

Community Satellite Processing Package for Geostationary Data (CSPP Geo) Gridded GLM Package Software Users' Guide

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Section 1: Introduction

Section 1.1 Overview

CSPP Geo Gridded GLM software processes data from the Geostationary Lightning Mapper (GLM) instrument on-board the GOES-R satellites series (that is, GOES-16, GOES-17 and GOES-18 (preliminary)), generating a new set of products that have been gridded to the Advanced Baseline Imager (ABI) 2-km resolution, and are aggregated at one-minute intervals.

The new products are:

- Minimum Flash Area
- Flash Extent Density
- Total Optical Energy

The intent is that this new set of higher level products can be more readily understood and utilized than the GLM Level 2+ data that is used as input (consisting of events, groups and flashes), and that the products can be more easily used with ABI data because they are on the same grid.

Spatial extent information that is not readily available in the GLM L2+ data is recovered and used to create the gridded products.

Gridded GLM can produce tiled GLM data that can be injected directly into Advanced Weather Interactive Processing System (AWIPS). Products are also compatible with the Satpy Python library, and with display packages that are built with Satpy such as Geo2Grid.

This software package was developed at the University of Wisconsin - Madison, SSEC / CIMSS, under funding provided by the GOES-R Program and NOAA STAR.

Questions and comments can be directed to csppgeo.issues@ssec.wisc.edu.

Section 1.2 Attribution

The software package is built on the open source glmtools software developed by Dr. Eric Bruning (Texas Tech University). Ongoing development of operational Gridded GLM products and related research is led by Dr. Scott Rudlosky (NOAA/NESDIS/STAR).

This release builds on several years of effort to refine the glmtools package in pre-operational demonstrations, and many of the contributors to that effort are co-authors on a paper (see Section 7: References) that describes the GLM imagery creation approach in detail.

The developers wish to thank Lee Byerle and Joe Zajic (NOAA/NWS TOWR-S team) for their assistance with tile development and Advanced Weather Interactive Processing System (AWIPS) compatibility.

Section 1.3 Copyright / License / Disclaimer

Portions of the source code in this software package are:

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Original UW/SSEC source code, scripts and automation included as part of this package are distributed under the GNU General Public License agreement version 3.

Binary executable files and third-party source code included as part of this software package are copyrighted and licensed by their respective organizations, and distributed consistent with their licensing terms.

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Section 2: Software

Section 2.1 What's New

CSPP Geo Gridded GLM v1.0 includes the following changes, relative to the earlier beta release (v1.0 beta1):

- Adds statistics files which accompany punctured tile files. Statistics files document potentially missing ("punctured") tiles and are required by AWIPS for it to perform multi-minute aggregations.
- GOES-18 support.
- Removed the script `cspp-geo-gglm-make-grids.sh`, which was a thin wrapper for a utility in the underlying GLM Tools library.
- Changed the short option for realtime mode ("`--realtime`") from "`-1`" to "`-r`".
- Added "`meso1`" and "`meso2`" as potential `--goes-sector` options. The old "`meso`" is still available, and equivalent to "`meso1`".
- Various performance improvements and bug fixes.

Section 2.2 System Requirements

System requirements for the CSPP Geo Gridded GLM software are as follows.

- CentOS 7 Linux (or other compatible 64-bit Linux distribution),
- 32 GB RAM,
- 6 CPU with an x86-64 instruction set.

This system has been found to be sufficient to process a GLM data stream received from a single satellite, generating full disk Gridded GLM products and tiles in near real-time. This assumes that no other significant processing is occurring on the same machine.

The "`xz`" package is needed to decompress software and data tarballs. On minimal operating system versions it may need to be installed manually (e.g. "`yum install xz`").

Section 2.3 Input Data

Input is Level 2+ GLM data in mission-standard format (that is, Lightning Cluster-Filter Algorithm (LCFA) NetCDF files), as generated at the GOES-R ground system. Data are available to users via multiple methods:

- The GOES Rebroadcast (GRB) data stream: Direct broadcast users can receive the GOES-East or GOES-West GRB stream on an antenna and run the CSPP Geo GRB software package to generate GLM L2+ and other GOES-R series products in near real-time.

- NOAA CLASS, under the “GOES-R Series GLM L2+ Data Product (GRGLMPROD)” tab.
- The cloud, via the [NOAA Open Data Dissemination Program](#) (formerly NOAA Big Data).

The files are available with a cadence of 3 per minute. For example, the four files produced with start times between 15:00:00 and 15:01:00 on 22 March 2021 (Day 081), are named thus:

```
OR_GLM-L2-LCFA_G16_s20210811500000_e20210811500203_c20210811500218.nc
OR_GLM-L2-LCFA_G16_s20210811500200_e20210811500404_c20210811500425.nc
OR_GLM-L2-LCFA_G16_s20210811500400_e20210811501003_c20210811501016.nc
OR_GLM-L2-LCFA_G16_s20210811501000_e20210811501205_c20210811501226.nc
```

As with many GOES-R (and JPSS) filenames, `s20210811500000_` within the file name refers to the start time of the data within the file (15:00:00.0 on day 081 in 2021), `e20210811500203_` denotes the end time of data within the file (15:00:20.3 on day 081 in 2021), and `c20210811500218` denotes the creation time (15:00:21.8 on day 081 in 2021). The number of files per day is 4320.

More information about the GLM mission standard files can be found in the GOES-R Series Product Definition and Users' Guide (PUG) - Volume 3, linked in the references at the end of this document.

Section 2.4 Processing Configuration

The Gridded GLM software is called directly at the Linux command line. The user is responsible for automation of Gridded GLM processing, as well as any downstream processing, data transport, archiving and clean-up of old products.

For example, in a direct broadcast setting where the CSPP Geo GRB software is processing the raw data stream, scripts could be developed to monitor GLM L2+ file creation, to start a Gridded GLM processing job when a new trio of 20-second input files is available, and to spawn any downstream processing.

Section 3: Installation

Section 3.1 Installing the Gridded GLM Software

The CSPP Gridded GLM software can be accessed at this website:

<https://cimss.ssec.wisc.edu/csppgeo/>

You may have to register, but that is free and easy and you'll end up here:

<https://download.ssec.wisc.edu/files/csppgeo/>.

At that website you'll find a compressed tarball that contains the software package (and a useful README). Extract the compressed information into a directory on your Linux machine and include the resultant gridded GLM bin directory in your \$PATH. Commands to do this are shown below.

```
tar xvf cspp-geo-gridded-glm-1.0.tar.xz
export PATH=$PWD/cspp-geo-gridded-glm-1.0/bin:$PATH
```

The second line above can optionally be added to your shell login script (for example .bashrc or .bash_profile) if the software will be run again from the same user account.

Section 3.2 Testing Your Installation

A test data tarball can be downloaded from the same location as the software. Reference output is included. The Gridded GLM test case consists of one minute of L2+ LCFA GLM data from GOES-16, GOES-17, and GOES-18.

Unpack the test data in your preferred location:

```
tar xvf cspp-geo-gridded-glm-test-data-20221110.tar.xz
```

Run the following commands sequentially, to process the test cases for the three satellites, generating Gridded GLM products and tiles. Note that the glob pattern in each invocation matches three 20-second input files covering a clock-aligned minute of GLM data.

```
cd cspp-geo-gridded-glm-test-data-20221110
```

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```
cspp-geo-gglm.sh \  
    --output-dir test-output/goes16/ \  
    --create-tiles \  
    input/goes16/*
```

```
cspp-geo-gglm.sh \  
    --output-dir test-output/goes17/ \  
    --create-tiles \  
    input/goes17/*
```

```
cspp-geo-gglm.sh \  
    --output-dir test-output/goes18/ \  
    --create-tiles \  
    input/goes18/*
```

You should not see any error messages or other output printed to screen. When processing is complete, test output will be located in the directory “test-output”, sorted by satellite.

Check the product file counts:

```
for d in test-output/*; do printf "${d}: "; ls ${d}/*.nc | wc -l; done
```

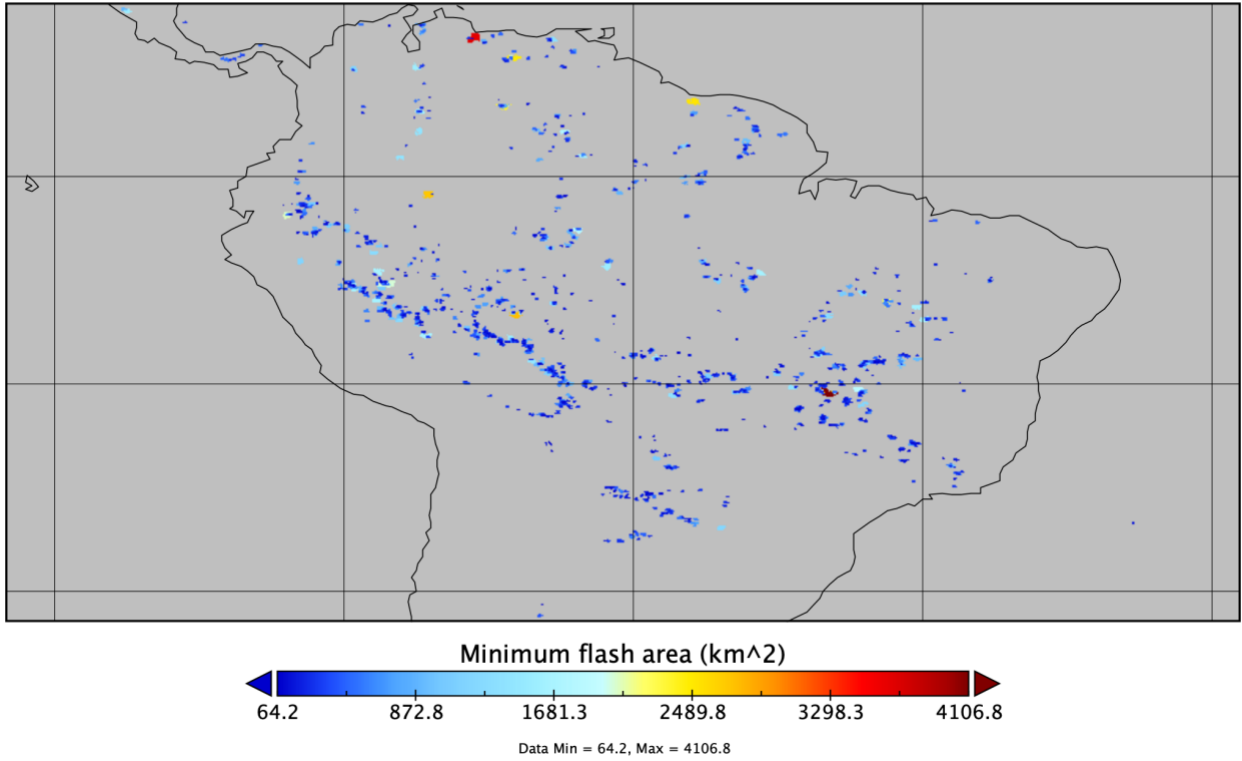
You should see the following:

```
test-output/goes16: 20  
test-output/goes17: 11  
test-output/goes18: 12
```

Note that file counts may be higher if the test case has been run more than once without clearing output directories. This is because the filename of the main product file (CG_GLM-L2*.nc) contains the file creation time and is thus unique for each invocation.

Output files can be compared to reference output files located in the directory “output”. Data in the output NetCDF4 files can be plotted using tools like Panoply.

Minimum flash area



Variable "minimum_flash_area" from output file CG_GLM-L2-GLMF-M3_G16.nc, displayed in Panoply and zoomed over South America.*

Section 4: Usage

The main processing script, `cspp-geo-gglm.sh`, creates one minute grids from GLM L2+ LCFA input files. In the default processing mode, all three 20-second input files must be specified for each clock-aligned minute, to ensure that the gridded product captures all lightning activity from that minute.

The script can also be run in "realtime" mode (option `--realtime`) where, provided a single input file, the script will determine if an entire minute is available in the same directory, and if so begin gridding. In realtime mode the processing script can be called for every 20-second input file arriving on the system and will only generate output for every third invocation (specifically the input file with a start time 40s after the minute boundary).

To list all options, run `cspp-geo-gglm.sh -h`. The result of this command is shown below.

```
usage: cspp-geo-gglm.sh [-h] [-v] [-l LOG_FN] [-o OUTPUT_DIR]
      [--goes-sector {full,conus,meso,meso1,meso2}] [-t]
      [--ctr-lat LATITUDE] [--ctr-lon LONGITUDE] [-r]

      [--system-environment-prefix SYSTEM_ENVIRONMENT_PREFIX]
      [--system-environment-prefix-tiles SYSTEM_ENVIRONMENT_PREFIX_TILES]
      filename [filename ...]
```

Create one minute NetCDF4 grids (and, optionally, AWIPS-compatible tiles) from GLM flash data.

positional arguments:

filename

optional arguments:

```
-h, --help          show this help message and exit
-v, --verbose       each occurrence increases verbosity 1 level through
                    ERROR-WARNING-INFO-DEBUG (default: ERROR)
-l LOG_FN, --log LOG_FN
                    specify a log filename (default: print to screen)
-o OUTPUT_DIR, --output-dir OUTPUT_DIR
                    output directory (default: use current directory)
--goes-sector {full,conus,meso,meso1,meso2}
                    If sector is meso, ctr_lon and ctr_lat are
```

interpreted

```
                    as the ctr_x and ctr_y of the fixed grid. (default:
                    full)
-t, --create-tiles  create AWIPS-compatible tiles (default: off)
--ctr-lat LATITUDE  center latitude (required for meso)
--ctr-lon LONGITUDE center longitude (required for meso)
-r, --realtime      enable 'realtime' mode, where we expect only one
input
                    file, find the surrounding trio, and automatically
                    determine if a full minute of data is available
                    (default: off)
--system-environment-prefix SYSTEM_ENVIRONMENT_PREFIX
```

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```

                                set the system environment prefix for the output
grids
                                (default: CG)
--system-environment-prefix-tiles SYSTEM_ENVIRONMENT_PREFIX_TILES
                                set the system environment prefix for the output
tiles
                                (default: CSPP_OR)
```

Section 5: Output

Section 5.1 Product Files

The Gridded GLM product is written by the main processing script in the form of netCDF4 files, each spanning a clock-aligned minute of input data. The file naming convention and file format are modeled after the GOES-R operational format, as documented in the GOES-R Product Definition and Users' Guide (PUG).

Example Gridded GLM product filename:

```
CG_GLM-L2-GLMF-M3_G16_s20223502102000_e20223502103000_c20223502103040.nc
```

Gridded GLM products are created one minute at a time; this is true even if more than one minute of input files are specified, for example using Unix wild-carding. Users should note this behavior (specifying more than one minute of input data) caused an error in earlier versions of the software.

A set of AWIPS-compatible tiles can optionally be created for each Gridded GLM file, using the `--create-tiles` flag. The tiles are also netCDF4 files. Tiles covering geographic areas without lightning activity are omitted. (Information on these missing (“punctured”) tiles is stored in the created Statistics files.) The time in the filename is the observation end time.

Example tile filename:

```
CSPP_OR_GLM-L2-GLMF-M3_G16_T13_20221216210300.nc
```

Example statistics filename:

```
CSPP_OR_GLM-L2-GLMF-M3_G16_statistics_e20221216210300.nc
```

The output grid can be specified with option `--goes-sector`. By default, output is gridded to the 2-km Full Disk projection of the ABI instrument located on the same satellite as the GLM instrument. This allows the Gridded GLM product to be overlaid on the Full Disk ABI product. The 2-km CONUS and mesoscale projections can also be specified. If mesoscale is specified, the center latitude and longitude must also be specified with options `--ctr-lat` and `--ctr-lon`. This is because the ABI mesoscale location is variable and cannot be determined based on GLM input data.

The default product file prefixes can be overridden with options `--system-environment-prefix` and `--system-environment-prefix-tiles`.

The names of the main output variables are shown in the table below.

variable name in Gridded GLM product files	variable name in AWIPS-compatible tile files	description
flash_extent_density	Flash_extent_density	Flash extent density

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total_energy	Total_Optical_energy	Total optical energy
minimum_flash_area	Minimum_flash_area	Minimum flash area

Section 5.2 Examples

Create a single one-minute gridded product file by specifying three input 20-second GLM L2+ files:

```
cspp-geo-gglm.sh /data/GLM-L2/2019299/17/OR_GLM-L2-LCFA_G16_s20192991759*
```

Create a single one-minute gridded product file by specifying only one of the three input 20-second GLM L2+ files ("realtime" mode):

```
cspp-geo-gglm.sh -r /data/GLM-L2/2019299/17/OR_GLM-L2-LCFA_G16_s20192991759400_e20192991800000_c20192991800031.nc
```

Create a gridded product file and tiles:

```
cspp-geo-gglm.sh -r -t /data/GLM-L2/2019299/17/OR_GLM-L2-LCFA_G16_s20192991759400_e20192991800000_c20192991800031.nc
```

Note that invoking `cspp-geo-gglm` and pointing it to files names such as this:

```
/dir/OR_GLM-L2-LCFA_G16_s20221490109000_e20221490109200_c20221490109214.nc  
/dir/OR_GLM-L2-LCFA_G16_s20221490109200_e20221490109400_c20221490109425.nc  
/dir/OR_GLM-L2-LCFA_G16_s20221490109400_e20221490110000_c20221490110019.nc
```

will create a file with a time stamp of **0109**, that is, 0109 UTC (in this case on 29 May 2022):

```
CG_GLM-L2-GLMF-M3_G16_s20221490109000_e20221490110000_c20221531858120.nc
```

If this is displayed in AWIPS, it will have a time-stamp of 0109 UTC -- when the data observations *start*. This is also how ABI data are time-stamped in the display.

Section 6: Caveats

The following issues are known to affect this release.

- The DQF (data quality flags) are always set to 0 in this version. Quality checks will likely be added in a future version, resulting in possible non-zero quality flags. (#46)
- The nominal_satellite_subpoint_lon variable has an unnecessary dimension (dim_0). We expect to remove this dimension in a future release. (#51)

Section 7: References

Papers:

- Bruning, E. C., Tillier, C. E., Edgington, S. F., Rudlosky, S. D., Zajic, J. K., Gravelle, C. M., Foster, M., Calhoun, K. M., Campbell, P. A., Stano, G. T., Schultz, C. J., and Meyer, T. C. (2019). Meteorological imagery for the Geostationary Lightning Mapper. 2019: Meteorological imagery for the Geostationary Lightning Mapper. J. Geophys. Res., 124 (24), 14 285–14 309, <https://doi.org/10.1029/2019JD030874> or <https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2019JD030874>

Online Documentation:

- [GOES-R Gridded GLM Quick Guides from CIRA](#)
- [NOAA Virtual Lab GLM Community](#) (includes links to further information)
- [NOAA Virtual Lab AWIPS Technical Library](#)
- [University of Maryland GLM Imagery](#)
- [GOES-R Series Product Definition and Users' Guide - Volume 3](#)

Software:

- [glmtools Software Repository](#)