Utilizing ISS Camera Systems for Scientific Analysis of Lightning Characteristics and comparison with ISS-LIS and GLM

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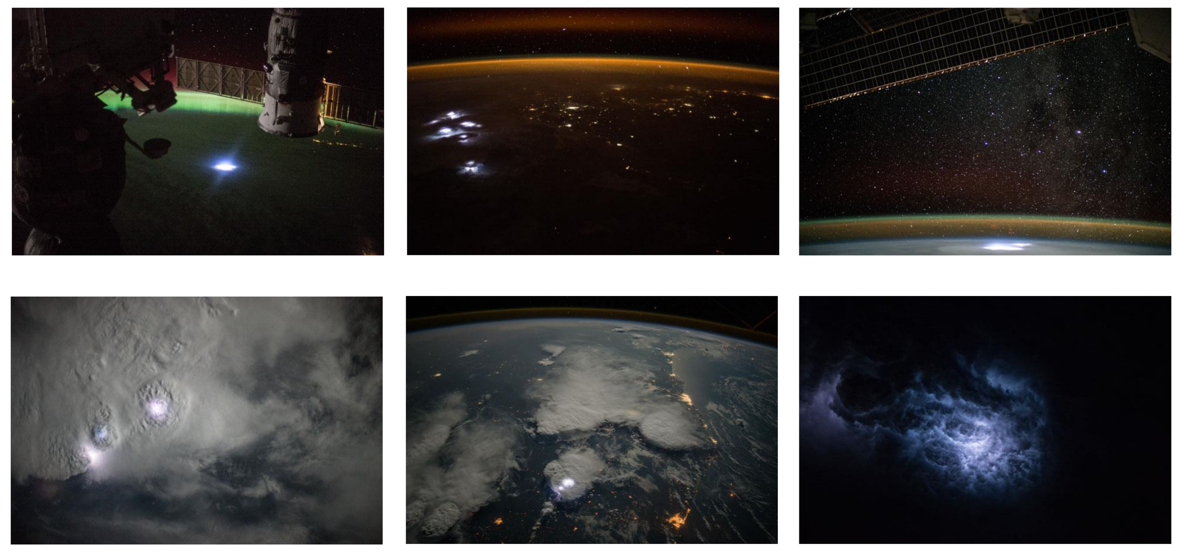
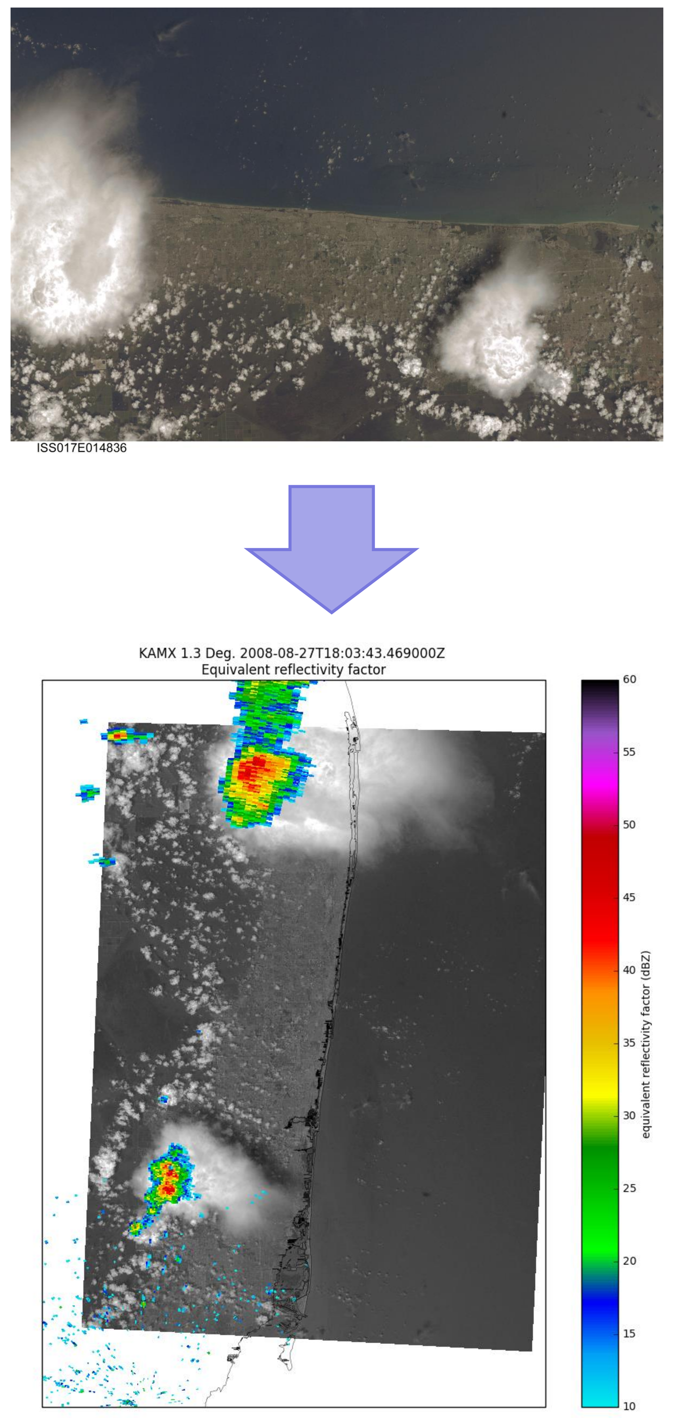
1. Introduction

Video and still frame images from cameras aboard the International Space Station (ISS) are used to inspire, educate, and provide a unique vantage point from low-Earth orbit that is second to none; however, these cameras have overlooked capabilities for contributing to scientific analysis of the Earth and near-space environment. The goal of this project is to study how georeferenced video/images from available ISS camera systems can be useful for scientific analysis, using lightning properties as a demonstration.



2. Geolocation Methodology

The geolocation process merges basic principles of photogrammetry with an algorithm derived from SSMI/S. The SGP4 orbital code along with two-line element (TLE) data for the ISS is used to find position and velocity data for the station at the time of the photograph or video frame. Pointing angle is often not known, but comparison and adjustment to coastlines and city lights can lead to accuracies of ~1-2 pixels for near-nadir shots. *Code is being open sourced soon.*



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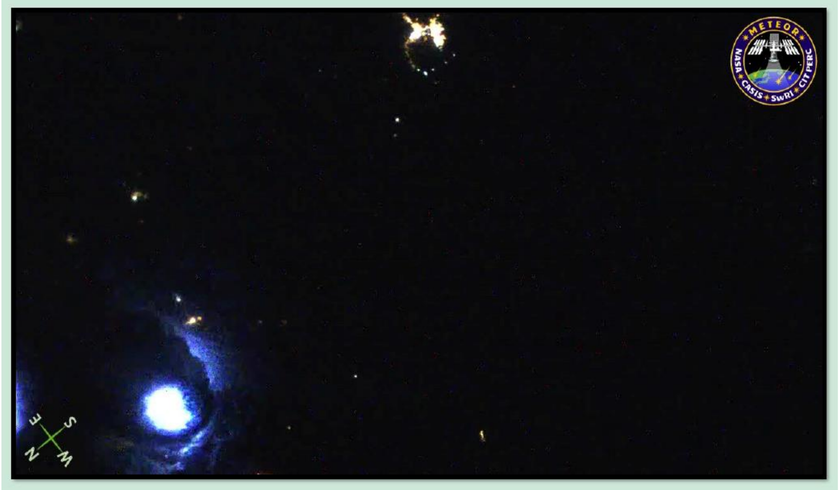
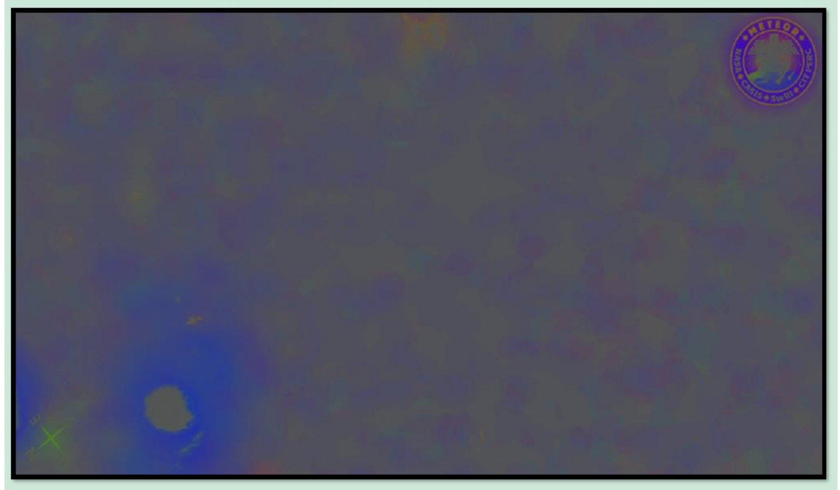
3. Lightning Identification and Classification

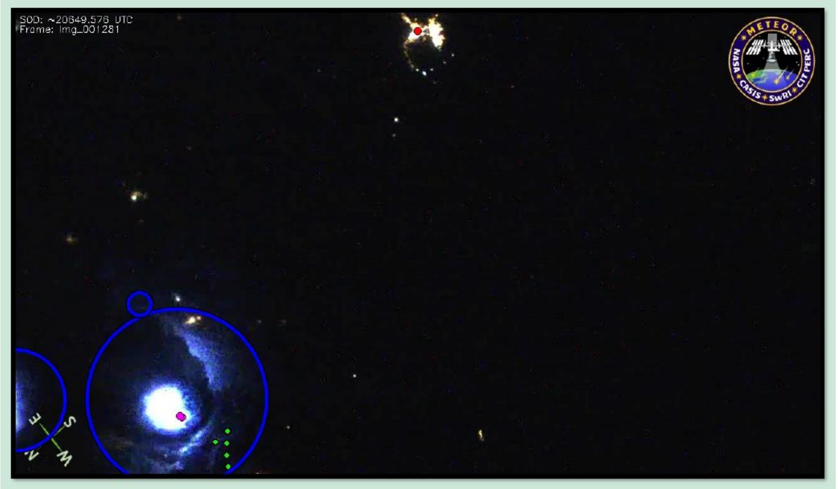


Input image from a METEOR video. Del Rio, TX is located top center. This image was chosen based off of the strong flash geometry used to initially verify timings for this METEOR video. The large amount of light escaping from the side of the cloud lead to some interesting edge case tests on the flash identification algorithm.



Input image after a bilateral blur with a 49x49 kernel size with 0.75 std. dev. for space and color. Standard analysis utilized a 9x9 kernel. The image was then converted to the red green chromaticity color space in order to remove intensity information of pixels for accurate thresholding, especially around city lights.

Red Green Chromaticity image after conversion to Hue Saturation Value color space and application of thresholds to find pixels with highest blue values. The resulting image is a binary mask that has underwent one erosion and seven dilations in order to remove high frequency noise and combine fragmented contours.



Final output of algorithm. The blue circles represent the minimum bounding circles around contours meeting a minimum radius of ten pixels. The green dots represent ISS-LIS event data, whereas the fuchsia dots are NLDN flash data. The single red dot is Del Rio, TX. Note the offset between ISS-LIS and NLDN Data.

- A novel image-based flash identification and classification algorithm (detailed above) was developed to take advantage of the availability of color photos/video, enabling the ability to distinguish between city lights and lightning. The algorithm leveraged the OpenCV library, and was capable of outputting information about temporal and spatial evolution of lightning (e.g., flash size)

- The algorithm was applied to the METEOR camera, which is a near-nadir-mounted HD color video camera being used to track meteors from the ISS. Sensor type is 2/3" HbCMOS, with a focal length of 10.5 mm.

- Key advantages of photographs and video over traditional 777-nm optical lightning tracking include color-based analysis and significantly higher spatial resolution [~0.25 km vs. 2 (8) km for LIS (GLM)]. Note the multiple scattering of light from the side of the cloud in the above pictures.

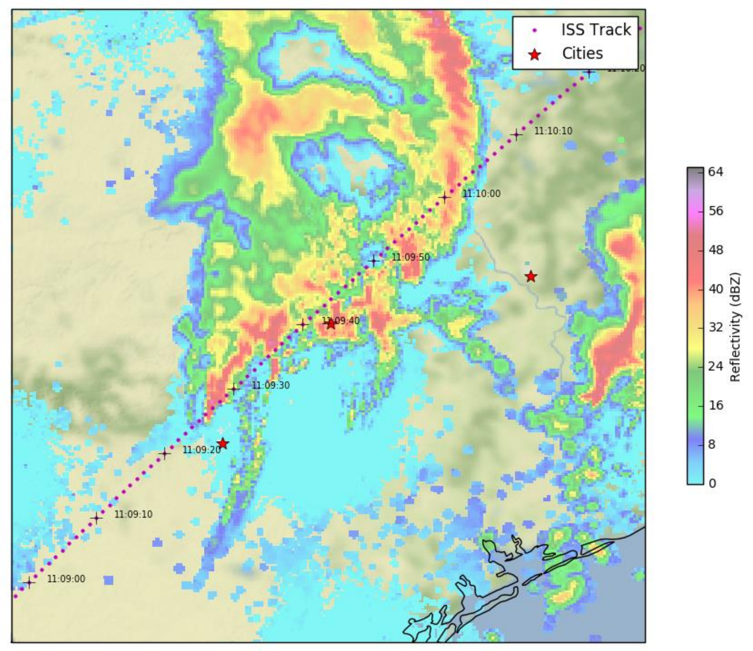
- Key disadvantages include reduced temporal resolution (e.g., 60-fps for METEOR camera vs. 500-fps for LIS/GLM), tendency to saturate in bright lightning, and no daytime detection capability.

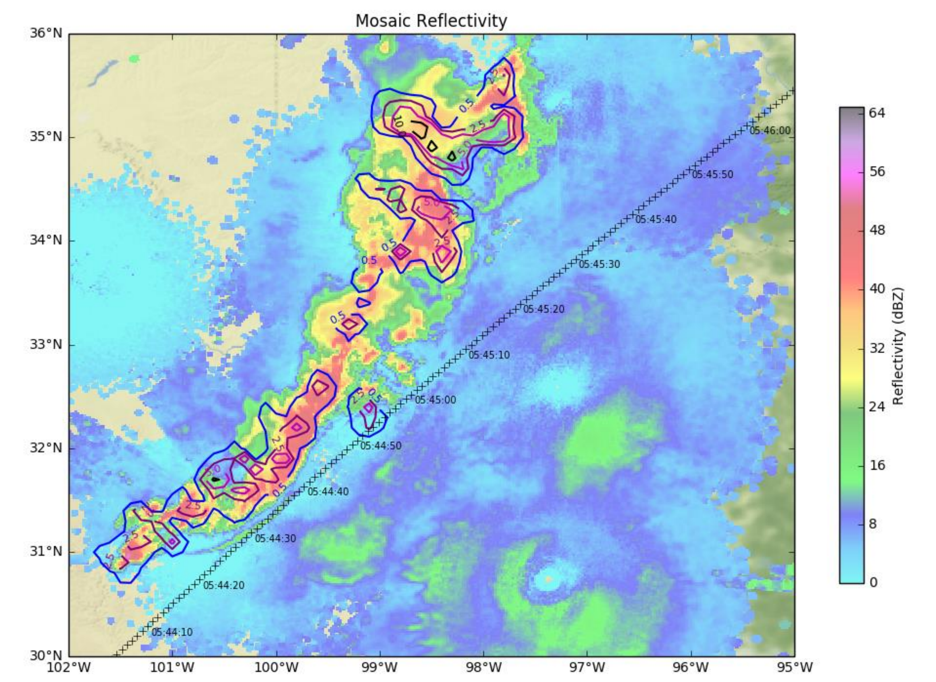
4. Comparing to ISS-LIS, GLM, and NLDN

2 January 2017 - NLDN

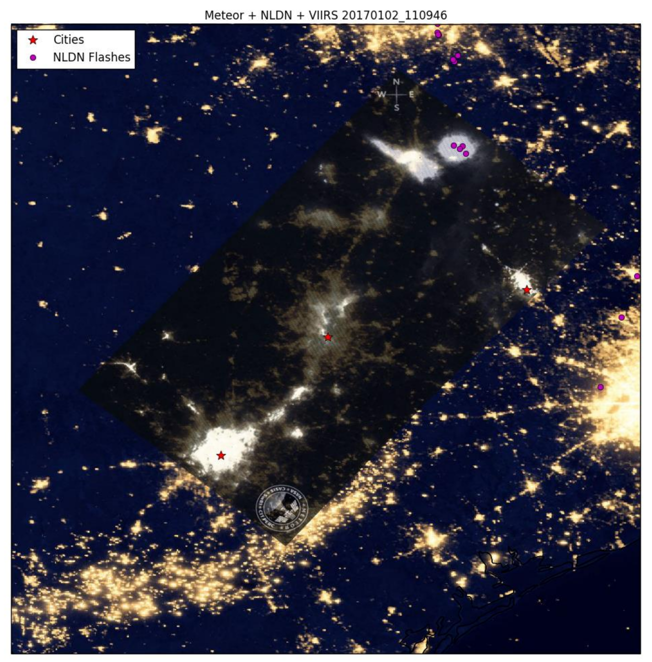
17 May 2017 – LIS, GLM, NLDN

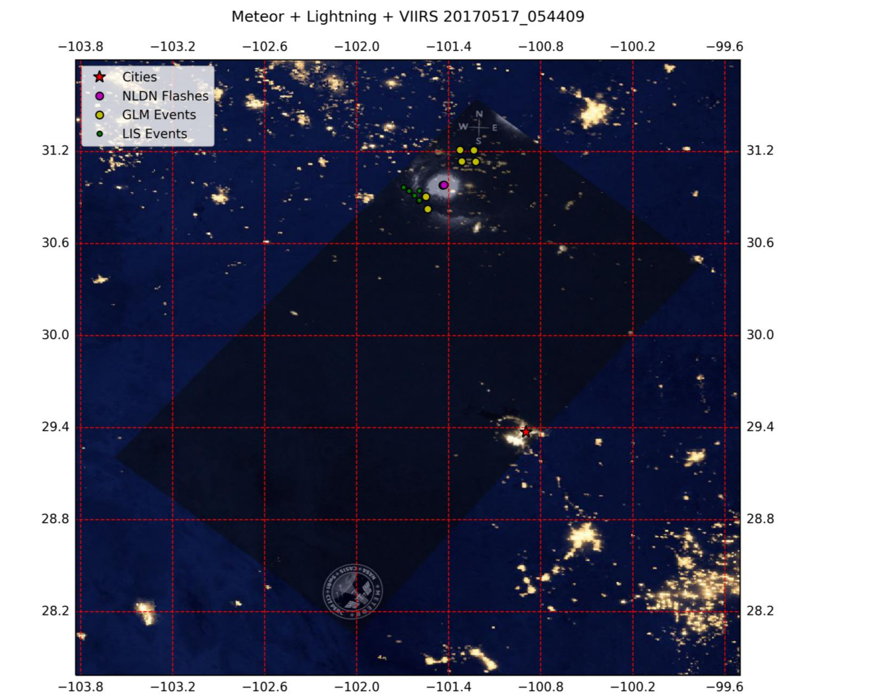
ISS Ground Track, Radar, Lightning



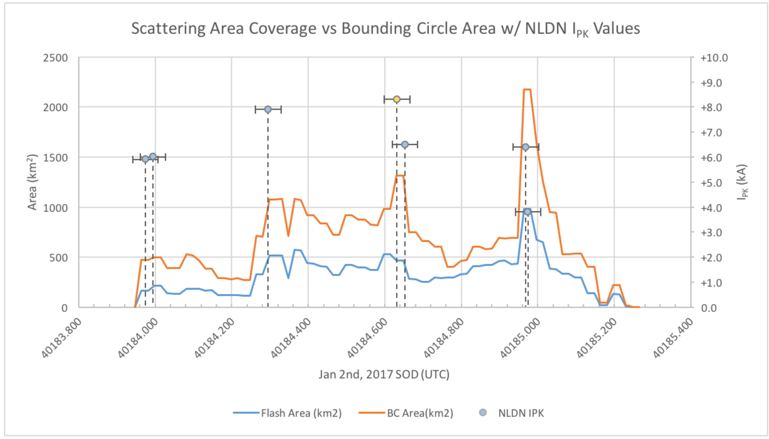


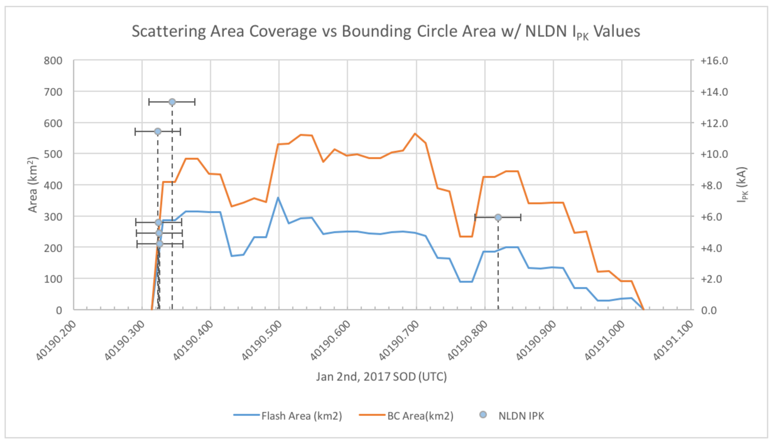
METEOR, City Lights, Lightning

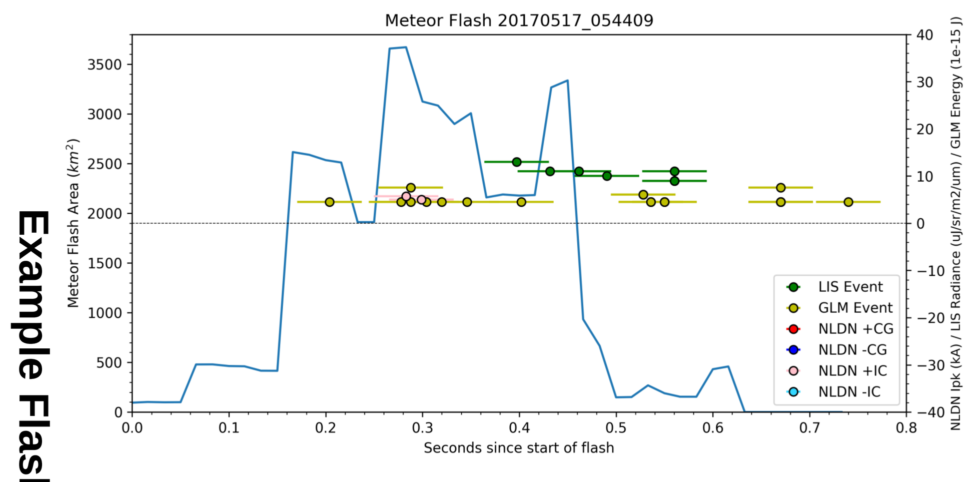




Example Flash Time Series







- Increases in video flash area correspond to NLDN-detected flashes. Video time series links multiple NLDN detections together.

- Spatial offset and timing issues in pre-release LIS and GLM datasets (soon to be corrected) are apparent, demonstrating potential cal/val utility of geolocated video and photographs.

Acknowledgments

Support was provided by the 2017 NASA Science Innovation Fund and the MSFC education office. Astronaut photographs are available at https://eol.jsc.nasa.gov/. Compressed METEOR video was provided by the Chiba Institute of Technology. NLDN flash data were provided by Vaisala, Inc. GLM and LIS data are pre-release and non-operational. TLE data are available from space-track.org. SGP4 and OpenCV are available on GitHub. #MadeWithPyART

5. Conclusions

This project demonstrated a proof-of-concept capability to use geolocated ISS photographs/video to quantitatively analyze lightning flashes and compare with other ground- and space-based lightning datasets. Future analysis should exploit the high spatial resolution and color imagery offered by digital photographs and HD video to better understand lightning characteristics and to help validate other data.