

GOES-18 GLM Level 2 (Events, Groups, Flashes) Release
Provisional Data Quality
October 31, 2022
Read-Me for Data Users

The GOES-R Peer/Stakeholder Product Validation Review (PS-PVR) for GLM L2 Provisional Maturity was held on October 31, 2022. As a result of this review, the PS-PVR panel chair declared the data was of Provisional validation maturity.

The GLM L2 product consists of geo-located and time-stamped *events, groups, and flashes*, with associated calibrated optical amplitudes (in units of Joules).

Provisional maturity, by definition, means that:

- Validation and quality assurance activities are ongoing and the general research community is now encouraged to participate;
- Severe algorithm anomalies are identified and under analysis. Solutions to anomalies are in development and testing;
- Incremental product improvements may still be occurring;
- Product performance has been demonstrated through analysis of a small number of independent measurements from select locations, periods, and associated ground-truth/field program efforts;
- Product analysis is sufficient to communicate product performance to users relative to expectations;
- Documentation of product performance exists that includes recommended remediation strategies for all anomalies and weaknesses. Any algorithm changes associated with severe anomalies have been documented, implemented, tested, and shared with the user community;
- Testing has been fully documented;
- Product is ready for operational use and for use in comprehensive calibration/validation activities and product optimization.

Provisional users bear all responsibility for inspecting the data prior to use and for the manner in which the data are utilized. Persons desiring to use the GOES-18 GLM Provisional-maturity L2 products for any reason, including but not limited to scientific and technical investigations, are encouraged to consult the GLM Calibration/Validation science team members for feasibility of the planned applications.

Commentary on important GLM data characteristics and known issues being resolved include:

1. **Flash Detection:** GOES-18 GLM flash detection efficiency (FDE) over the field-of-view and over a many day analysis period averaged **74%** at the West park position (137.0 W longitude). As with GLM-16/17, FDE is substantially smaller in anomalous (i.e. inverted polarity) storms, and in severe (e.g., hail-producing) storms, or storms with deep liquid water path. In general, because the FDE associated with

reference data is itself variable and typically below 100%, it is not always possible to exactly/unambiguously determine the GLM FDE in all cases.

2. False Events: GOES-18 GLM flash false alarm rate (FAR) over the field-of-view and over a many day analysis period averaged **12%** at the West park position (137.0 W longitude). There are a variety of noise sources that contribute to false alarms. For example, solar glint occurs from specular reflection off of lakes, rivers, oceans, and solar farms. Sunrise and sunset leads to solar glint off the Atlantic and Pacific oceans, respectively, resulting in routine sunrise and sunset false events over predictable oceanic regions. Solar intrusion, which involves solar rays intruding directly into the GLM lens system (i.e., for relatively short periods during the eclipse season) is also a source of false events. These various noise sources lead to “blooming” which occurs when the photo-electric charge in a pixel exceeds the saturation level and spills over to adjacent pixels. A blooming filter was implemented into the Operational Environment (OE) on 25 July 2019; it is effective in removing a substantial fraction of blooming events, but not all. Other examples of noise include false events at Real-Time Event Processor (RTEP) boundaries, and false events due to high energy radiation particles, aka "radiation dots", and these have been mitigated with other filters. GLM-18 was set slightly more sensitive than GLM-17 (which had an FAR of 10% from PS-PVR Full Validation analyses).

3. Position Errors: GOES-18 GLM group location errors are in-family with GOES-17 GLM location error analyses (i.e., most probable location error of 3.5 km). Parallax errors near the edges of the field-of-view are a persistent feature of GLM-16/17/18.

4. Timestamps: GOES-18 GLM flash timing errors are in-family with GOES-17 GLM timing error analyses (i.e., the most probable timing error is -0.8 ms). There are still time-order issues with L2 data event times (as well as group time, flash start time, and flash end time), but these issues normally do not pose any major problems for most analyses; and a fix is planned for next year.

5. Family Links: Family linkages refer to the correspondence between events, groups, and flashes. For example, a “childless” group is a group with no events, and an “orphan” event is an event with no parent group. All downward family links have been fixed (effective when the DO.07.00.00 software version went operational on October 15, 2018). Upward family links will not be done, due to bandwidth constraints.

6. Unsigned Integer Read: In order to save storage space, some floating-point variables (such as times, latitude, and longitude) are stored in the GLM NetCDF file as a lower resolution internal format with a “scale_factor” and “add_offset” attribute. Some of the GLM data is stored in a non-standard format (as unsigned integers). This is an issue that affects multiple instruments on GOES-16/17, and a pilot fix was worked via ADR 844 with implementation on November 5, 2018. The classic model for NetCDF does not support internal storage of unsigned integers larger than 8 bits. Despite this, many of the variables in the GOES-16/17 data are stored internally in the NetCDF files as either 16-bits or 32-bits unsigned integers. A future version of NetCDF (CDF5) will have options for internal storage of unsigned integers, but the GOES program does not use that version (CDF5). To get around this lack of unsigned integer support, the GOES program added a non-standard attribute “_Unsigned”, to designate which variables are stored internally as unsigned. Unfortunately, with the DO.07 version of the code, some variables that are stored as unsigned integers are not marked as such with the “_Unsigned” attribute (this is a bug in the code). So, until a fix is achieved (for both the non-standard “_Unsigned” attribute and the totally unmarked unsigned integers), we recommend using the low level NetCDF readers (the ones that read

the NATIVE file formats) and use the following process to convert from the native format to the actual data format:

Retrieve the variable data (using low level routines): For MOST of the variables that should be read as unsigned integers, there is an attribute “_Unsigned” for that variable. The internal variable should then be read and cast to an unsigned integer of either 16 or 32 bits (depending on the size of the internal variable). This step must be completed before applying scale_factor and add_offset values to convert from scaled unsigned integer to science units.

Exceptions to the Rule: As it turns out, not all unsigned internal variables are actually marked with the attribute “_Unsigned”. We have designated these variables as “stealth unsigned variables” (SUVs). There is no physical way to determine which of the remaining variables are SUVs. The list below indicated the current set (the ones we have found) that are SUVs in DO.07 and will need to be converted like the variables that have the “_Unsigned” attribute (note, each of these):

Variable	Meaning	When Added
event_time_offset	GLM L2+ Lightning Detection: event’s time of occurrence	DO.01.00.00
group_time_offset	GLM L2+ Lightning Detection: mean time of group occurrence actually marked with the attribute	DO.01.00.00
flash_time_offset_of_first_event	GLM L2+ Lightning Detection: time of occurrence of first constituent event in flash	DO.01.00.00
flash_time_offset_of_last_event	GLM L2+ Lightning Detection: time of occurrence of last constituent event in flash	DO.01.00.00
group_frame_time_offset	GLM L2+ Lightning Detection: mean frame time of group’s constituent events’ times of occurrence	DO.07.00.00
flash_frame_time_offset_of_first_event	GLM L2+ Lightning Detection: frame time of occurrence of first constituent event in flash	DO.07.00.00
flash_frame_time_offset_of_last_event	GLM L2+ Lightning Detection: frame time of occurrence of last constituent event in flash	DO.07.00.00

7. Gridded Data & Data Quality Products: The Ground Segment now generates gridded GLM products identical to those developed for and used by National Weather Service (NWS) forecasters. A few steps remain prior to full integration of this operational feed into the NWS. The science team continues to work toward including a data quality product in the gridded product suite. In the interim, this training website summarize the noise sources “Quickly Diagnosing GLM Noise” (<https://arcg.is/a4zC8>) and real-time GLM status information is available here (<https://lightningdev.umd.edu/aert/StatusPage.html>). Only unofficial gridded product archives are available as we work toward hosting a long-term archive via the NASA Global Hydrometeorology Resource Center (GHRC). Unidata presently provides access to rolling 14-day archives of the gridded GLM products that can be found at the following two links:
<https://thredds.ucar.edu/thredds/catalog/satellite/goes/east/products/GLMISatSS/catalog.html>
<https://thredds.ucar.edu/thredds/catalog/satellite/goes/west/products/GLMISatSS/catalog.html>.

8. Data Recommended: The Calibration Working Group (CWG) recommends that data on, or after, 02 November 2022 is best to use because this follows a Look Up Table (LUT) update that adjusted the blooming filter.

Contact for further information: OSPO User Services at SPSD.UserServices@noaa.gov

GLM contacts for specific information on the GLM L2 data

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