Documenting Changes in Lightning Imaging Sensor (LIS) Statistics

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ABSTRACT: The Lightning Imaging Sensor (LIS) has been detecting lightning from space onboard the TRMM satellite since November 1997. During this time it has completed over 88000 orbits and has detected over 21,000,000 million lightning flashes. This study documents changes in LIS lightning statistics that resulted from a boost in the satellite altitude (from 350 km to 402.5 km) which occurred in August 2001. This orbital altitude boost was made in order to reduce atmospheric drag to prolong the satellite lifetime. This resulted in a larger ground observation footprint after the boost. The LIS field of view prior to the orbital boost was about 560×560 km which increased to 640 km × 640 km post boost. The nadir pixel resolution increased from about 3.5 km pre-boost to 4.2 km post-boost, while the viewing time of a point observed by LIS as it travels overhead increased from 80 s pre-boost to 92 s post-boost.

For the LIS lightning parameters, the mean LIS flash radiance was decreased from 914 μJ m^{-2} sr^{-2} nm^{-1} pre-boost to 690 μJ m^{-2} sr^{-2} nm^{-1} post-boost. The mean LIS event radiance decreased from 14.1 μJ m^{-2} sr^{-2} nm^{-1} pre-boost to 13.7 μJ m^{-2} sr^{-2} nm^{-1} post-boost. The mean number of events per flash decreased from 64.7 pre-boost to 50.2 post-boost. The mean flash duration decreased by 9 ms (from 267 to 258 ms).

INTRODUCTION

The Lightning Imaging Sensor (LIS) (Christian et al., 2000) has been detecting lightning from space onboard the TRMM (Tropical Rainfall Measuring Mission) satellite since November 1997. During this time LIS has completed over 88000 orbits and has detected over 21,000,000 million lightning flashes. Buechler et al. (2014) documented the stability of the LIS during its time in orbit by examining the background (BG) pixel radiance values of Deep Convective Clouds (DCCs) and found no discernible change in the LIS DCC BG radiance from 1998-2010. This indicates that the LIS has suffered little, if any, performance degradation over the period. During August 2001, the orbital altitude of the TRMM satellite was increased from 350 to 402.5 km in order to reduce atmospheric drag and lengthen the life of the mission. This study documents changes in various lightning parameters observed by LIS due to an orbit boost that occurred during August 2001. In the following discussion, the term "pre-boost" refers to the period from January 1998 through July 2001 while "post-boost" refers to the period from September 2001 through December 2013.

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LIS INSTRUMENT

The LIS instrument detects lightning from space by detecting rapid optical transients produced by lightning. The LIS consists of a 128×128 pixel charge-coupled device (CCD), a narrowband (0.909 nm width) interference filter centered at a wavelength of 777.4 nm, a wide field-of-view lens system, and a Real Time Event Processor (RTEP) (Christian et al., 1989). The 777.4 nm wavelength is used to optimize lightning detection since the lightning spectrum contains a prominent oxygen emission triplet near 777.4 nm.

The CCD array is read out every 2 ms in order to detect short duration events. The CCD image is also stored digitally in order to produce a background image which is also read out. Since daytime solar illumination is much stronger than the lightning signal, a modified frame-by-frame background subtraction is implemented to remove the slowly varying background signal from the raw data coming off the LIS focal plane. If the current value of a pixel exceeds that of the average of the 6 previous frames by a certain threshold, then that is identified as an event. Further processing is performed once the data have been transmitted to ground in order to filter out noise events (glint, high energy particles, etc.). The remaining events are then identified as LIS lightning events. The LIS lightning events are then clustered into groups (contiguous events occurring at the same frame time - similar to strokes), and flashes (spatially and temporally correlated groups). For further details on the LIS instrument design see Christian et al. (1989) and Christian et al. (2000).

RESULTS

After the orbit boost, the LIS field of view increased from about 560 km × 560 km pre-boost to 640 km × 640 post-boost. The nadir pixel resolution increased from about 3.5 km pre-boost to 4.2 km post-boost. The viewing time that a point on the ground is observed by LIS as it passes overhead increased from 80 s pre-boost to 92 s post-boost.

Figure 1 shows distributions and statistics for lightning events detected by LIS. The LIS detected a total of 253,276,318 lightning events during the 43 pre-boost months, and 884,902,558 lightning events in the post-boost period (148 months). The mean event radiance decreased from 14.1 μJ m^{-2} sr^{-2} nm^{-1} pre-boost to 13.7 μJ m^{-2} sr^{-2} nm^{-1} post-boost. Yearly plots (not shown) confirm that the decrease occurs during August 2001, with values remaining steady before and after August 2001. The mean LIS event footprint size increases from 22.6 km^2 pre-boost to 25.3 km^2 post-boost.

LIS lightning group statistics are shown in Figure 2. There were 46,244,848 groups detected pre-boost while post-boost 201,177,873 groups were observed. The mean group radiance decreased from 72.2 μJ m^{-2} sr^{-2} nm^{-1} pre-boost to 61.6 μJ m^{-2} sr^{-2} nm^{-1} post-boost. The mean group footprint size pre-boost was 117.4 km^2 which decreased to 112.8 km^2 post-boost. The average number of events per group decreased from 5.1 pre-boost to 4.5 post-boost.

For LIS flash statistics (Figure 3), there were a total of 3,915,595 flashes detected pre-boost and 17,622,280 flashes post-boost. Pre-boost mean LIS flash radiance values were 913.8 2 μJ m^{-2} sr^{-2} nm^{-1} which decreased to 689.2 2 μJ m^{-2} sr^{-2} nm^{-1} post-boost. The mean LIS flash footprint size decreased from 304.1 km^2 pre-boost to 290.9 km^2 post-boost. There was a mean value of 64.7 LIS events per flash pre-boost which decreased to 50.2 post-boost. The mean number of LIS groups per flash decreased from a pre-boost value of 12.4 to 11.3 post-boost. The mean LIS flash duration pre-boost was 0.267 s which decreased by 9 ms to 0.258 s post-boost. The decrease in the number of groups per flash post-boost is consistent with the decrease in flash duration seen post-boost.

SUMMARY AND CONCLUSIONS

Statistics for LIS optical lightning measurements for when the TRMM satellite was at an altitude of 350 km (pre-boost) and 402.5 km (post-boost) were presented for LIS lightning events, groups and flashes. The LIS event footprint increased from pre-boost to post-boost, but the group and flash footprint size decreased due to a decrease in the number of events detected per group and flash. The mean duration of lightning flashes detected by LIS decreased by 9 ms from pre-boost (267 ms) to post-boost (258 ms). The decrease in flash duration is consistent with the decrease in the number of groups per flashes observed pre-boost (12.4) and post-boost (11.3).

These LIS lightning statistics provide a baseline for comparison with future space based optical measurements of lightning such as those that will be obtained by the Geostationary Lightning Mapper (GLM) onboard the GOES-R (Geostationary Operational Environmental Satellite-R series) satellite (Goodman et al, 2013).

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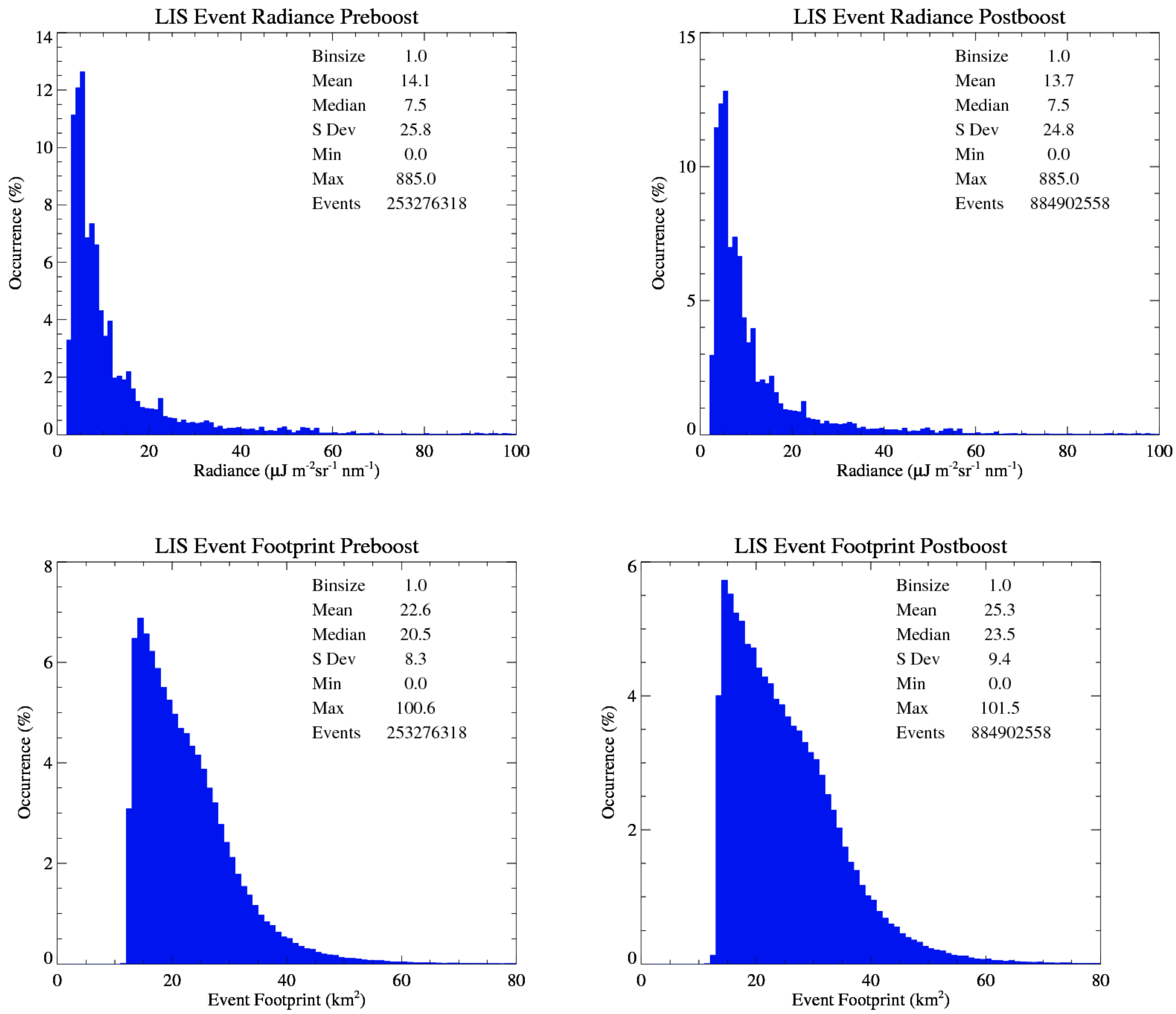

Figure 1. LIS event radiance and footprint size statistics pre- (left column) and post (right column) orbit boost.

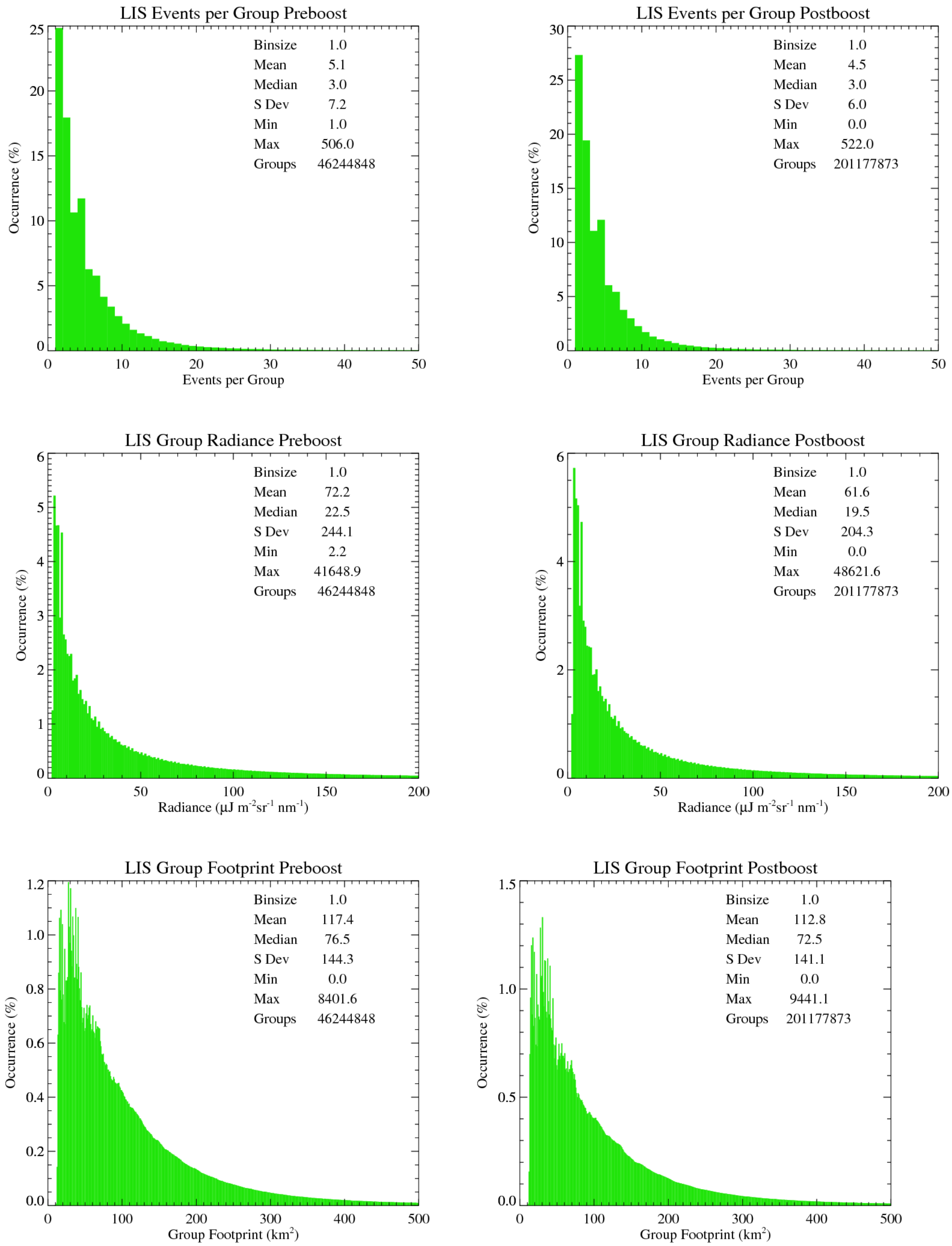

Figure 2. LIS group radiance and footprint size and number of events per group statistics pre- (left column) and post (right column) orbit boost.

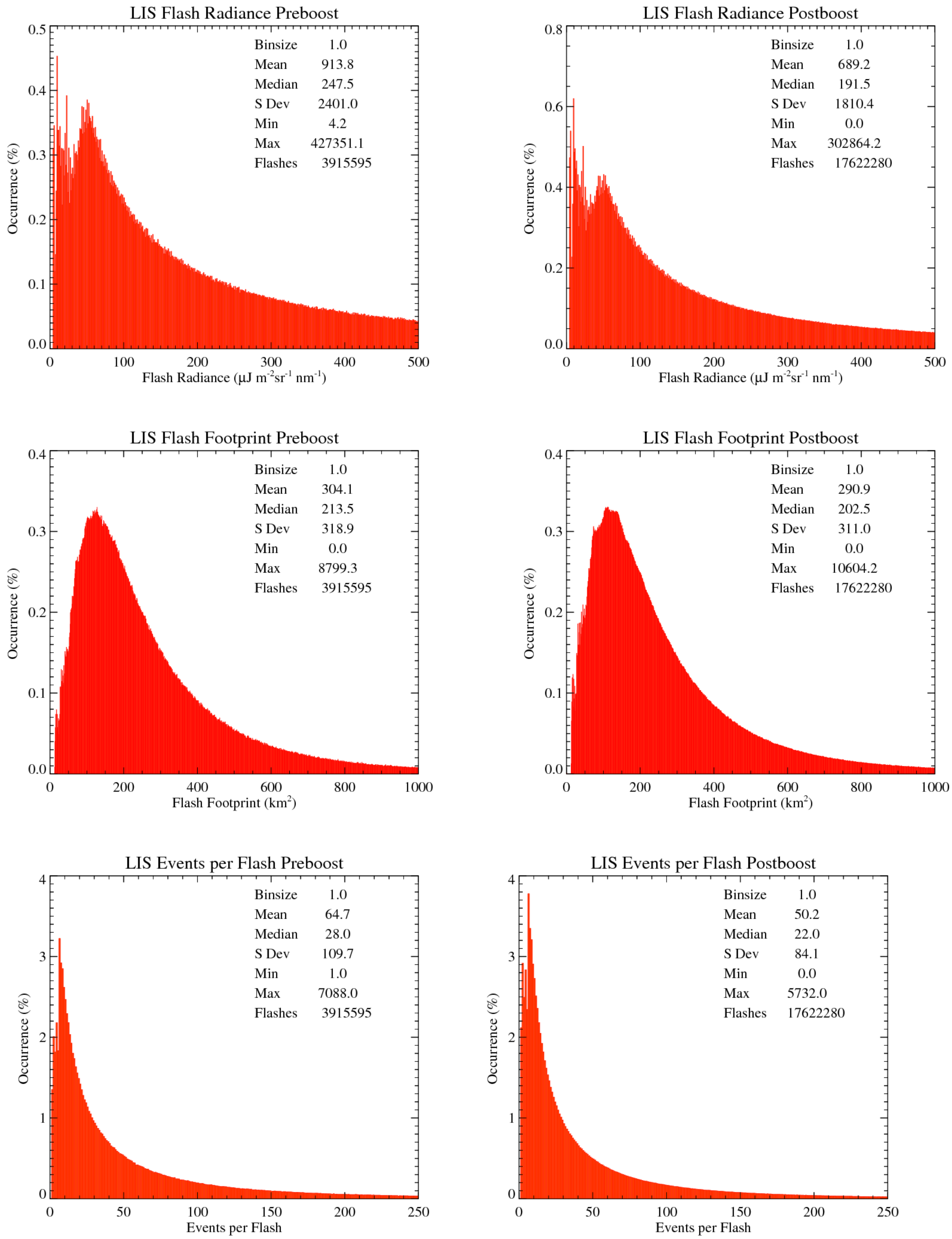

Figure 3. LIS flash statistics for flash radiance and footprint size, the number of events per group, number of groups per flash, and flash duration for pre- (left column) and post (right column) orbit boost periods.

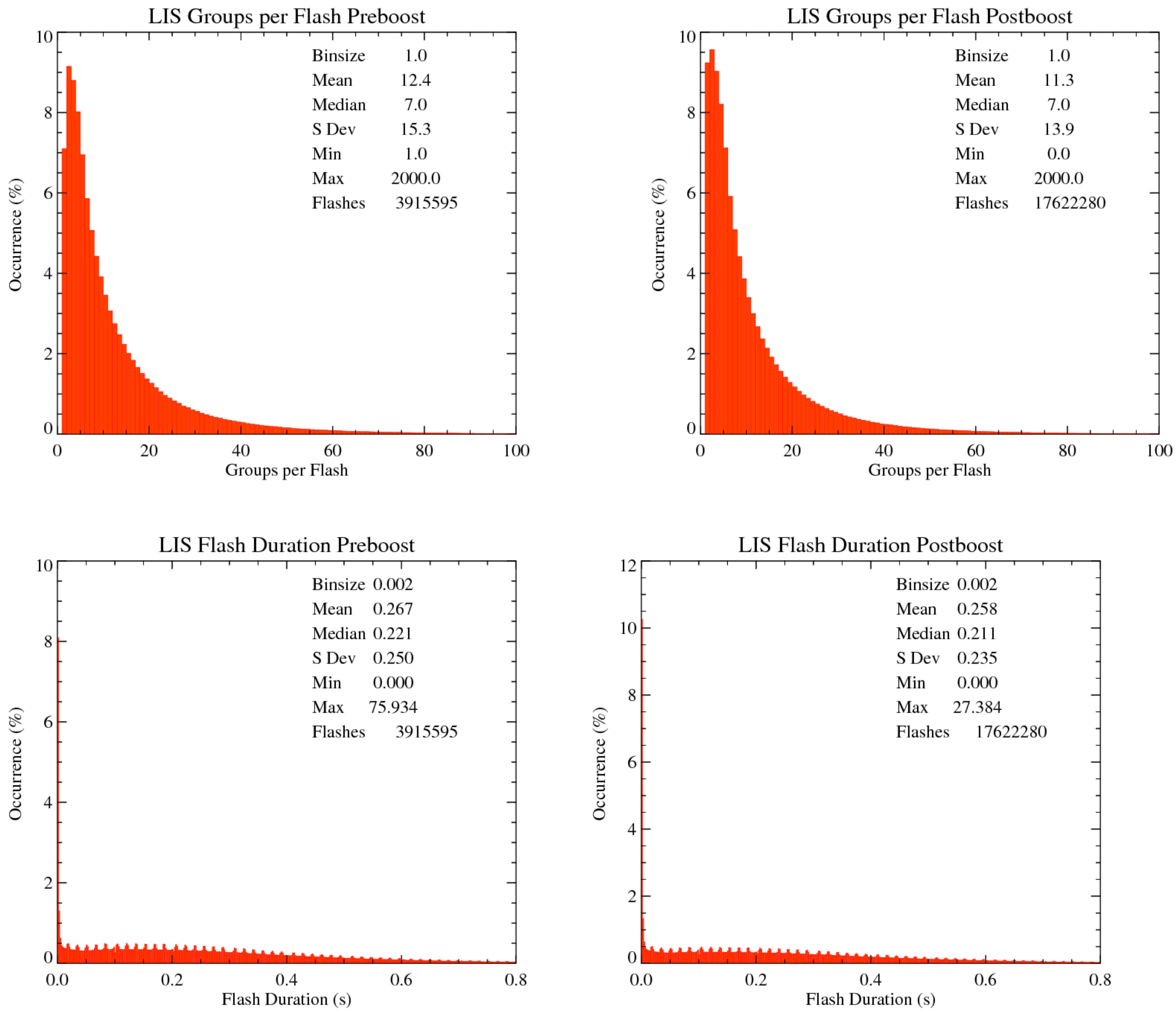

Figure 3 (Continued) LIS flash statistics for flash radiance and footprint size, the number of events per group, numberof groups per flash, and flash duration for pre- (left column) and post (right column) orbit boost periods.