Development and Evaluation of detection algorithm for FY-4 Geostationary Lightning Imager (GLI) measurement

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ABSTRACT: The Feng-Yun-4 satellite (FY-4) is the second generation of China's geostationary meteorological satellite, it is scheduled launch in 2016. The FY-4 will carry the instrument of Geostationary Lightning Imager (GLI) which is the first lightning detection sensor on China's satellite. The GLI will be used to observe regional lightning activity in China. The GLI products will be used in forecasting and warning of convection precipitation, and studying of earth electric field.

The GLI products generation algorithm has been developed based on filtering and clustering algorithm. It considered the Optical Transient Detector (OTD) and Lightning Image Sensor (LIS) clustering algorithm and could generate Level 2 lightning products (flashes, groups, events) from Level 1c GLI geo-located, time tagged lightning event data. During development of the GLI products generation algorithm, the data of ground-based lightning location network in China and LIS were combined and used to generate the simulated Level 1c proxy data. The details of simulated Level 1c proxy data will be provided in this paper. The proxy data was also used as input to the algorithm, and the output was evaluated using the measured data according to the fact that group is in correspondence with individual return strokes in a cloud-to-ground flash or individual high current discharges (K-changes) in a cloud flash. The speed and accuracy of algorithm will be further tested. It is believed that the GLI will make better analysis of characteristics of lightning distribution in China.

INTRODUCTION

The detection of lightning discharges from geostationary orbit during day and night will monitor storms on continual basis [Christian et al., 1989]. There are two existing lightning mapper in low earth-orbit. The OTD which flied aboard the Microlab-1 spacecraft and LIS which was equipped on TRMM (Tropical Rainfall Measuring Mission Satellite) [Christian et al., 2000]. The Geostationary Operational Environmental Satellite R-series (GOES-R) which would carry Geostationary Lightning Mapper (GLM) is scheduled for launch in late 2015 [Goodman et al., 2013]. The Meteosat Third

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Generation-Lightning Imager (MTG-LI) is planned for launch in 2018. The capability to continually track and monitor changes in total lightning activity within individual storms has the potential to improve forecasting of oncoming severe weather [Schultz et al., 2011].

To make evaluation of the lightning image sensor equipped on satellite, there are many comparisions of LIS and ground-based lightning location network, just as LMA and LIS [Thomas et al., 2000], OTD and NLDN [Boccippio et al., 2001], and so on. The work is also useful for generating the simulated proxy data which is used to test the GLI products generation algorithm.

The FY-4 GLI could measure total lightning (both intracloud and cloud-to-ground) activity within its field of view continuously during both day and night. It will provide measurement with a resolution of 7.8 km at the sub-satellite point and full disk continuously observed with time resolution of about 2 ms. The CCD (Charge-Coupled Device) camera will operate at 777.4 nm to count flashes and measure their intensity. For that 777.4 nm is within the solar reflective band, a vicarious calibration using Deep Convective Clouds (DCCs) as stable targets is applicable [Buechler et al., 2014]. The GLI will be deployed as an instrument on the FY-4 spacecraft (36,000 km altitude, 5^{o} inclination). The GLI 400×600 pixel CCD focal plane will stare continuously at storms from FY-4 satellite. The GLI shall have continuous monitoring capability across a coverage (9,000 km diagonal field-of-view) with a near-uniform round sample 8-14 km pixel footprint resolution. Figure1 shows the expected field-of-view coverage of the GLI. The total lightning climatology shown in Fig.1 was daily lightning flash density (in units of flashes/grid/day) is provided from observations by the LIS (July, 2008). The grid size is $0.5^{0}\times0.5^{0}$. The GLI will map lightning location to about 8-14 km and will have a minimum lightning flash detection efficiency of 70%.

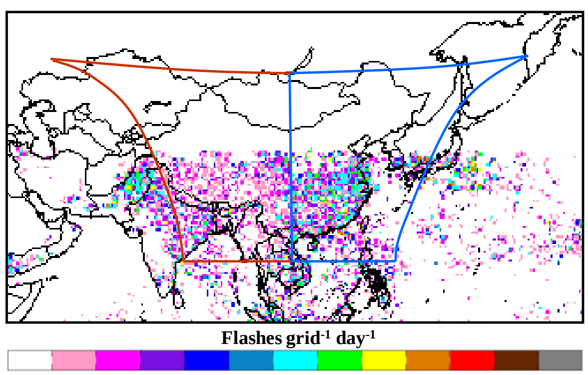


Fig. 1 FOV view from the FY-4 GLI superimposed on one month (July, 2008) of lightning observations from the NASA Lightning Imager Sensor on board the Tropical Rainfall Measuring Mission (TRMM/LIS) low earth-orbiting satellites

PROXY DATA FOR THE GEOSTATIONARY LIGHTNING IMAGER

Simulated proxy data

Proxy data used to develop the GLI products generation algorithms as well as cal/val performance monitoring tools. Validation Level 1c proxy datasets have been developed were derived from the LIS instruments in low Earth orbit [Cecil et al., 2014] and from the ground-based lightning location network in China. The network locate cloud-to-ground lightning by the combined technique of magnetic direction finding (DF) [Krider et al., 1976] and time of arrival (TOA) [Cummins et al., 1998].

Simulated proxy data generation

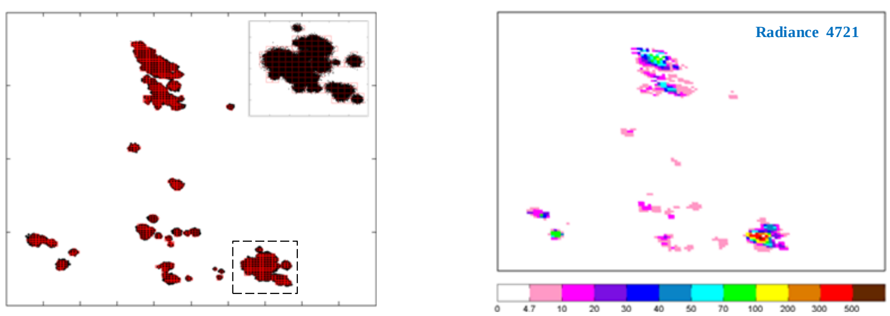
The principal methodology of simulated proxy data generation is similar to MTG-LI proxy data generation [Finke, 2011]. The proxy data are generated by steps as follows.

(1) According to the position and intensity of “strike” (just like return stroke of cloud-to-ground lightning), the position and time of pulse are generated (one pulse is corresponding one “optical event”). The pulse parameters are also generated.

(2) Simulation of the optical signal from the lightning pulses based on empirical statistics equation.

(3) Simulation of the detection process until the output of the detected event data

Figure 2 shows examples of generated proxy data and detected events for a single storm simulation, the resolution is $0.1^0 \times 0.1^0$. Figure 2(a) shows the distribution of photons. Figure 2(b) shows the distribution of radiance of “optical events”. There are 4721 optical events (radiance is the sum of every optical events, in units of $\mu J \cdot m^{-2} \cdot sr^{-1}$) those are filtered and clustered to 25 flashes and 363 groups (see as Figure 3).



(a) (b)

Fig. 2 Generated detected events from proxy data.

(a) A simulated storm in an area of $10^0 \times 10^0$ with the generated photons (black dots) and detected events (red squares), (b) radiance of detected events for a simulated storm distribution for a day in August

ALGORITHM FOR FY-4 GEOSTATIONARY LIGHTNING IMAGER

Algorithm specification

The filter and cluster algorithm for FY-4 GLI performs temporal-spatial clustering of the lightning event data into groups (just like return strokes and k-changes) and flashes. The concept of the product algorithm is considered the GLM Lightning Cluster Filter Algorithm (LCFA). It is closely based on the heritage OTD/LIS data processing algorithm in that it builds a parent-child tree-structure that identifies the clustering of optical events into groups, and groups into flashes (Mach et al., 2007; Goodman et al., 2012a,b). The generated Level 1c simulated proxy data are used to test the FY-4 GLI product algorithm. Figure 3 shows the distribution of Level 2 products (flashes and groups) which are from the output of the product algorithm using Level 1c simulated proxy data as input.

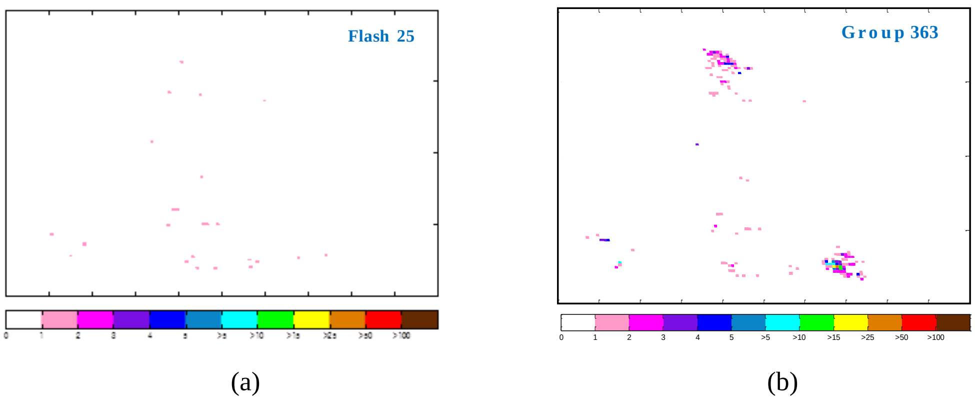


Fig. 3 Distribution of the flashes and groups from the output of the product algorithm
(a) detected flashes for a simulated storm distribution for a day in August, (b) detected groups for a simulated storm distribution for a day in August

Evaluation of algorithm

According to the fact that the "group" in Level 2 product is corresponding to the detected "strike", the evaluation of FY-4 product algorithm is completed according to the comparison of detected 509 "strikes" and 363 "groups" which are output of the filter and cluster algorithm in time and space. Figure 4 shows the distribution of uncertainty of the location derived from the output of the product algorithm. At last there are 290 samples was compared. It is found that about 80% of the absolute uncertainty are less than 20 km, with average is 14.4 km, standard deviation is 13.2 km. The maximum uncertainty is about 41 to 42 km. The maximum uncertainty is mainly due to that there are many detected "strikes" which are close in space and occur at same time. For reduce the uncertainty, different detected "strikes" which are used to generate simulated proxy data should occur at particular intervals of time. In this algorithm research, the background radiance estimate (BG) wasn't considered.

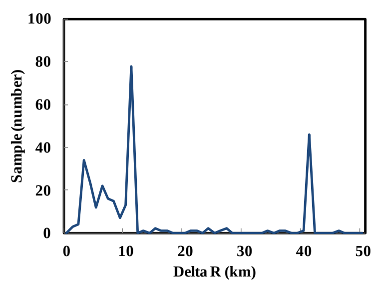


Fig. 4 Distribution of uncertainty of the location derived from the output of the product algorithm

CONCLUSIONS

The results of this study indicated that the filter and cluster algorithm for FY-4 GLI have been developed and evaluated preliminarily using simulated proxy data sets.

(1) We considered the principal methodology of MTG-LI proxy data generation to generate the Level 1c simulated proxy data derived from the LIS instruments in low Earth orbit and from ground-based lightning location network in China. The generated Level 1c simulated proxy data are used to develop the product algorithm for FY-4 GLI.

(2) The filter and cluster algorithm for FY-4 GLI performs temporal-spatial clustering of the lightning event data into groups (just like return strokes and k-changes) and flashes.

(3) The evaluation of FY-4 product algorithm is completed according to the comparison of detected "strikes" and clustered "groups" which are output of the filter and cluster algorithm in time and space.

The stability and redundancy of the product algorithm for FY-4 GLI should be tested further. Tuning and optimizing the algorithm are also important. The validation of FY-4 GLI Level 2 production activities should be performed based on simultaneous concurrent observations (of the same lightning activity) of ground-based lightning location network, aircraft, and space-based lightning locating systems in future.

ACKNOWLEDGMENTS

This work was supported by the National Natural Science Foundation of China (Grant No. 41305015). This work was also supported by NSMC-CMA where I'm working in. The provision of the LIS data and the LIS/OTD software package from NASA MSFC is gratefully acknowledged. The v2.2 gridded satellite lightning data were produced by the NASA LIS/OTD Science Team (Principal Investigator, Dr. Hugh J. Christian, NASA/Marshall Space Flight Center) and are available from the Global Hydrology Resource Center (http://ghrc.msfc.nasa.gov). The data of ground-based lightning location network were produced by the Meteorological Observation Centre, China Meteorological Administration.

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