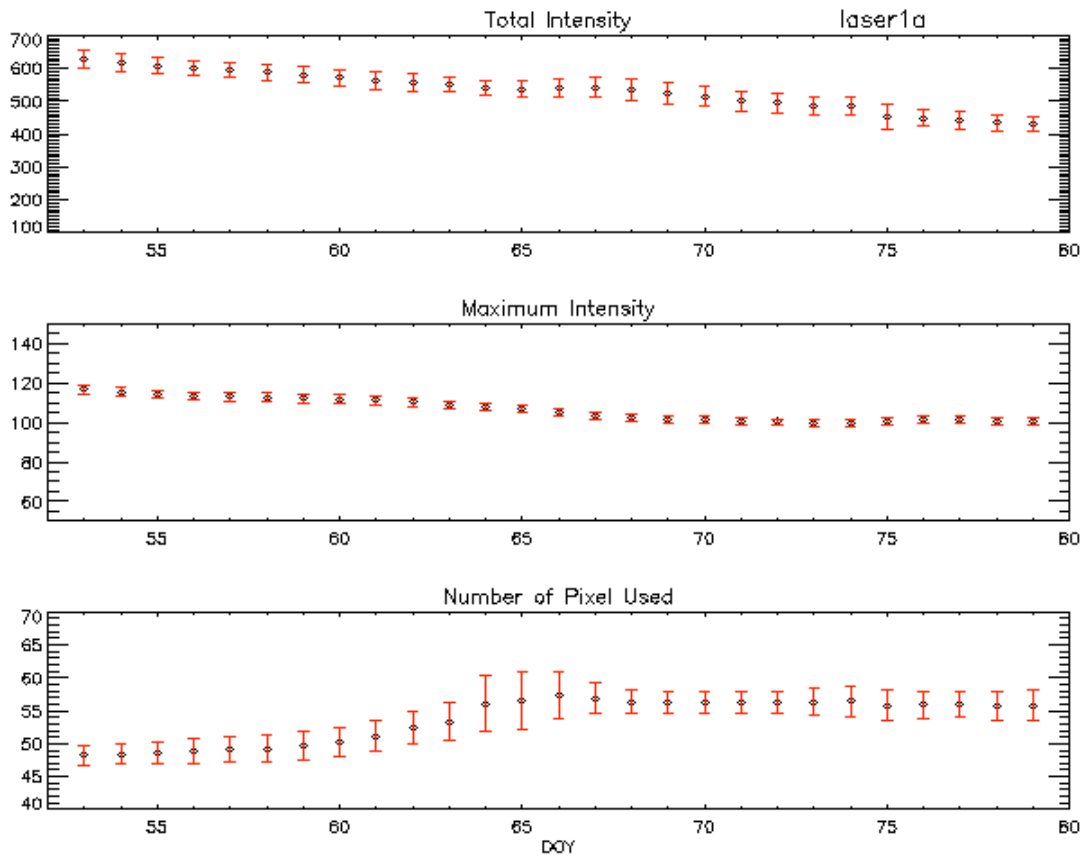
Figure 2. Campaign L1a LPA total intensity, maximum intensity, and number of LPA pixels within the $1/e^2$ criterion.
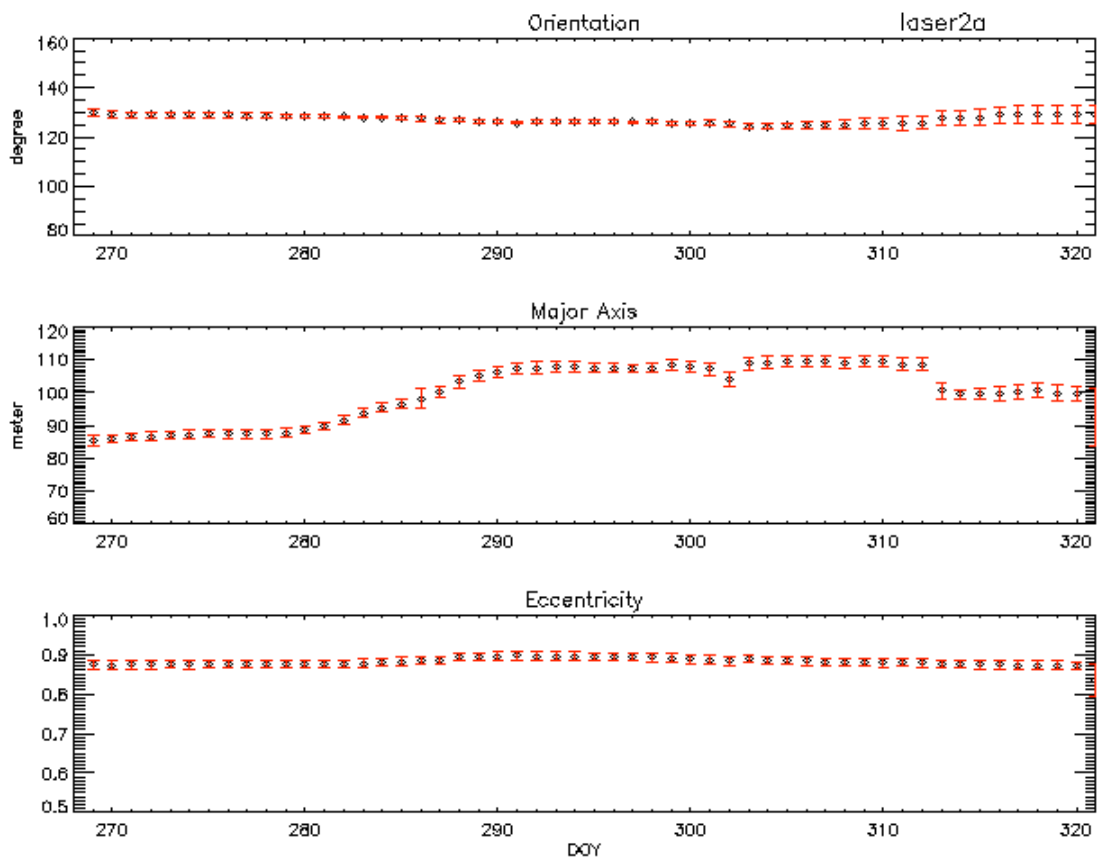
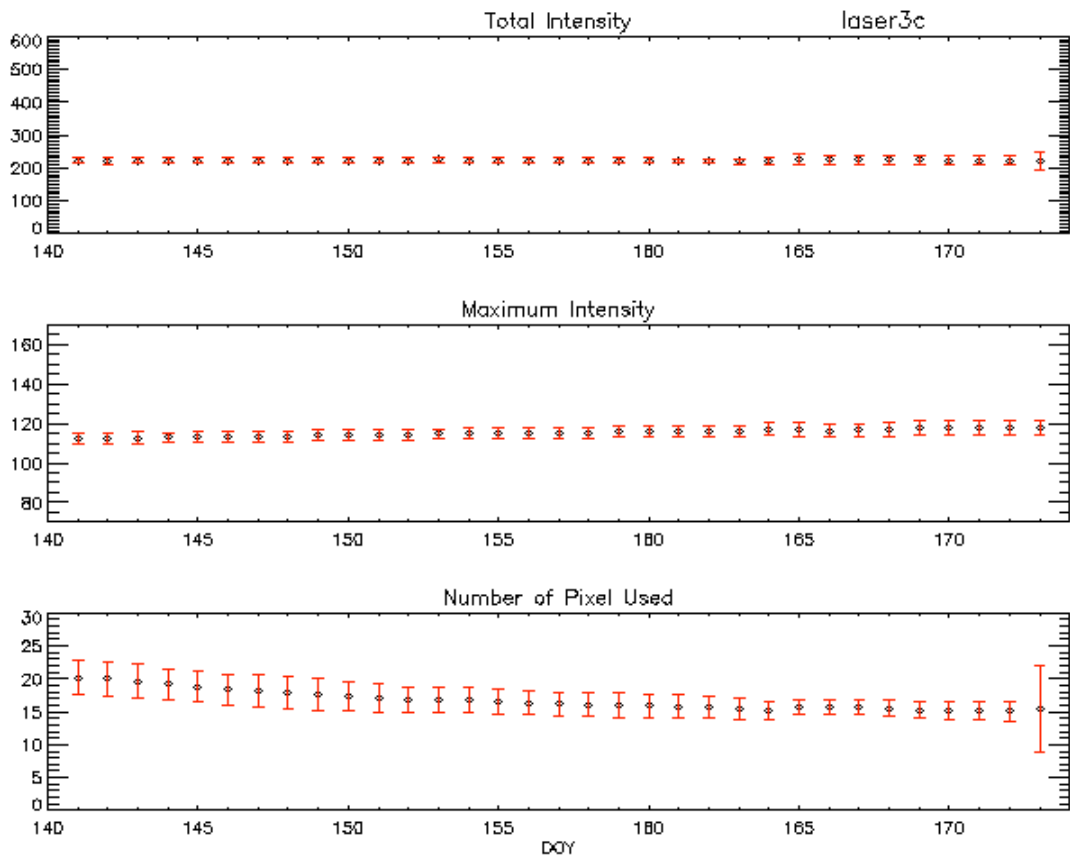Figure 3. Campaign L2a LPA orientation, major axis and eccentricity.
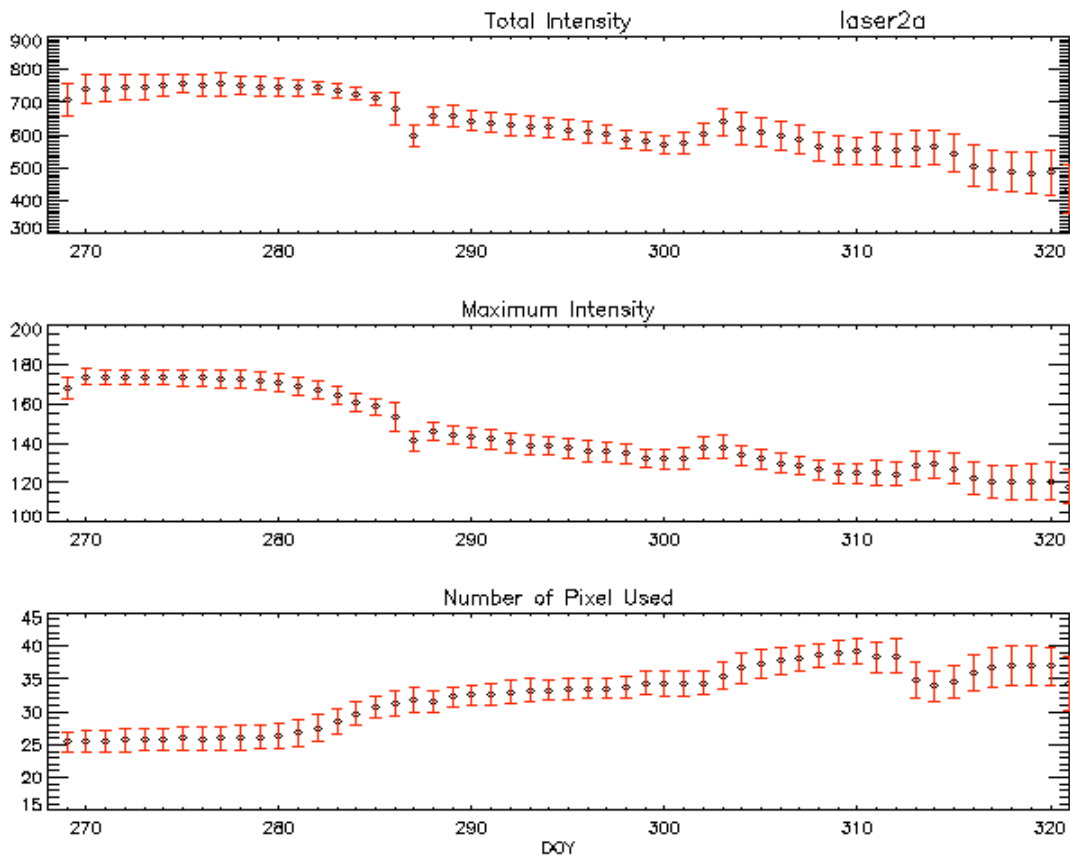
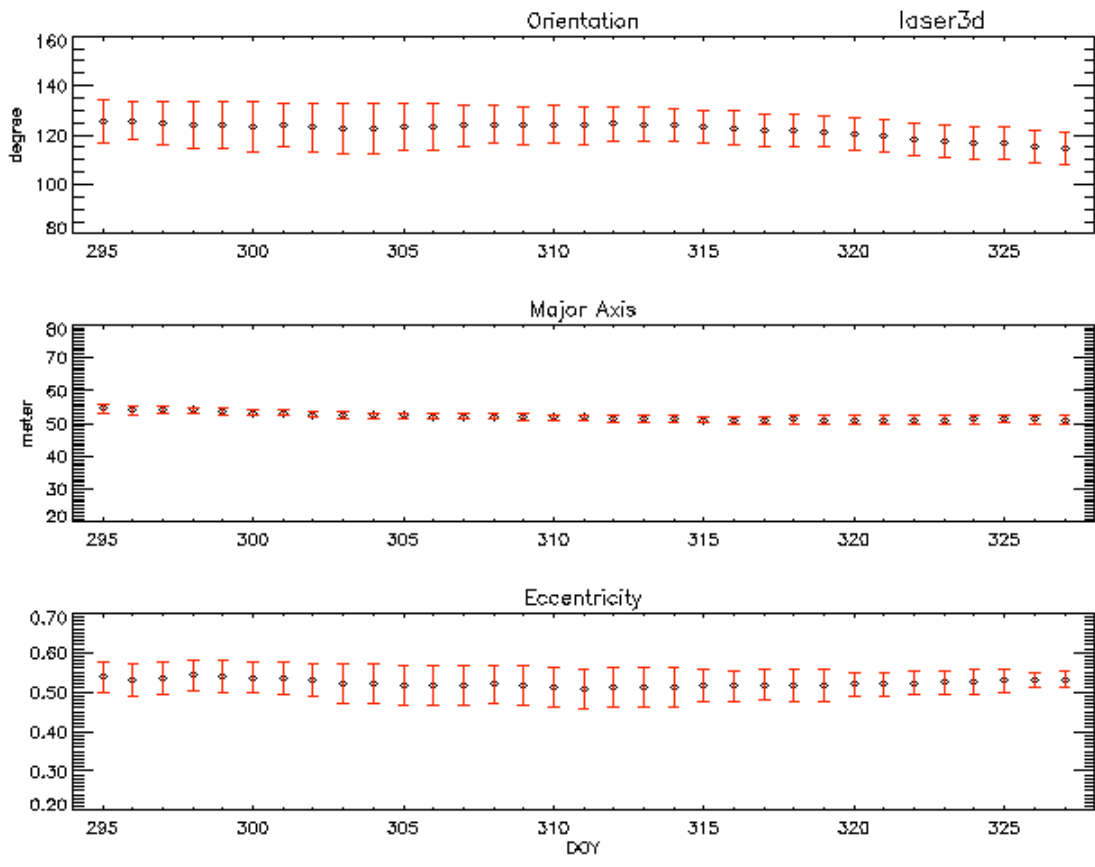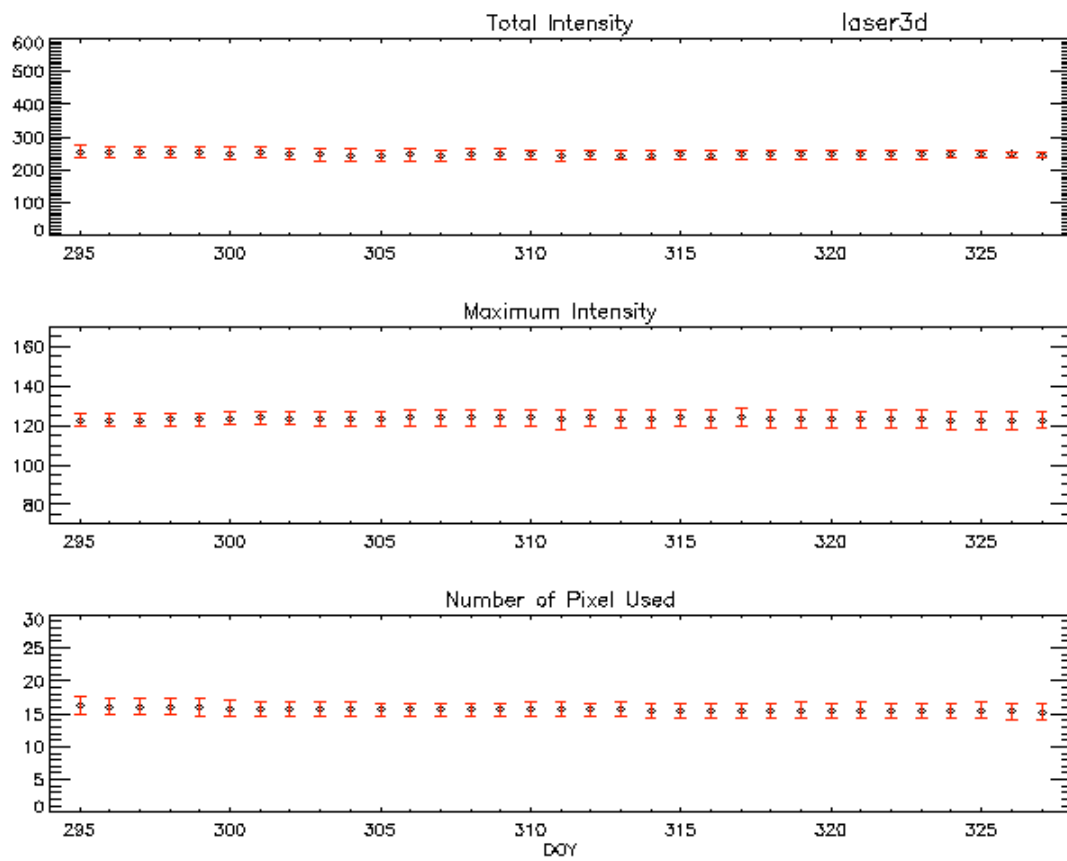Figure 4. Campaign L2a LPA total intensity, maximum intensity, and number of LPA pixels within the $1/e^2$ criterion.
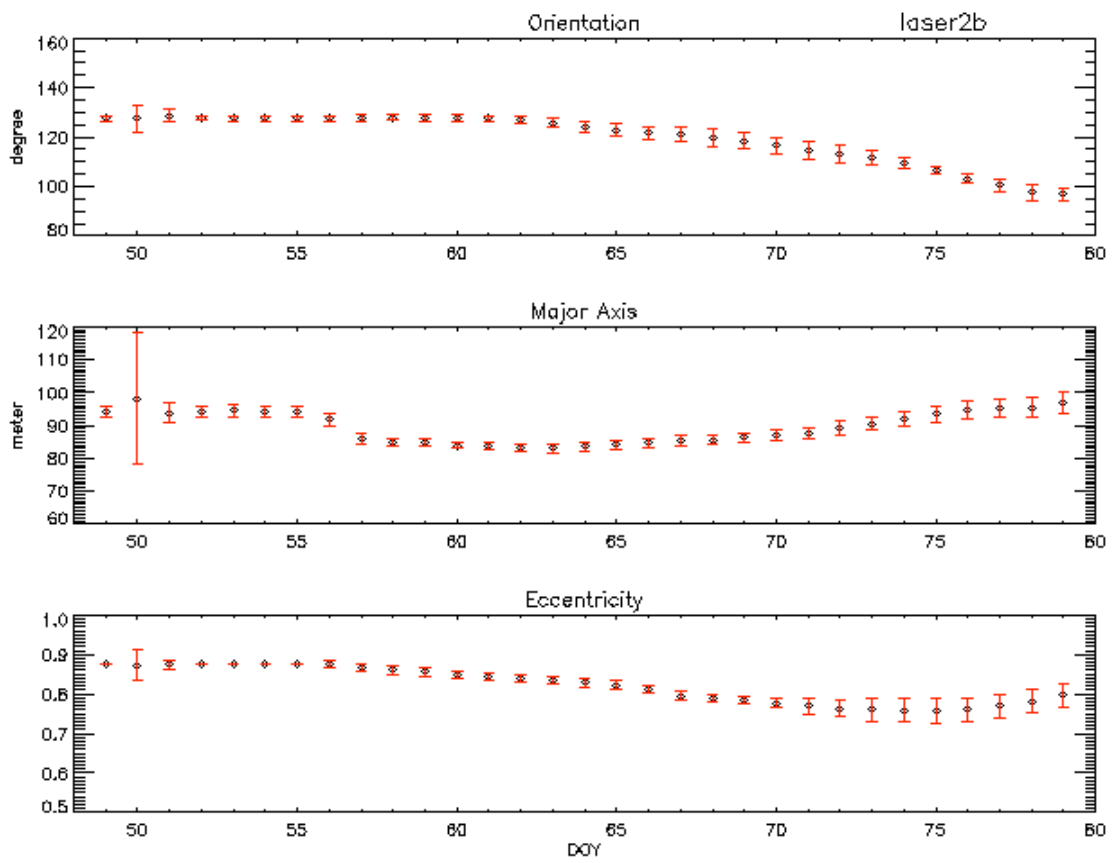
Figure 5. Campaign L2b LPA orientation, major axis and eccentricity.
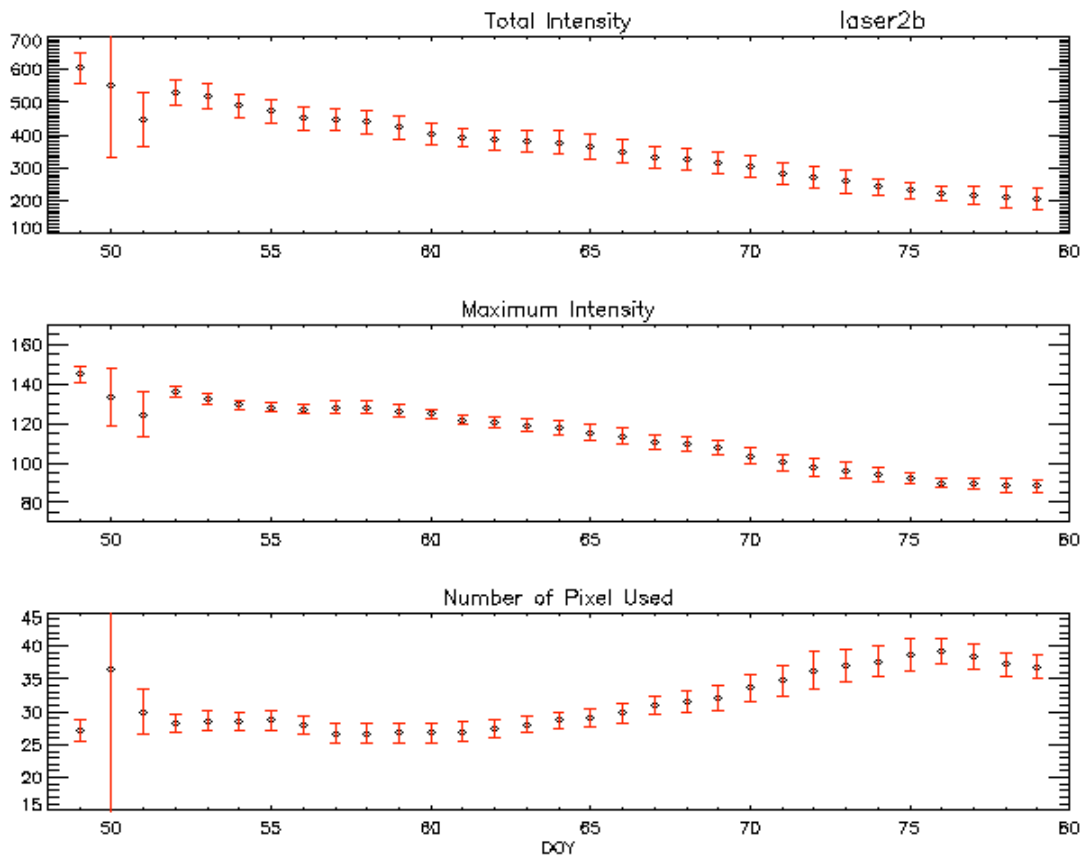
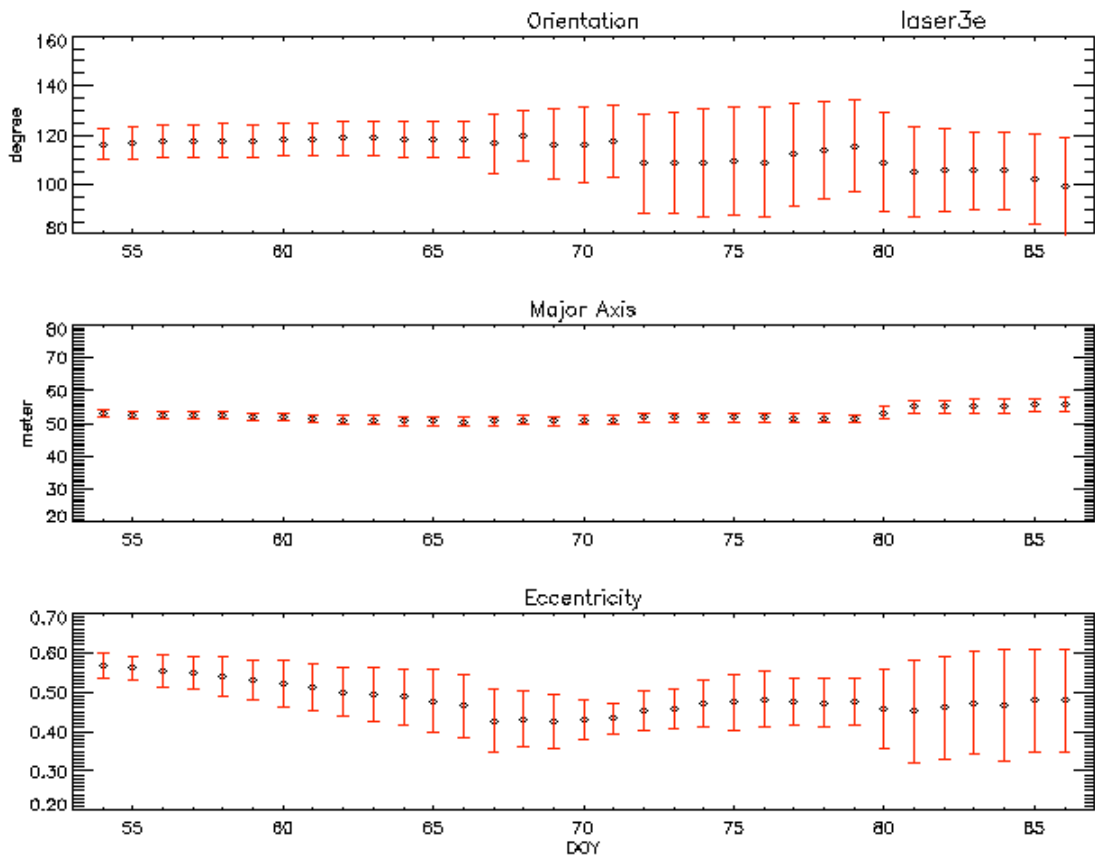Figure 6. Campaign L2b LPA total intensity, maximum intensity, and number of LPA pixels within the $1/e^2$ criterion.
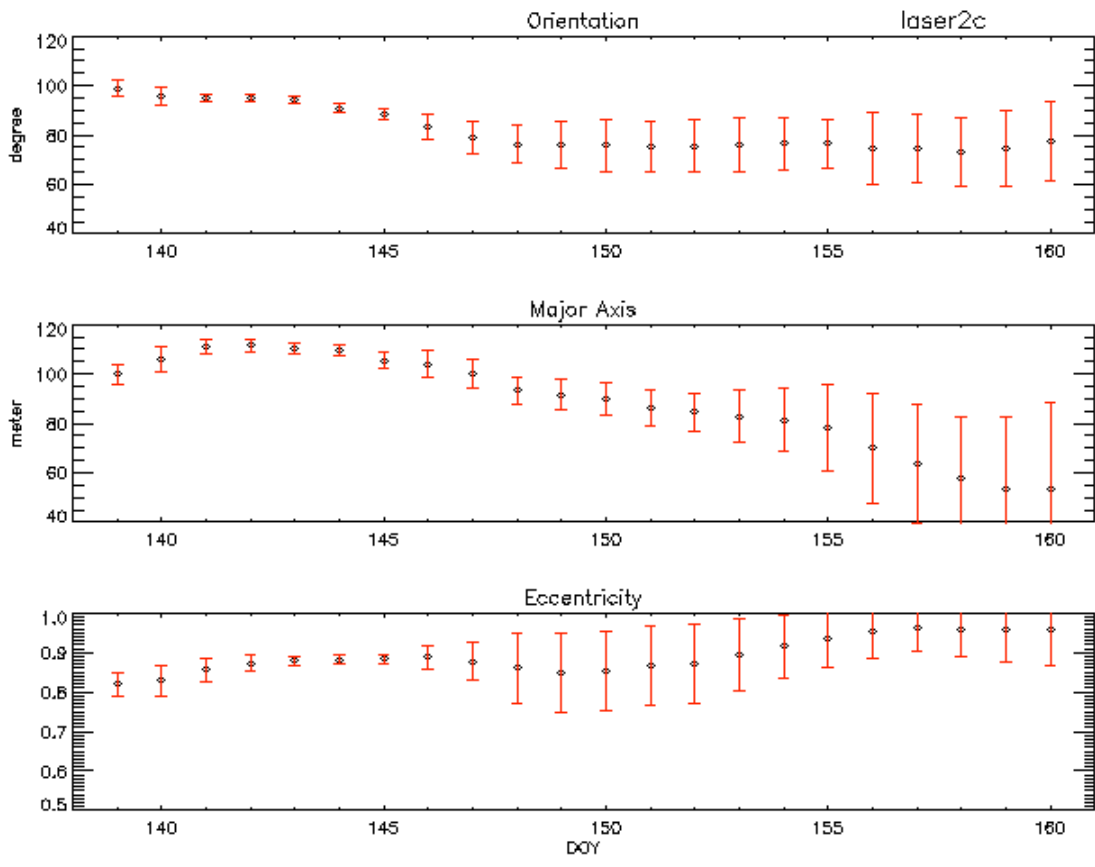
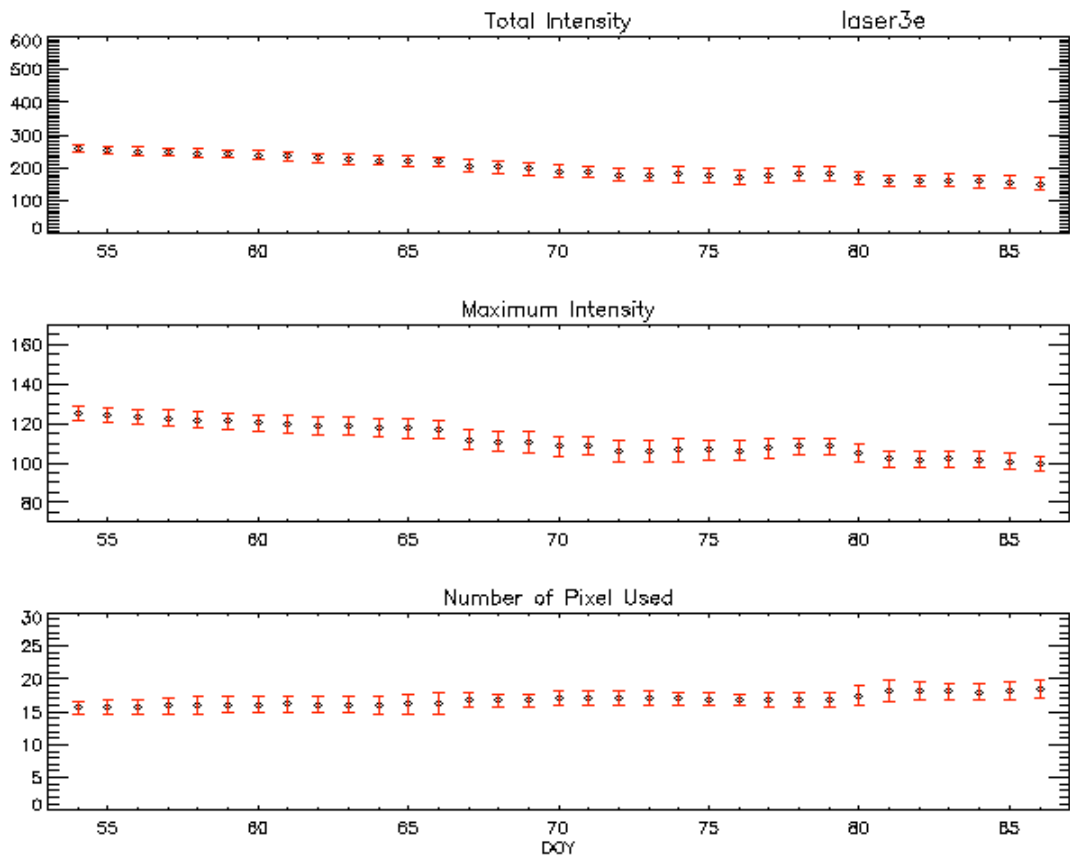Figure 7. Campaign L2c LPA orientation, major axis and eccentricity.
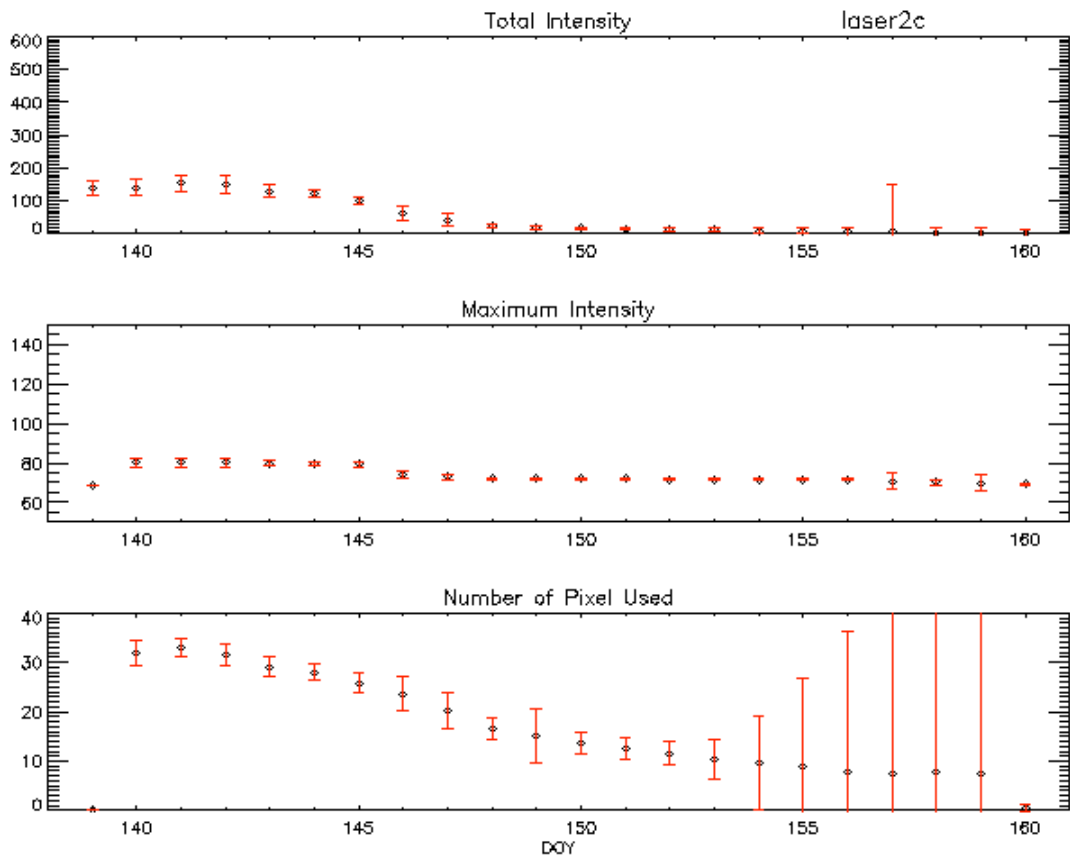
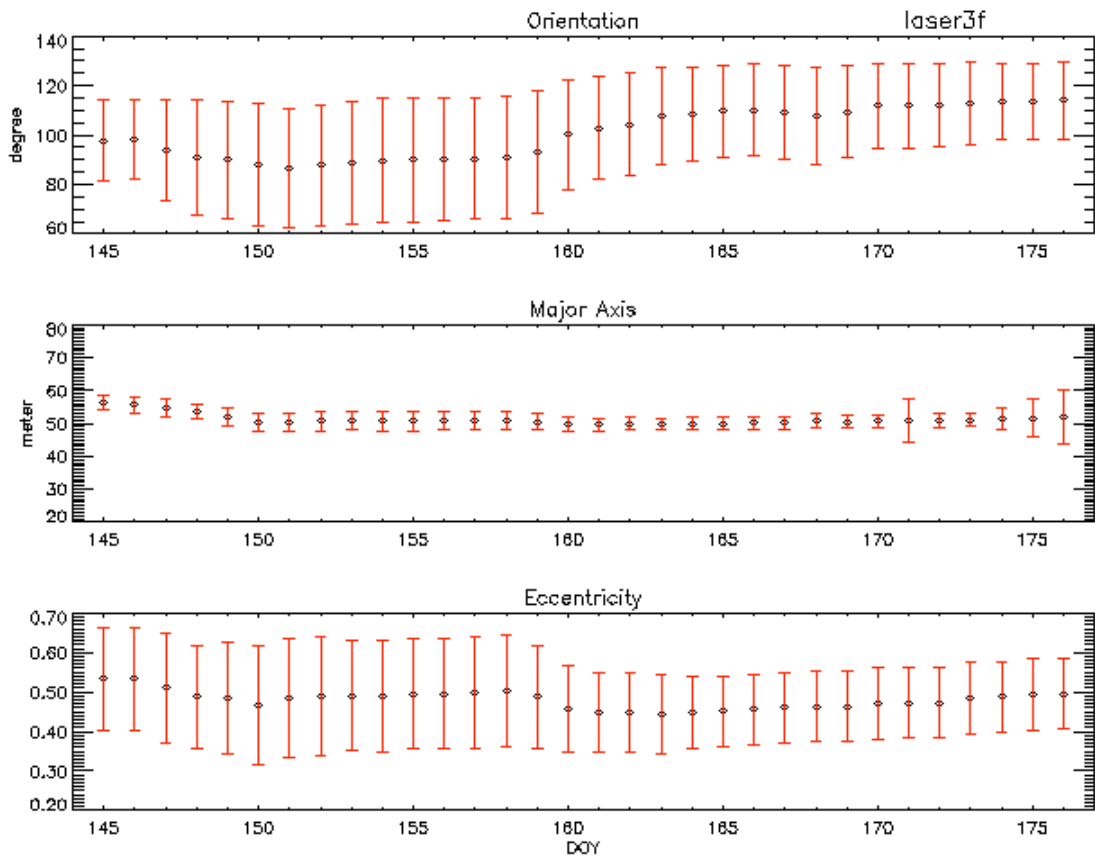Figure 8. Campaign L2c LPA total intensity, maximum intensity, and number of LPA pixels within the $1/e^2$ criterion.
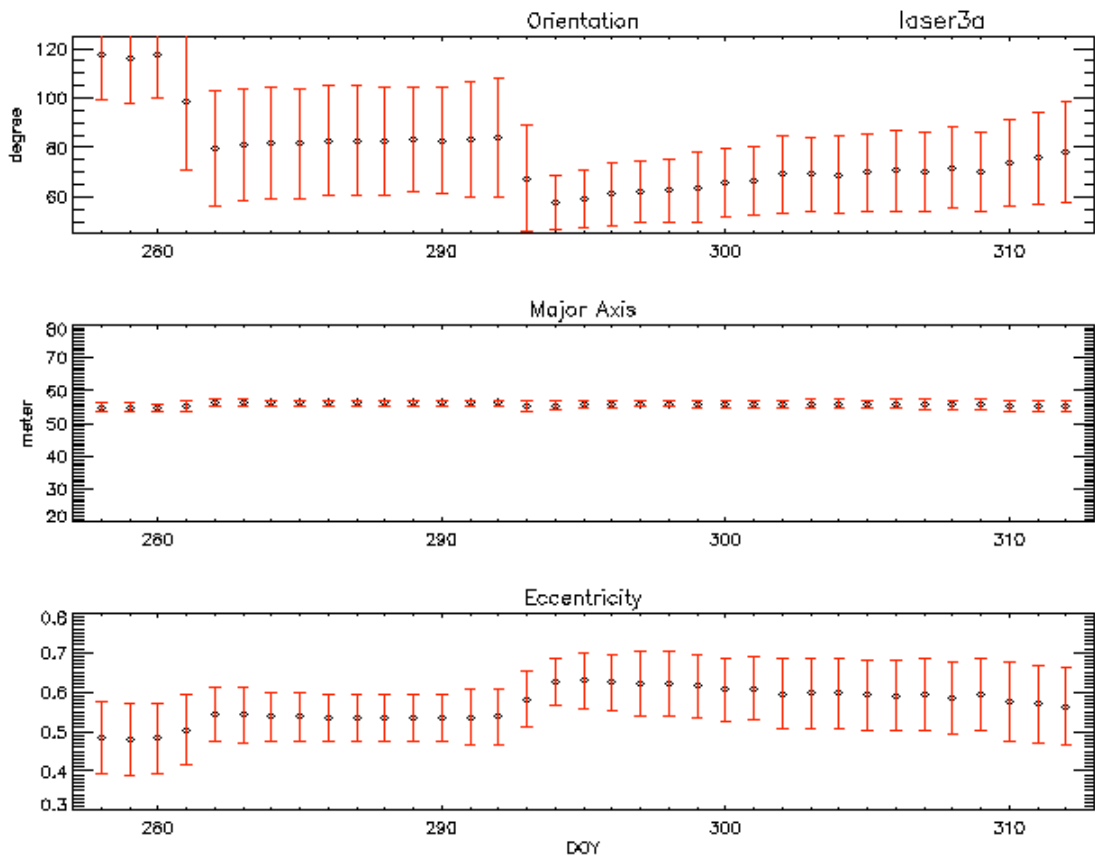
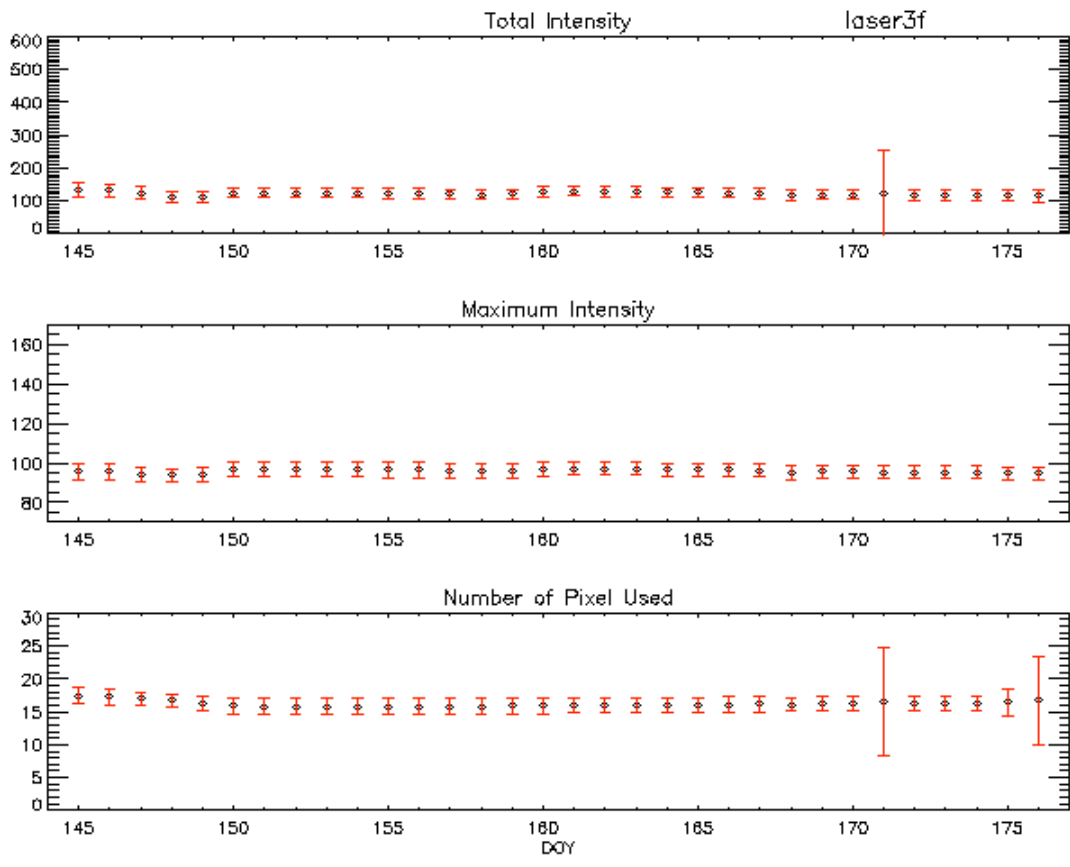Figure 9. Campaign L3a LPA orientation, major axis and eccentricity.
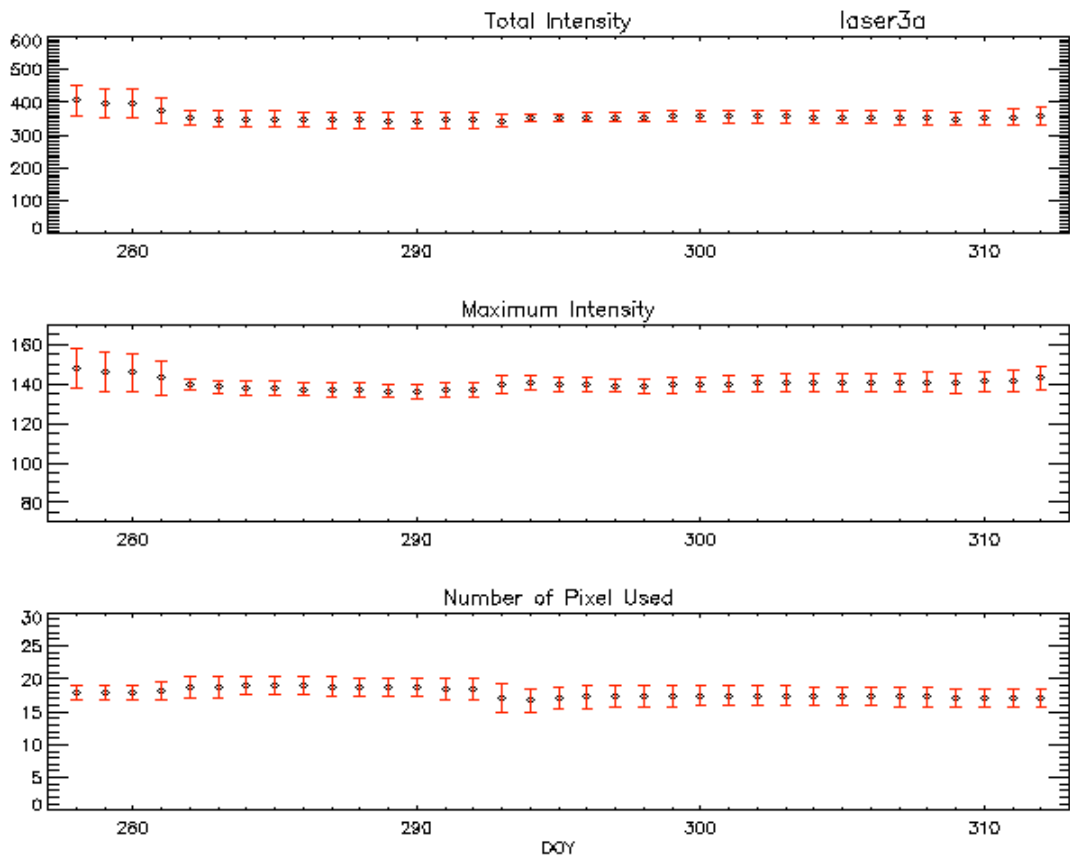
Figure 10. Campaign L3a LPA total intensity, maximum intensity, and number of LPA pixels within the *1/e²* criterion.
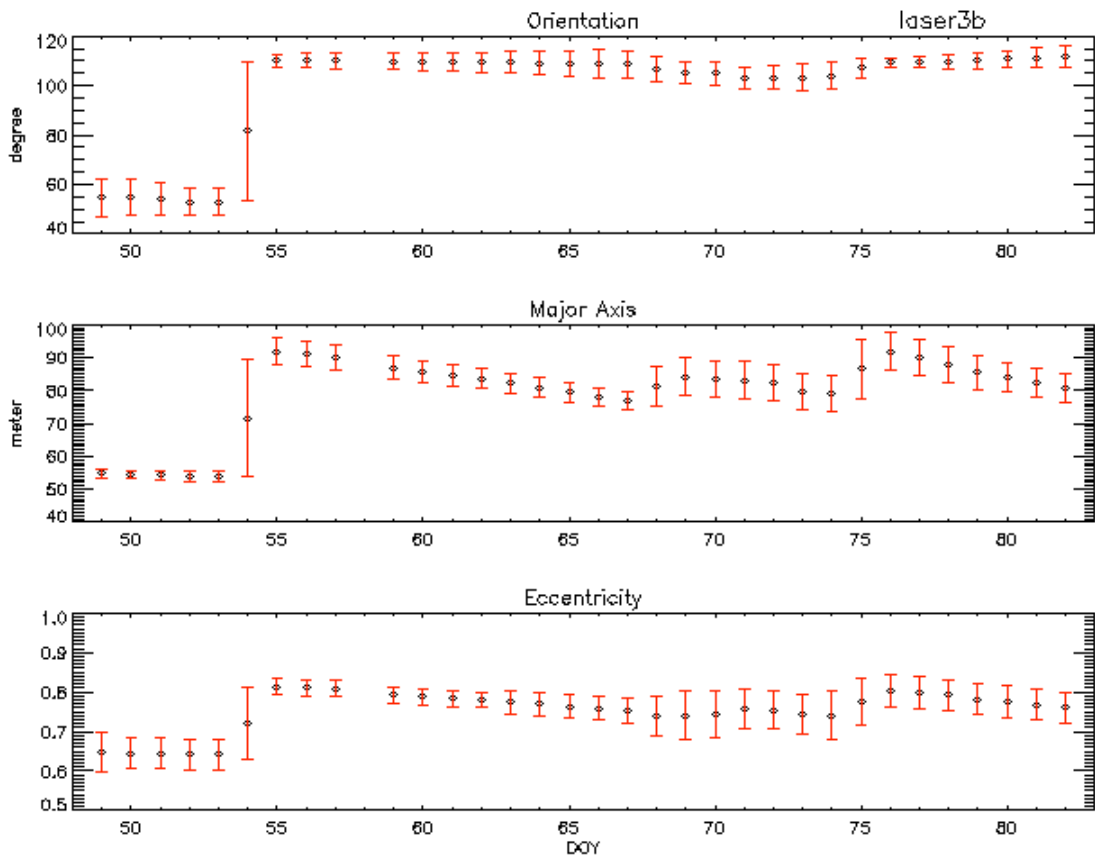
Figure 11. Campaign L3b LPA orientation, major axis and eccentricity.
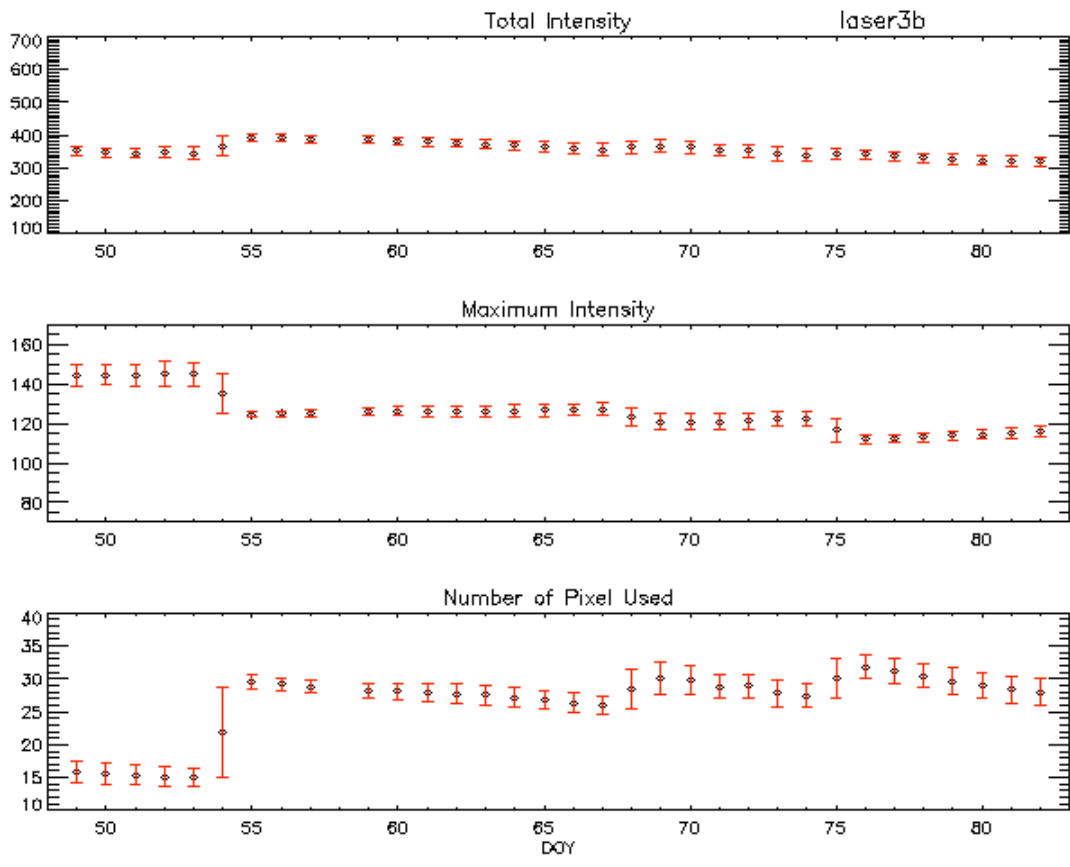
Figure 12. Campaign L3b LPA total intensity, maximum intensity, and number of LPA pixels within the $1/e^2$ criterion.
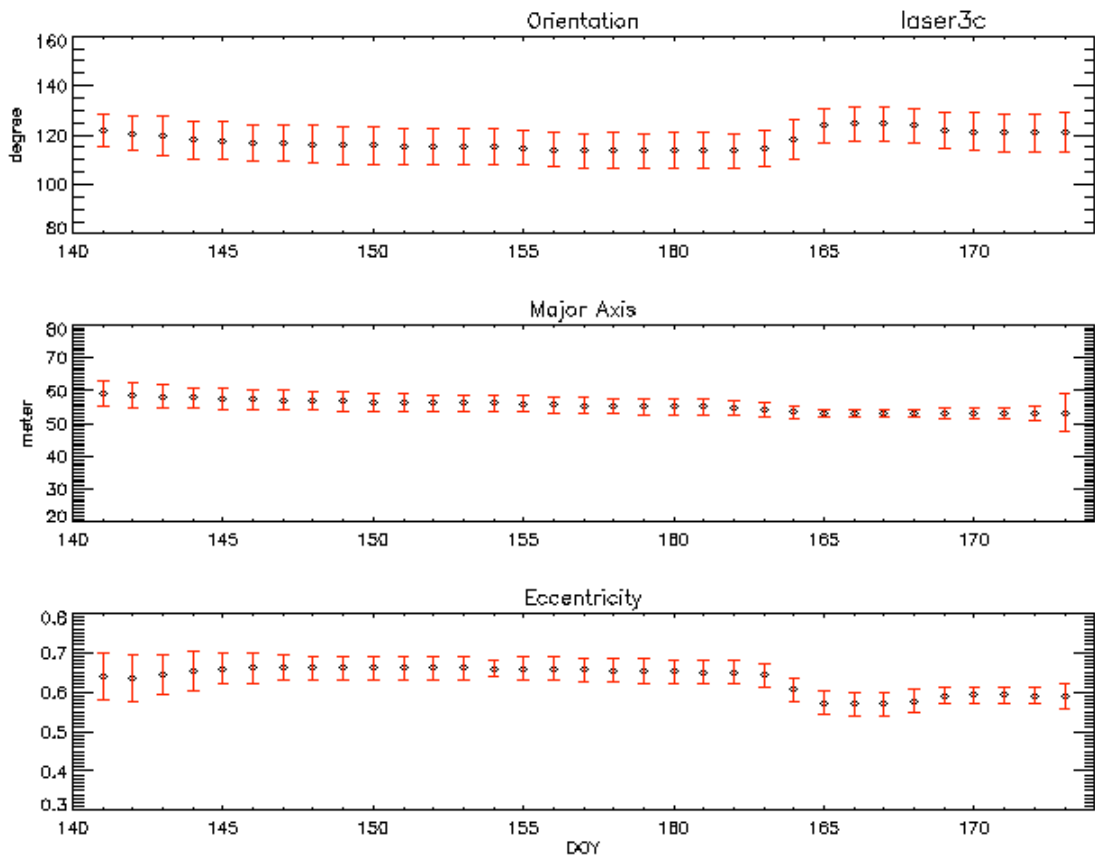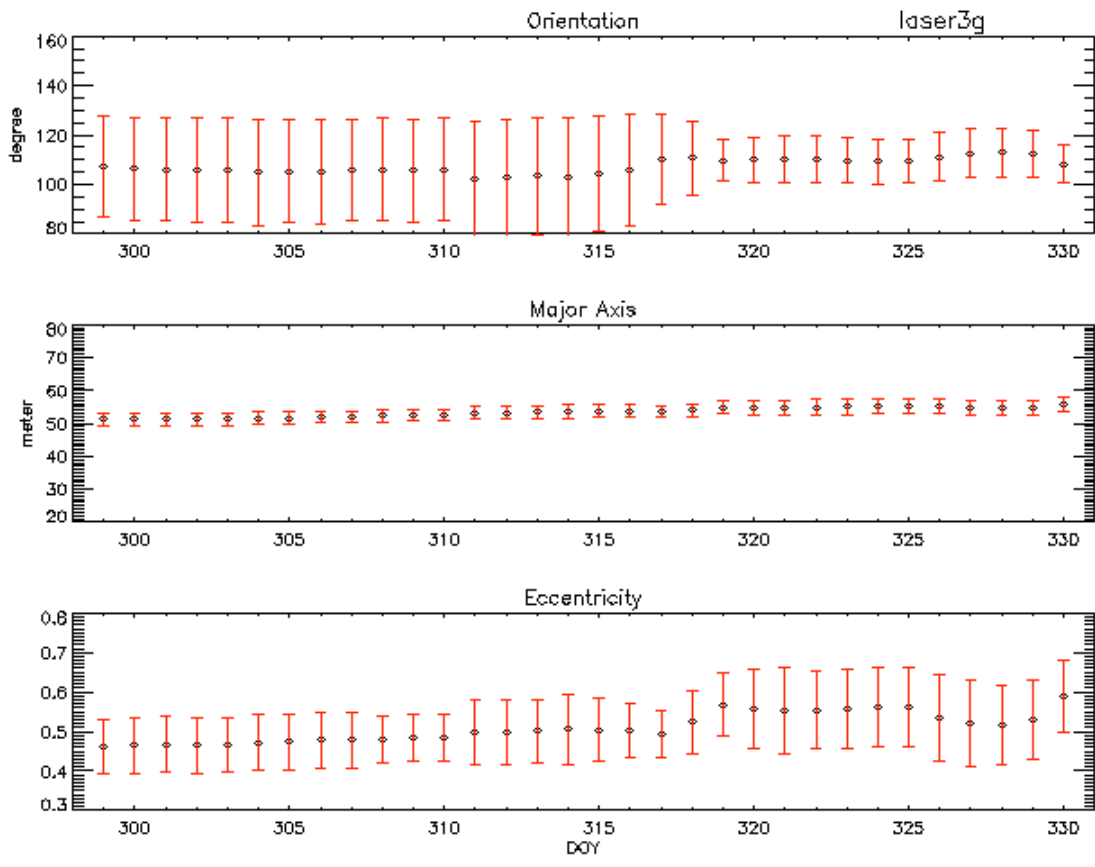
Figure 13. Campaign L3c LPA orientation, major axis and eccentricity.

Figure 14. Campaign L3c LPA total intensity, maximum intensity, and number of LPA pixels within the $1/e^2$ criterion.

Figure 15. Campaign L3d LPA orientation, major axis and eccentricity.
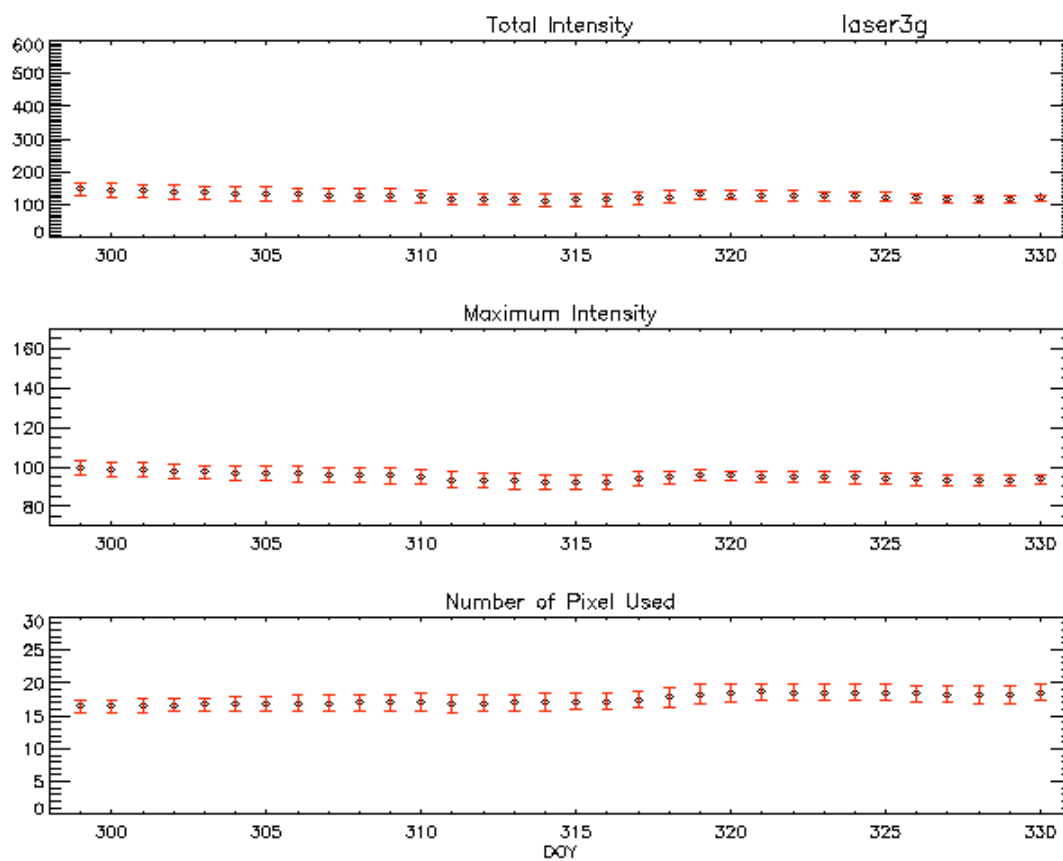
Figure 16. Campaign L3d LPA total intensity, maximum intensity, and number of LPA pixels within the $1/e^2$ criterion.
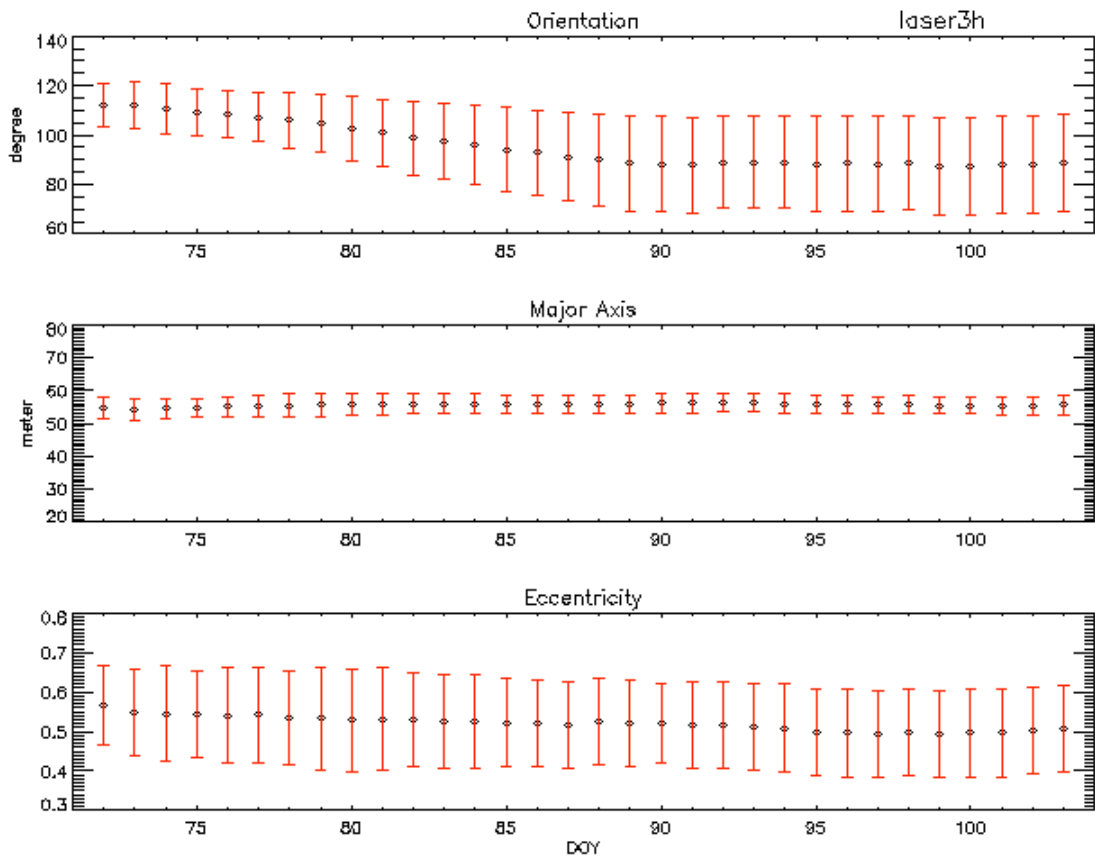
Figure 17. Campaign L3e LPA orientation, major axis and eccentricity.
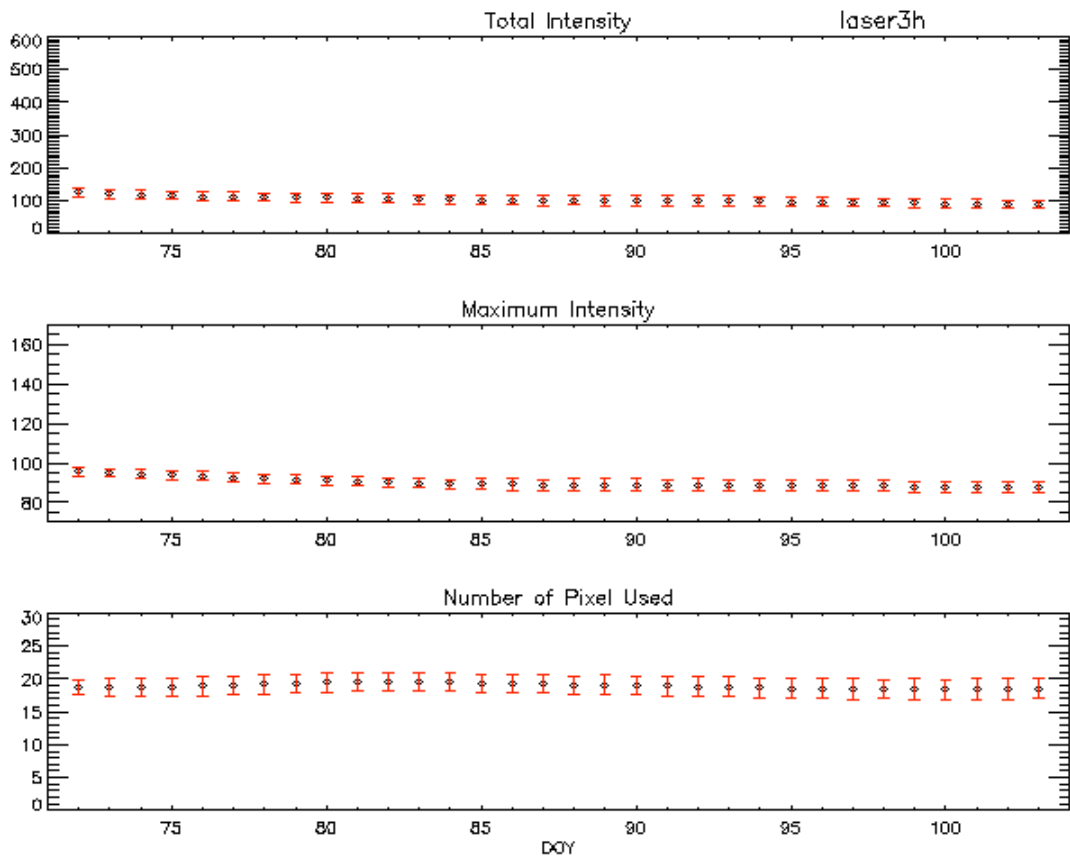
Figure 18. Campaign L3e LPA total intensity, maximum intensity, and number of LPA pixels within the $1/e^2$ criterion.

Figure 19. Campaign L3f LPA orientation, major axis and eccentricity.

Figure 20. Campaign L3f LPA total intensity, maximum intensity, and number of LPA pixels within the $1/e^2$ criterion.
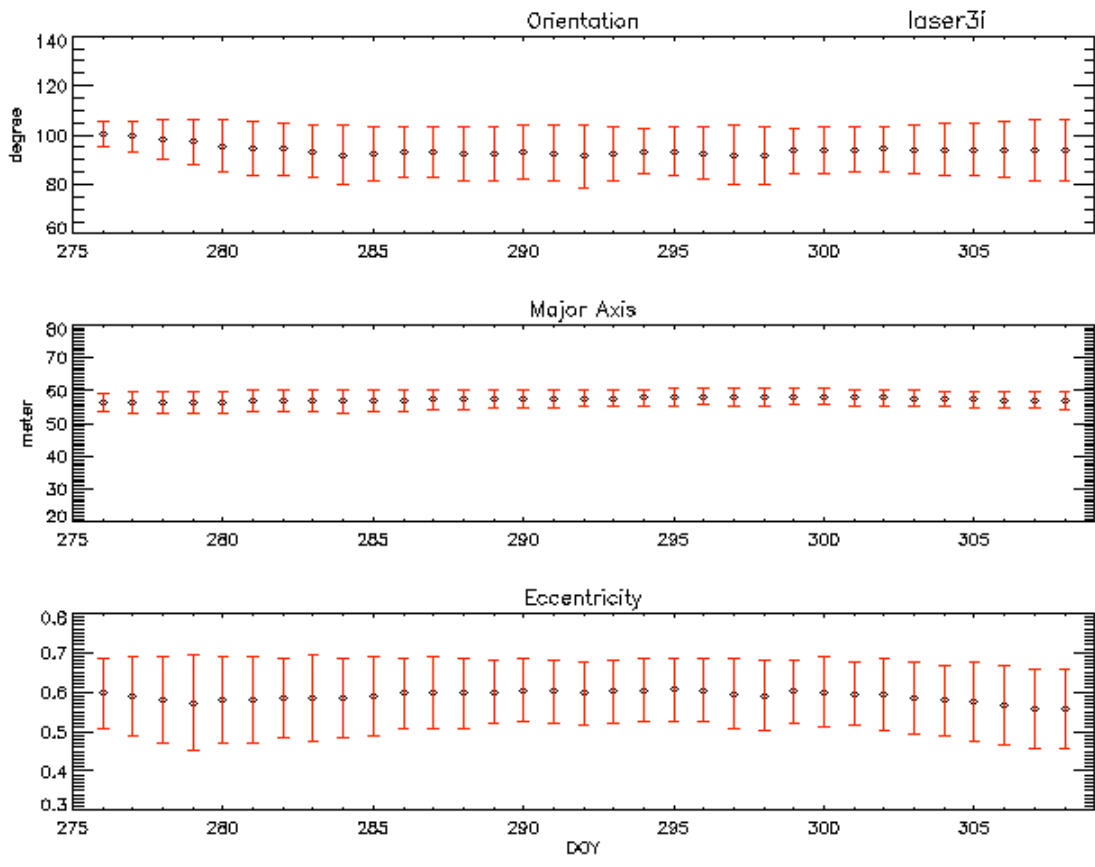
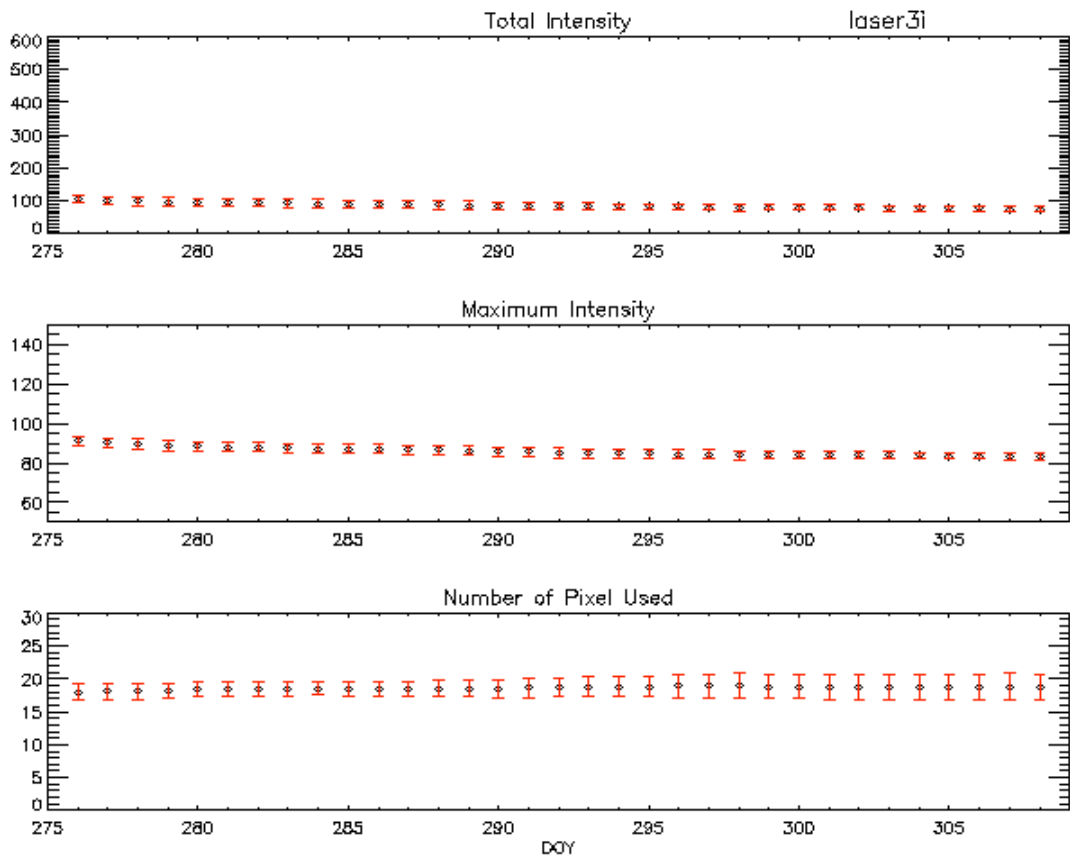Figure 21. Campaign L3g LPA orientation, major axis and eccentricity.

Figure 22. Campaign L3g LPA total intensity, maximum intensity, and number of LPA pixels within the $1/e^2$ criterion.

Figure 23. Campaign L3h LPA orientation, major axis and eccentricity.

Figure 24. Campaign L3h LPA total intensity, maximum intensity, and number of LPA pixels within the $1/e^2$ criterion.

Figure 25. Campaign L3i LPA orientation, major axis and eccentricity.

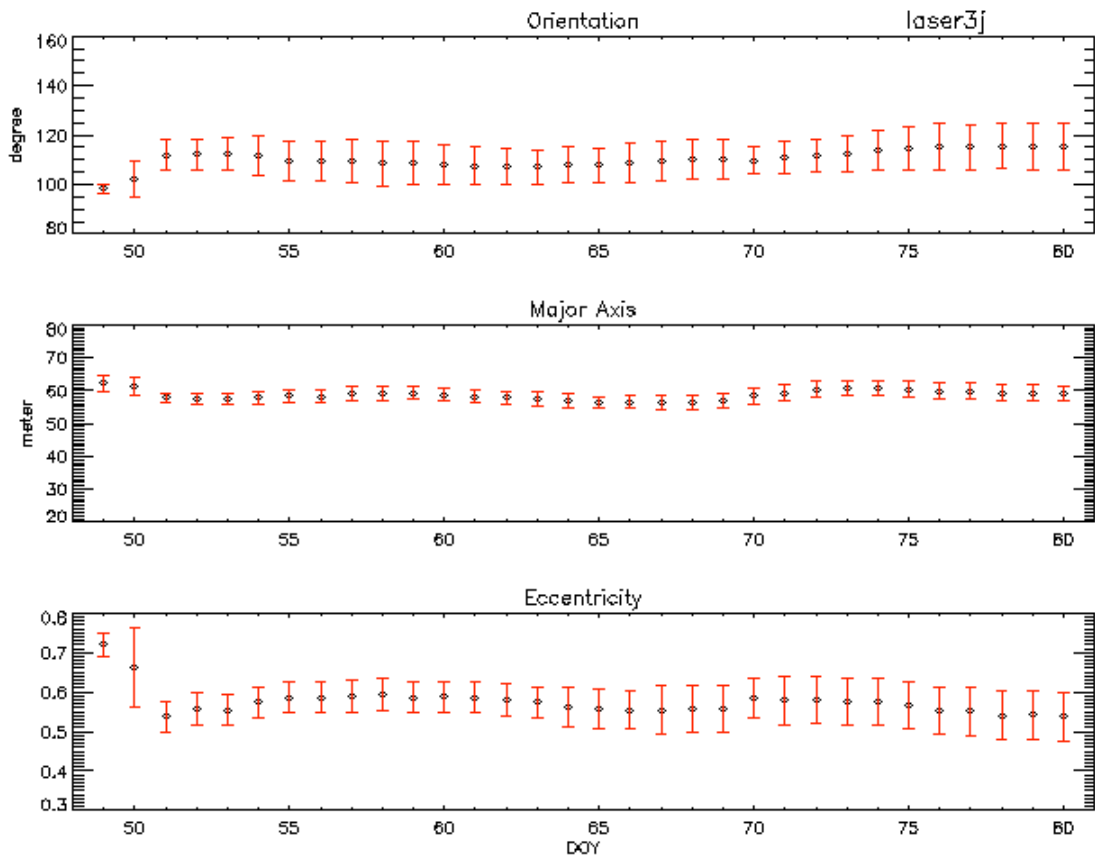Figure 26. Campaign L3i LPA total intensity, maximum intensity, and number of LPA pixels within the $1/e^2$ criterion.

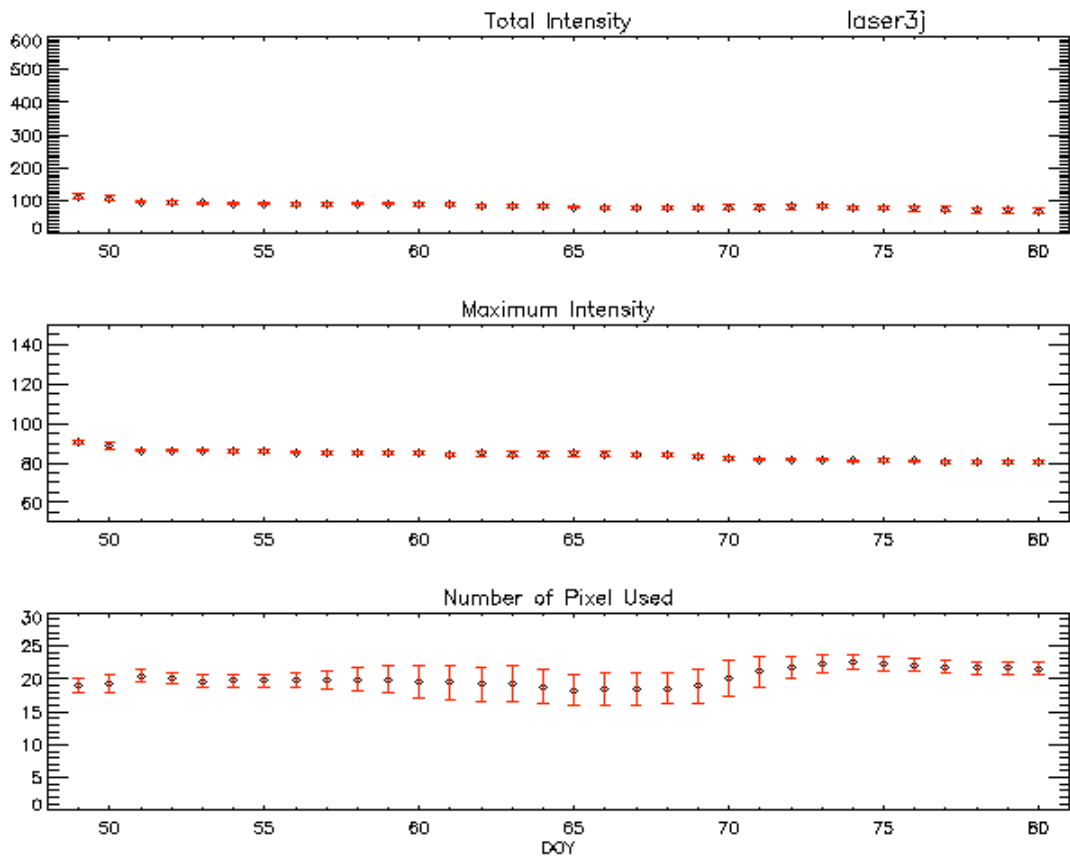Figure 27. Campaign L3j LPA orientation, major axis and eccentricity.

Figure 28. Campaign L3j LPA total intensity, maximum intensity, and number of LPA pixels within the $1/e^2$ criterion.
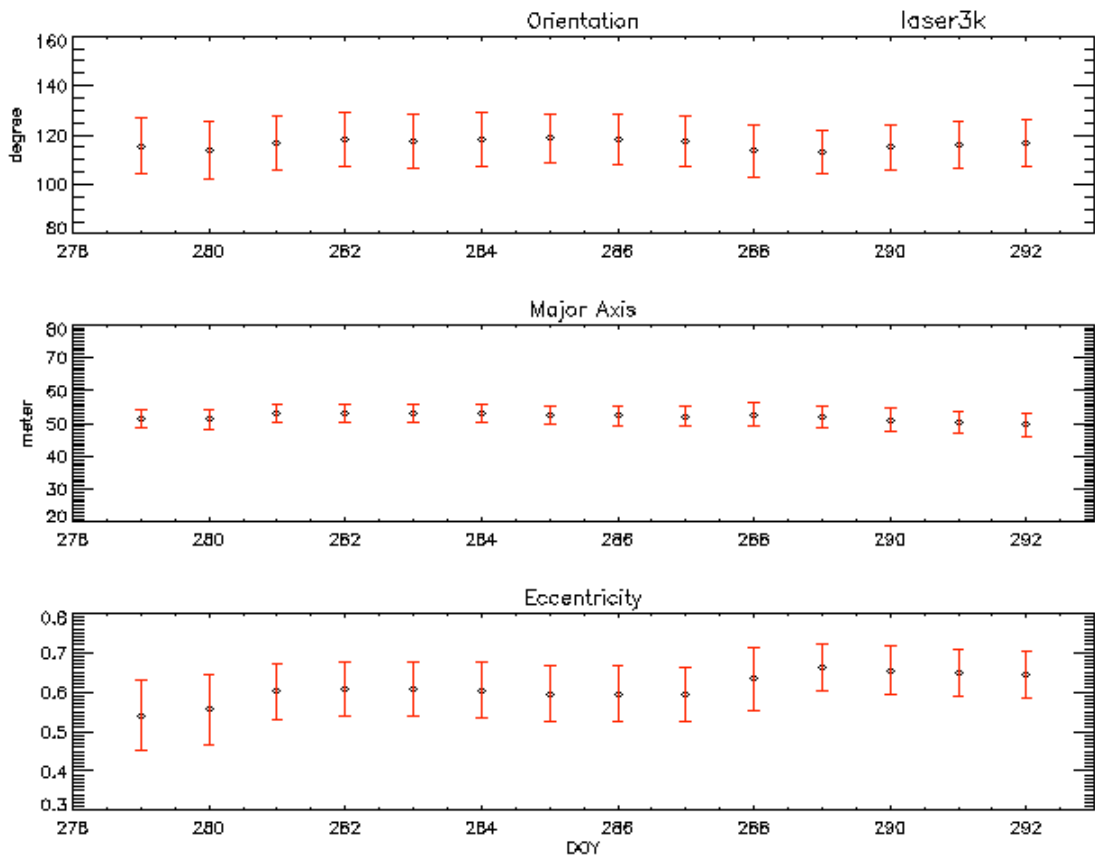
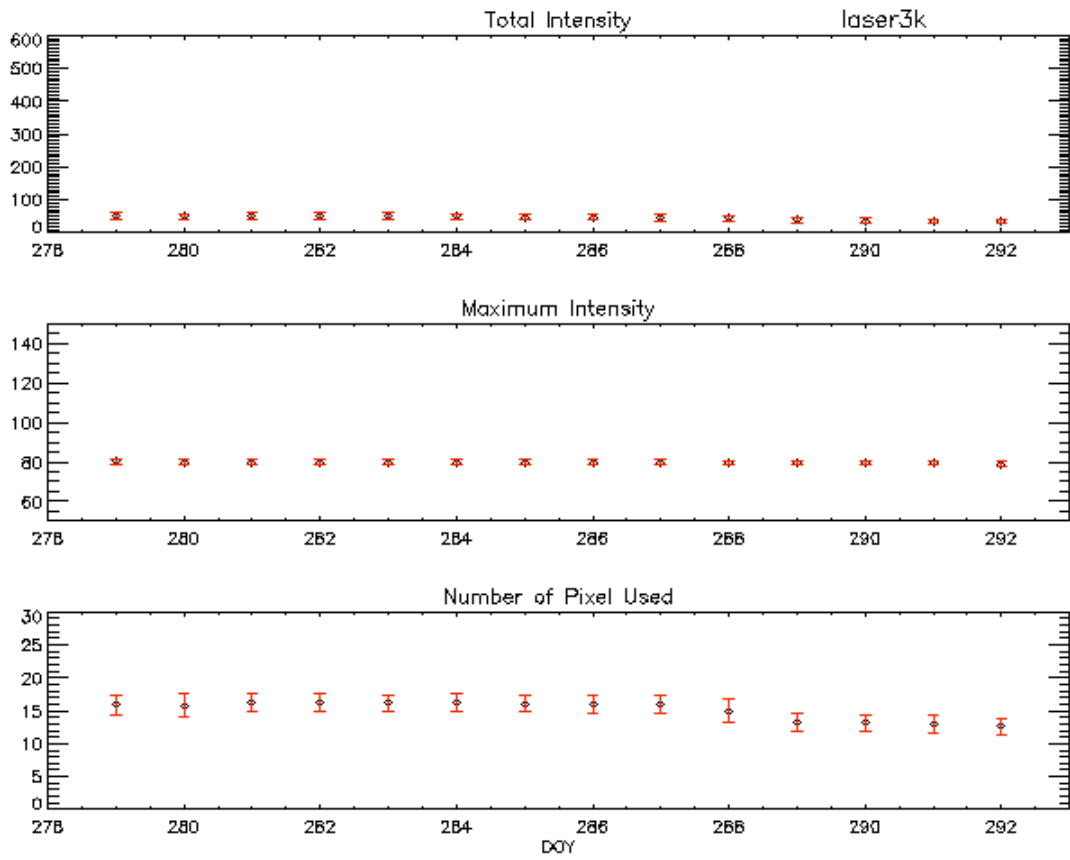Figure 29. Campaign L3k LPA orientation, major axis and eccentricity.

Figure 30. Campaign L3k LPA total intensity, maximum intensity, and number of LPA pixels within the $1/e^2$ criterion.