A Practical Introduction to
LightningCast

Presented by **Levi Pfantz**

Algorithm Development

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Community Satellite Processing Package for Geostationary Data LightningCast Package by the CSPP Geo Team

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University of Wisconsin - Madison

Impact of Lightning in the U.S.

Human Cost

~400 strikes per year

27 deaths per year

Economic Damage

$1 - $2 Billion

Annual insurance payouts

High Vulnerability Areas

- Aircraft & Mariners
- Stadiums & Festivals
- Amusement Parks

Wildfire Ignition

Major ignition source.

Lightning-ignited fires burn more acres than human-ignited fires.

LightningCast Algorithm

Model Architecture

- Image-based AI model: CNN
- Model: "U-net"
- Learns salient spatial & multispectral features

Predictors (GOES-R ABI)

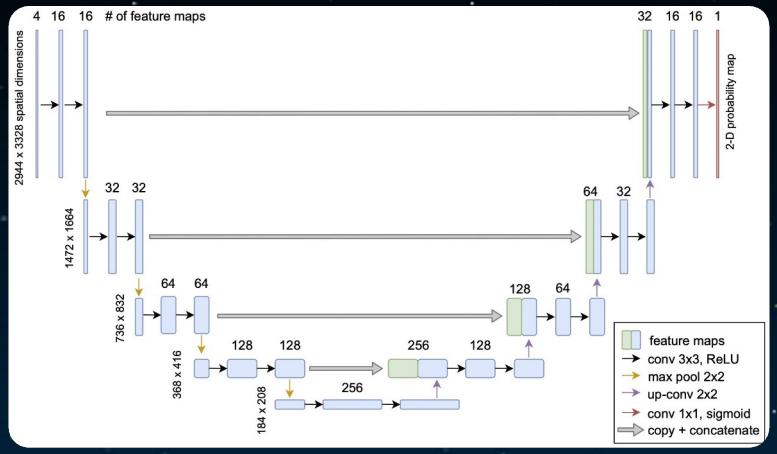
- Band 2 (0.64-µm reflectance at 0.5-km)
- Band 5 (1.6-µm reflectance 1-km)
- Band 13 (10.3-µm BT 2-km)
- Band 15 (12.3-µm BT 2-km)

Target / Truth (GOES-R GLM)

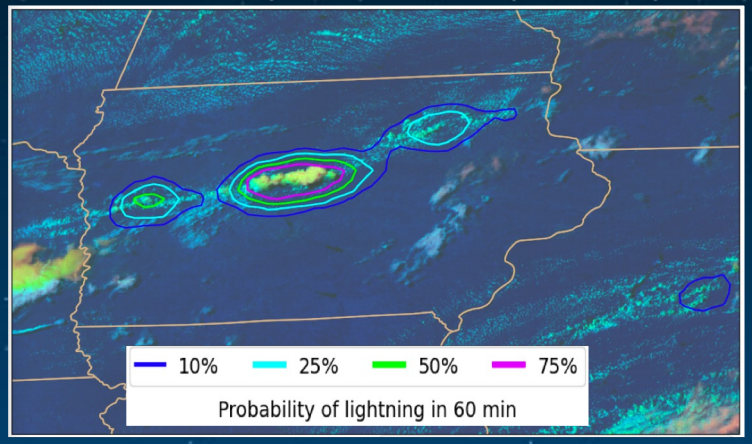
- Next Hour Flash Extent Density
- Optical sensor (777.4 nm)
- 8-km resolution

Output:

- Probability of Lightning within 1 hour
- 2-km resolution



U-Net Architecture Diagram



Example Prediction Output

Cintineo et al. 2022 (WAF)

From Science to CSPP Geo LightningCast Package

- **I work as a Software Engineer on both teams**
  - Allowed for rapid development of LightningCast Package
  - Allowed for wider testing and faster responsiveness in the science code
- **Demonstration of LightningCast Package**
  - Plug and play
  - Streamlined interface
  - Somewhat differing capabilities
  - V1 beta 2 out now with V1 coming soon

Satellite Support

- **LightningCast Package supports GOES-R Series**
  - All Sectors including: Full Disk, CONUS / PACUS, Mesoscales 1 and 2
  - Full functionality
- **LightningCast Package supports Himawari**
  - Both Himawari 8 and 9
  - Only Full Disk sector
  - Most functionality

**The LightningCast Package doesn't support Meteosat but the science team has limited support for MTG / FCI.*

Resource Requirements

Single Image Domain / Subset

Any one of:

- Meso domain (GOES-East or GOES-West)
- CONUS domain (GOES-East or GOES-West)
- Any AWIPS Full Disk predefined cut-out (GOES-East*, GOES-West or Himawari)

`3.8GHz, 20-core, 64GB RAM`

Full Parallel Processing

Comprehensive Coverage:

- All image domains and subsets for GOES-East, GOES-West and Himawari Running in parallel (all satellites, sectors and AWIPS cutouts)

`3.20GHz, 32-core, 256GB RAM`

**More than twice the size of CONUS*

LightningCast Package Features

Satellite Processing Options

- Optional parallax correction
- Region of Interest (Required for Full Disk)

Advanced Visualization / Image Generation

- Satellite based imagery
  - Uses additional satellite bands
  - 8 image types
  - Hierarchical borders (Upcoming Feature)
  - Full color customization for contours
  - Geostationary Lightning Mapper (GLM) overlay
- GeoTIFFs
- Meteograms (upcoming feature)

Comprehensive Data Output Formats

- NetCDF file for both AWIPS and non-AWIPS systems (including built-in AWIPS sectors)
- GeoJSON data output
- GR PlaceFile (used by U.S. NWS)

Parallax Correction

- Custom heights may be used
- May be set to on, off, or both
- Affects (but not required for) GeoJSON output and NetCDF output
- Required for and used in meteogram and GR Placefile output
- **Example invoke:**

```
lightningcast --parallax both --parallax-height 9000
$INPUT_FILE_PATH
```

Parallax Correction Off vs On

Images from GOES 16, April 5, 2025 over Arkansas, USA

Parallax Correction: OFF

Parallax Correction: ON

**Visualized from LightningCast GeoJSON output using geojson.io*

Region of Interest

- Required for Full Disk
- Enables predictions for specific targeted areas
- Optimizes processing time by ignoring unnecessary data
- Configurable using latitude/longitude bounding boxes or data index boxes
- **Example command:**

```
./lightningcast --border-level 2 --make-tcirp-image --ll-bbox -
74.0 -34.7 -33.8 5.3 $INPUT_FILE_PATH
```

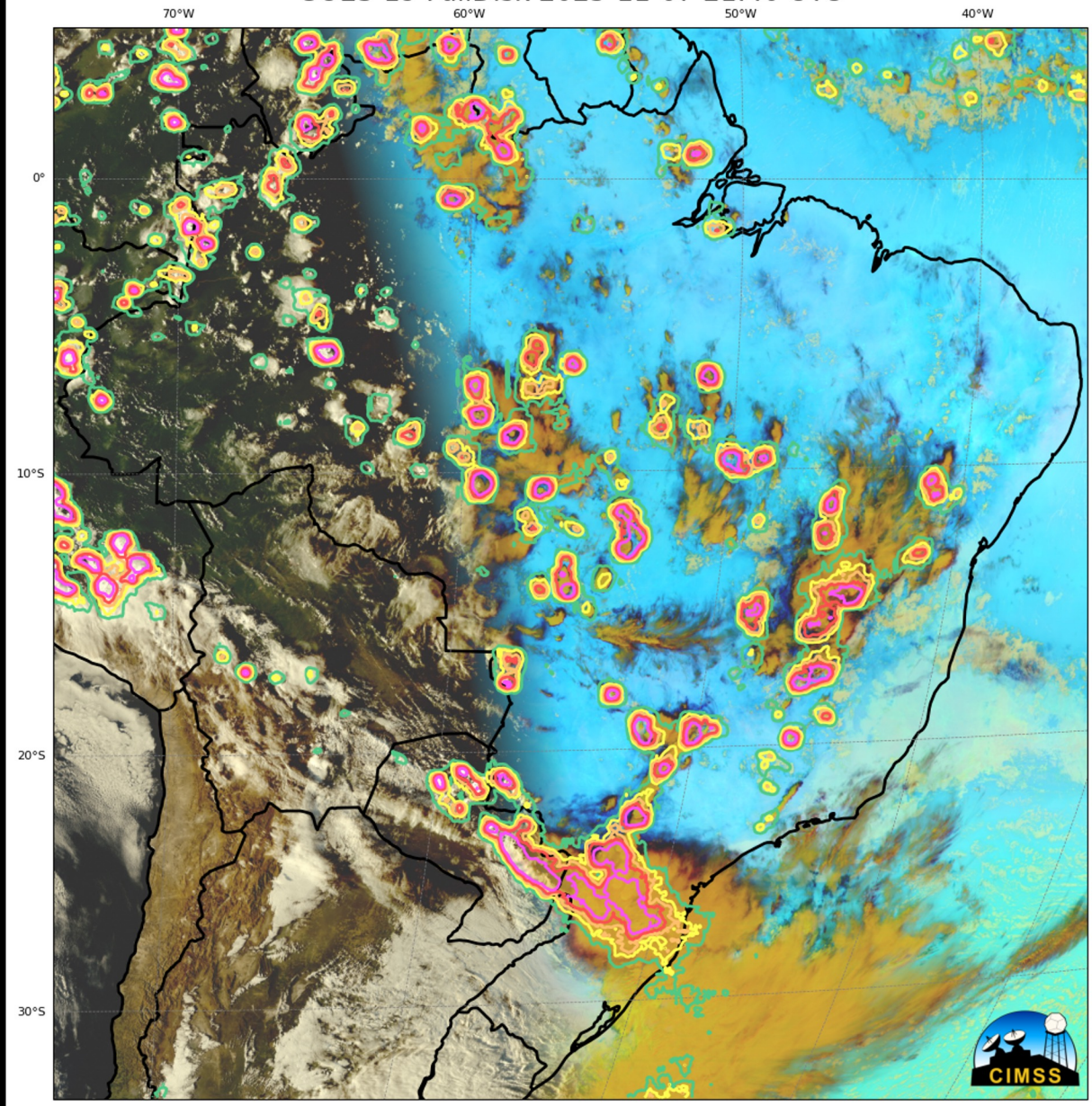

GOES-19 FullDisk 2025-11-07 21:40 UTC
70°W
60°W
50°W
40°W
0°
10°S
20°S
30°S
CIMSS
10%
30%
50%
70%
90%
Probability of lightning in 60 min

Image Type: Day Land Cloud (DLC)

- Useful for differentiating both land and cloud features
- Documentation here
- **Example command:**

```
./lightningcast --border-level 2 --make-dlc-image --ll-bbox -74.0
-34.7 -33.8 5.3 $INPUT_FILE_PATH
```

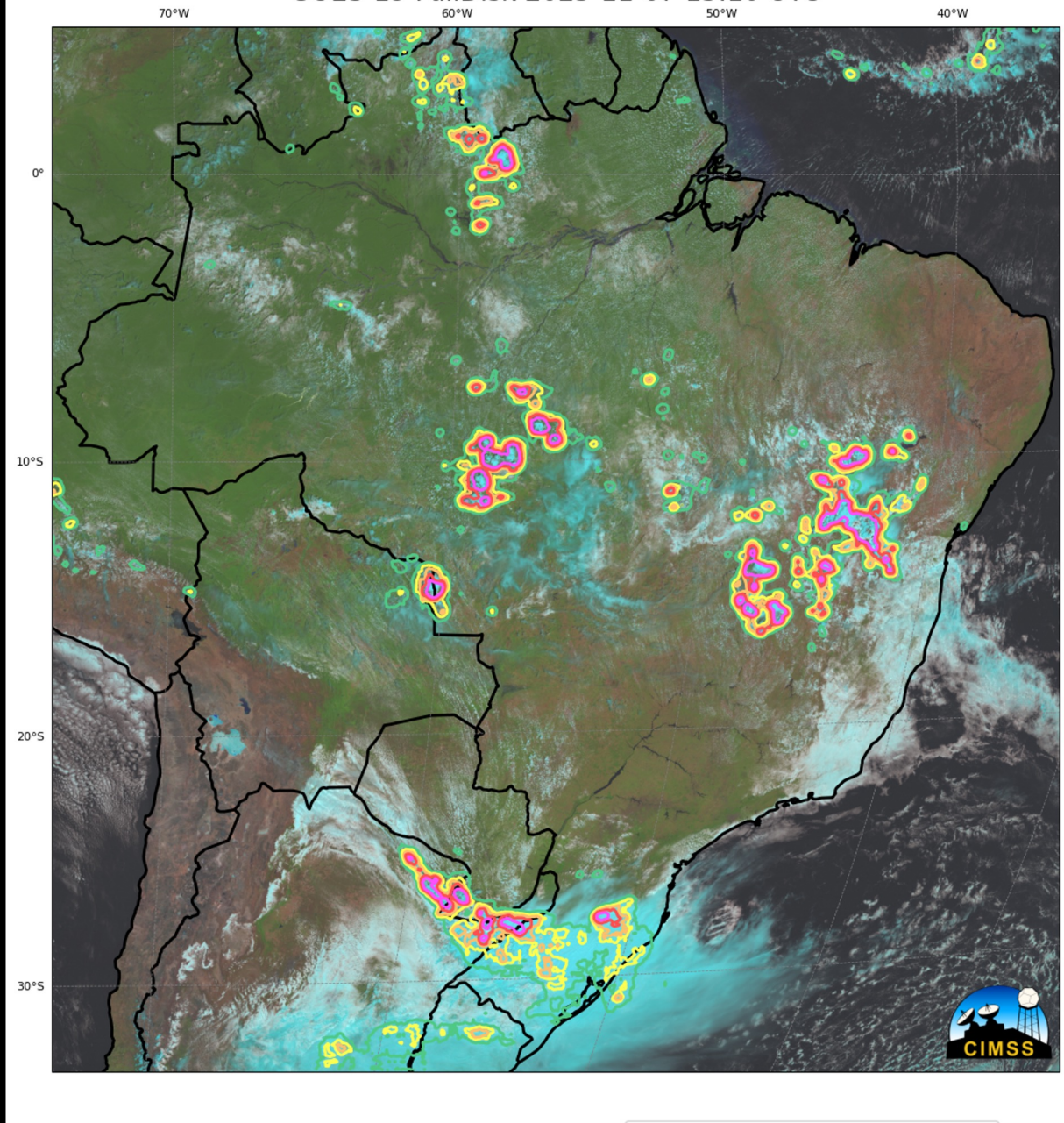

GOES-19 FullDisk 2025-11-07 15:10 UTC
70°W
60°W
50°W
40°W
0°
10°S
20°S
30°S
CIMSS
10%
30%
50%
70%
90%
Probability of lightning in 60 min

Image Type: Visible Image

- Uses just the visible / red band
- **Example command:**

```
./lightningcast --border-level 2 --make-visible-image --ll-bbox -
74.0 -34.7 -33.8 5.3 $INPUT_FILE_PATH
```

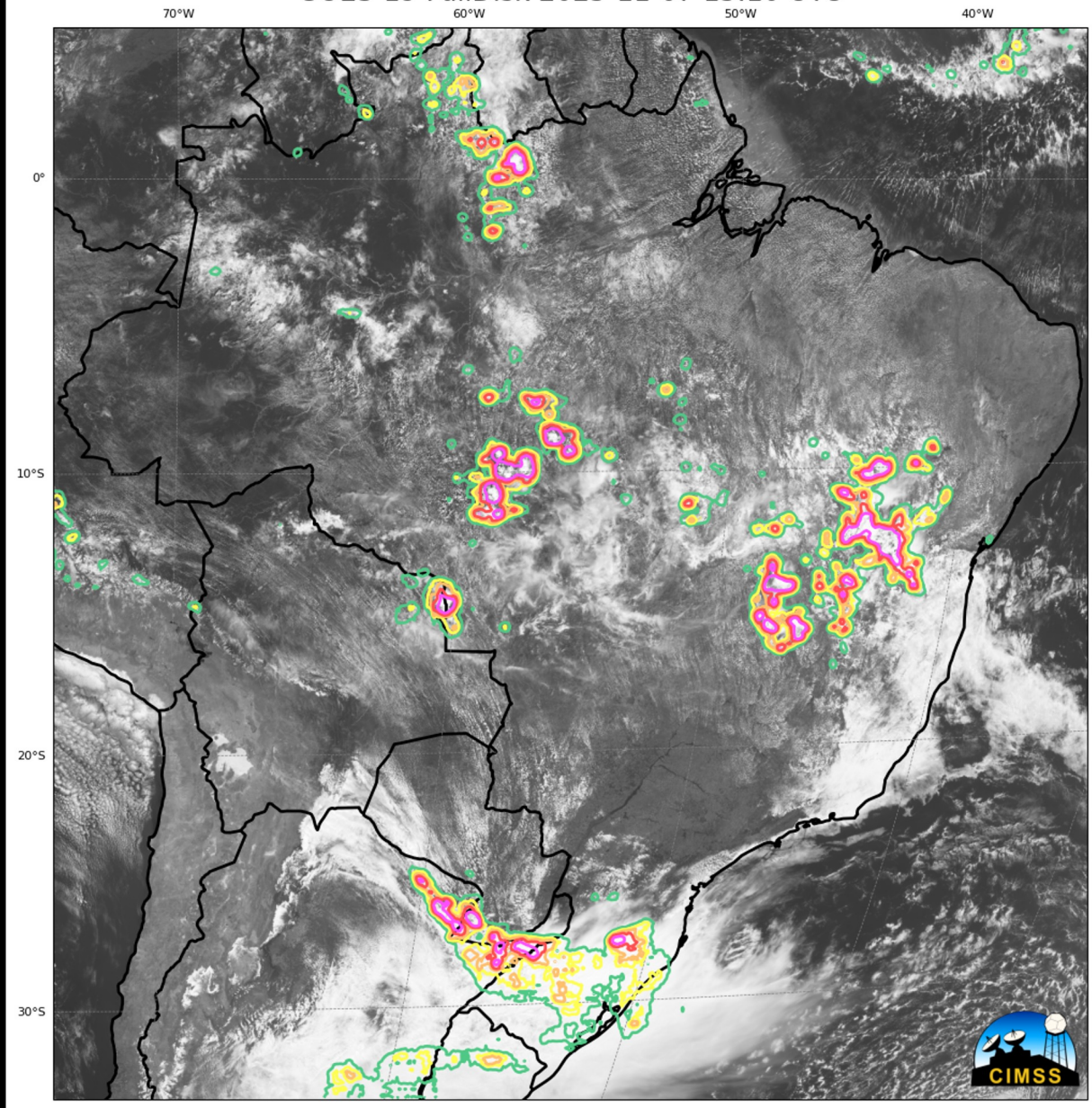

GOES-19 FullDisk 2025-11-07 15:10 UTC
70°W
60°W
50°W
40°W
0°
10°S
20°S
30°S
CIMSS
10%
30%
50%
70%
90%
Probability of lightning in 60 min

Image Type: Day Cloud Convection

- Useful for visualizing cloud convection features
- Documentation here
- **Example command:**

```
./lightningcast --border-level 2 --make-dcc-image --ll-bbox -74.0
-34.7 -33.8 5.3 $INPUT_FILE_PATH
```

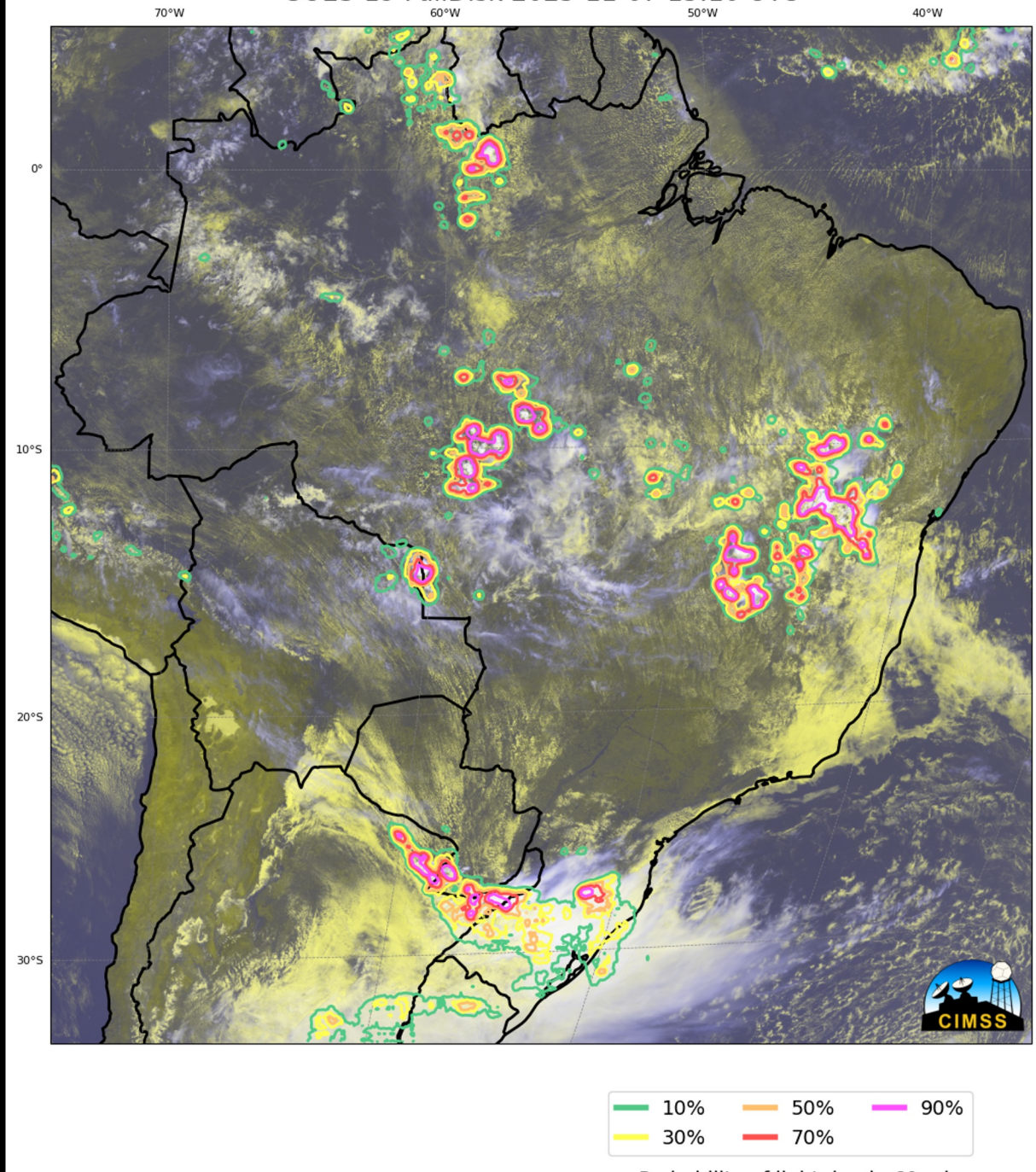

GOES-19 FullDisk 2025-11-07 15:10 UTC
70°W
60°W
50°W
40°W
0°
10°S
20°S
30°S
CIMSS
10%
30%
50%
70%
90%
Probability of lightning in 60 min

Image Type: Sandwich

- Useful for visualizing cloud convection features
- Documentation here
- **Example command:**

```
./lightningcast --border-level 2 --make-sandwich-image --ll-bbox -
74.0 -34.7 -33.8 5.3 $INPUT_FILE_PATH
```

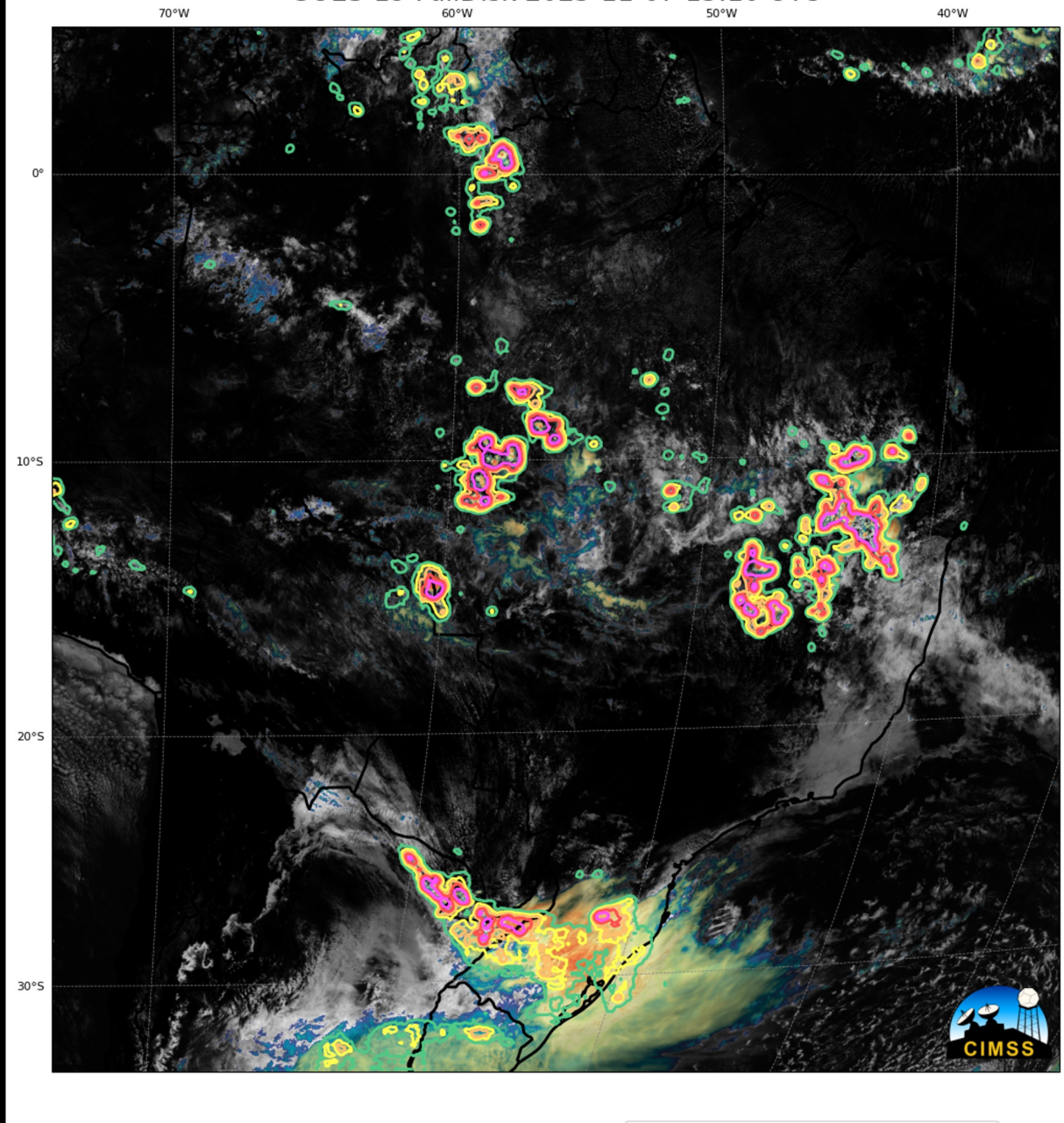

GOES-19 FullDisk 2025-11-07 15:10 UTC
70°W
60°W
50°W
40°W
0°
10°S
20°S
30°S
CIMSS
10%
30%
50%
70%
90%
Probability of lightning in 60 min

Image Type: Day Cloud Phase Distinction (DCP)

- Useful for identifying cloud phase during the day
- Documentation here
- **Example command:**

```
./lightningcast --border-level 2 --make-dcp-image --ll-bbox -74.0
-34.7 -33.8 5.3 $INPUT_FILE_PATH
```

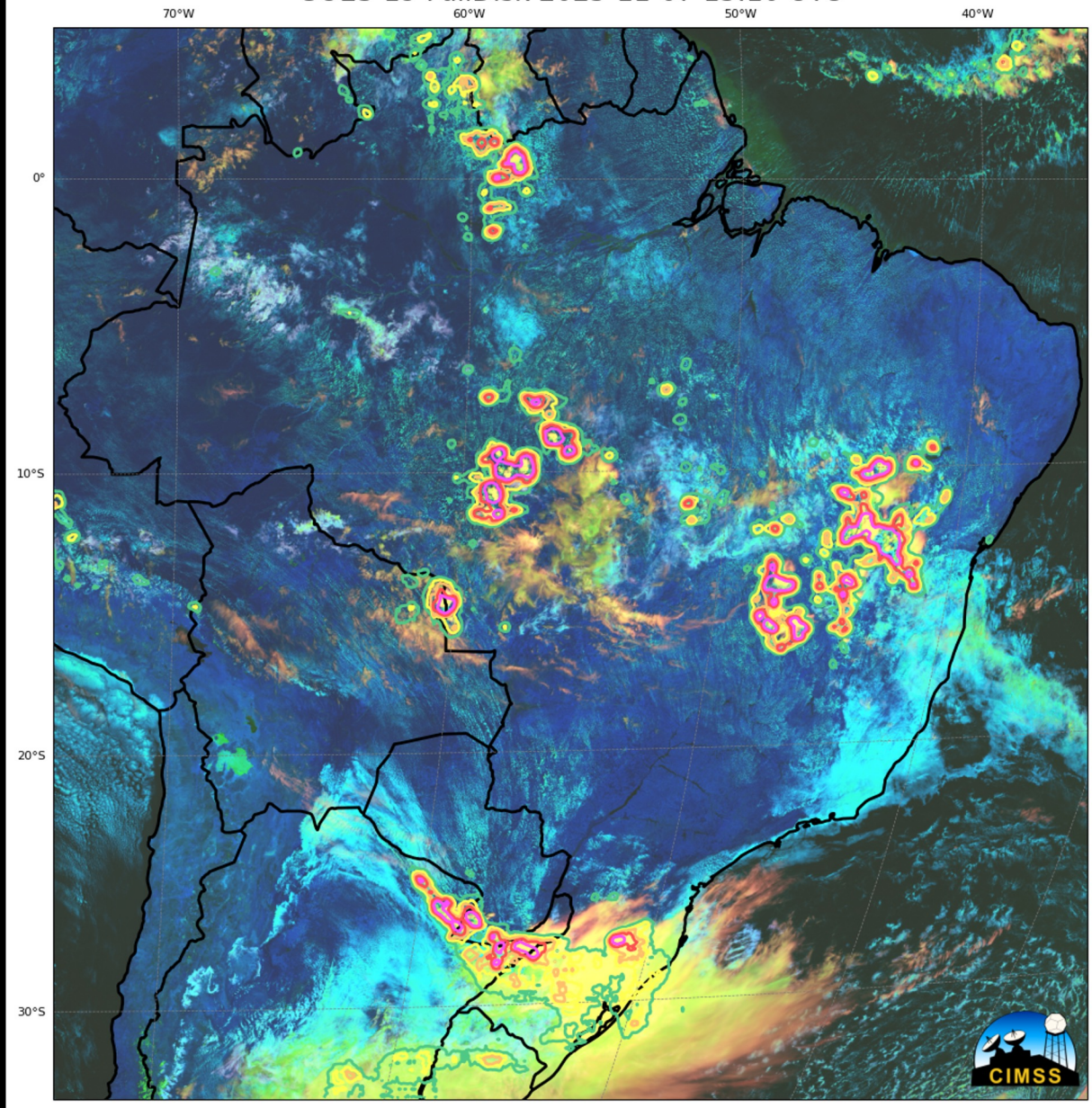

GOES-19 FullDisk 2025-11-07 15:10 UTC
70°W
60°W
50°W
40°W
0°
10°S
20°S
30°S
CIMSS
10%
30%
50%
70%
90%
Probability of lightning in 60 min

Image Type: True Color (TC)

- For GOES satellites this is technically false true color
- Appears similar to what the earth would look like from orbit to human eyes
- **Example command:**

```
./lightningcast --border-level 2 --make-tc-image --ll-bbox -74.0 -
34.7 -33.8 5.3 $INPUT_FILE_PATH
```

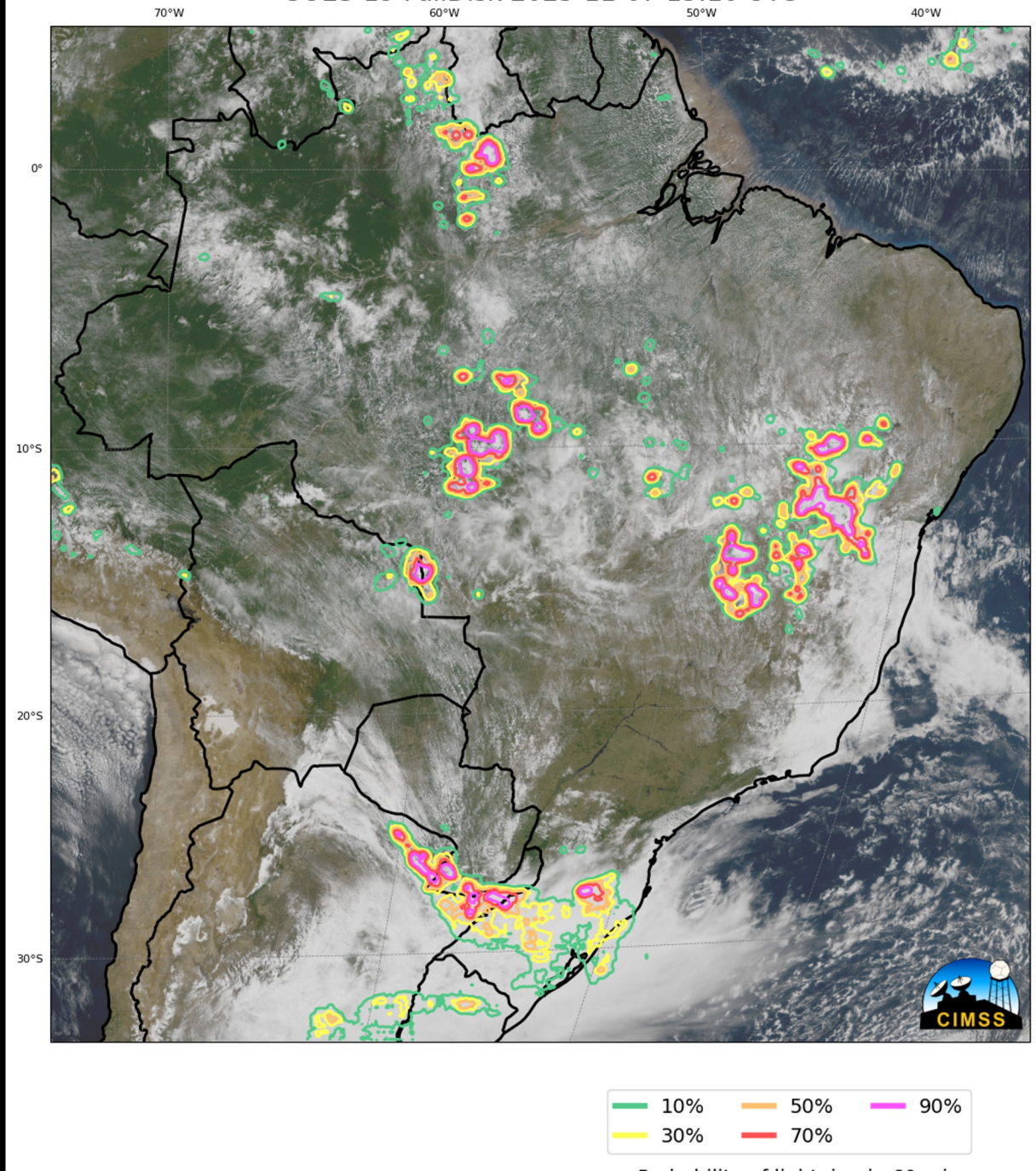

GOES-19 FullDisk 2025-11-07 15:10 UTC
70°W
60°W
50°W
40°W
0°
10°S
20°S
30°S
CIMSS
10%
30%
50%
70%
90%
Probability of lightning in 60 min

Image Type: IR Cloud Phase (IRCP)

- Useful for identifying cloud temperatures at night
- Any other image type (except True Color-IRCP Hybrid) will default to this if solar zenith angle > 85°
- **Example command:**

```
./lightningcast --border-level 2 $MAKE_IMG_ARG --ll-bbox -74.0 -
34.7 -33.8 5.3 $INPUT_FILE_PATH
```

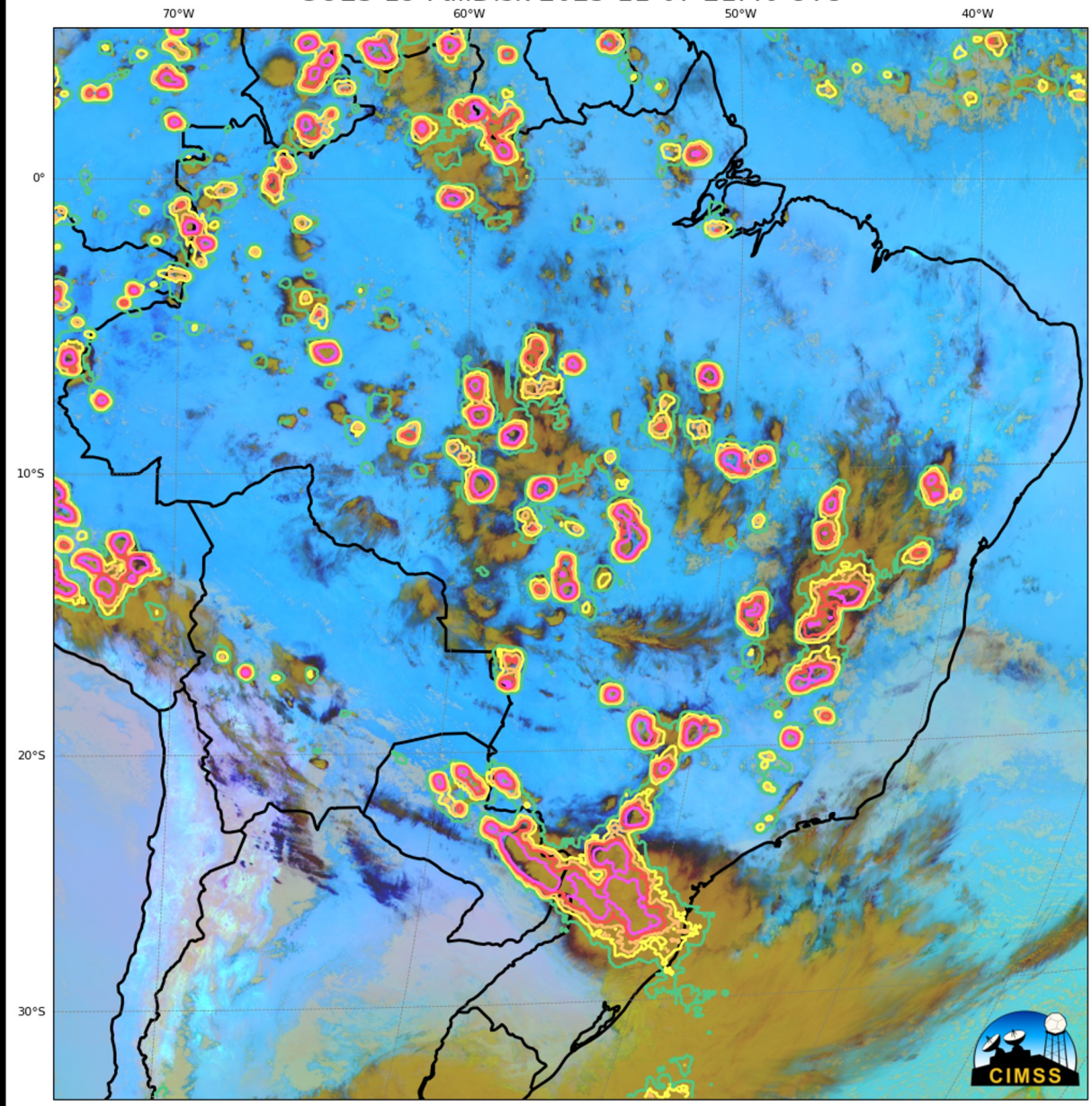

GOES-19 FullDisk 2025-11-07 21:40 UTC
70°W
60°W
50°W
40°W
0°
10°S
20°S
30°S
CIMSS
10%
30%
50%
70%
90%
Probability of lightning in 60 min

Image Type: True Color IR Cloud Phase (TCIRP)

- Can use True Color, IRCP, or a mix
- Prefers True Color
- Uses IR Cloud Phase where True Color isn't possible
- **Example command:**

```
./lightningcast --border-level 2 --make-tcirp-image --ll-bbox -
74.0 -34.7 -33.8 5.3 $INPUT_FILE_PATH
```

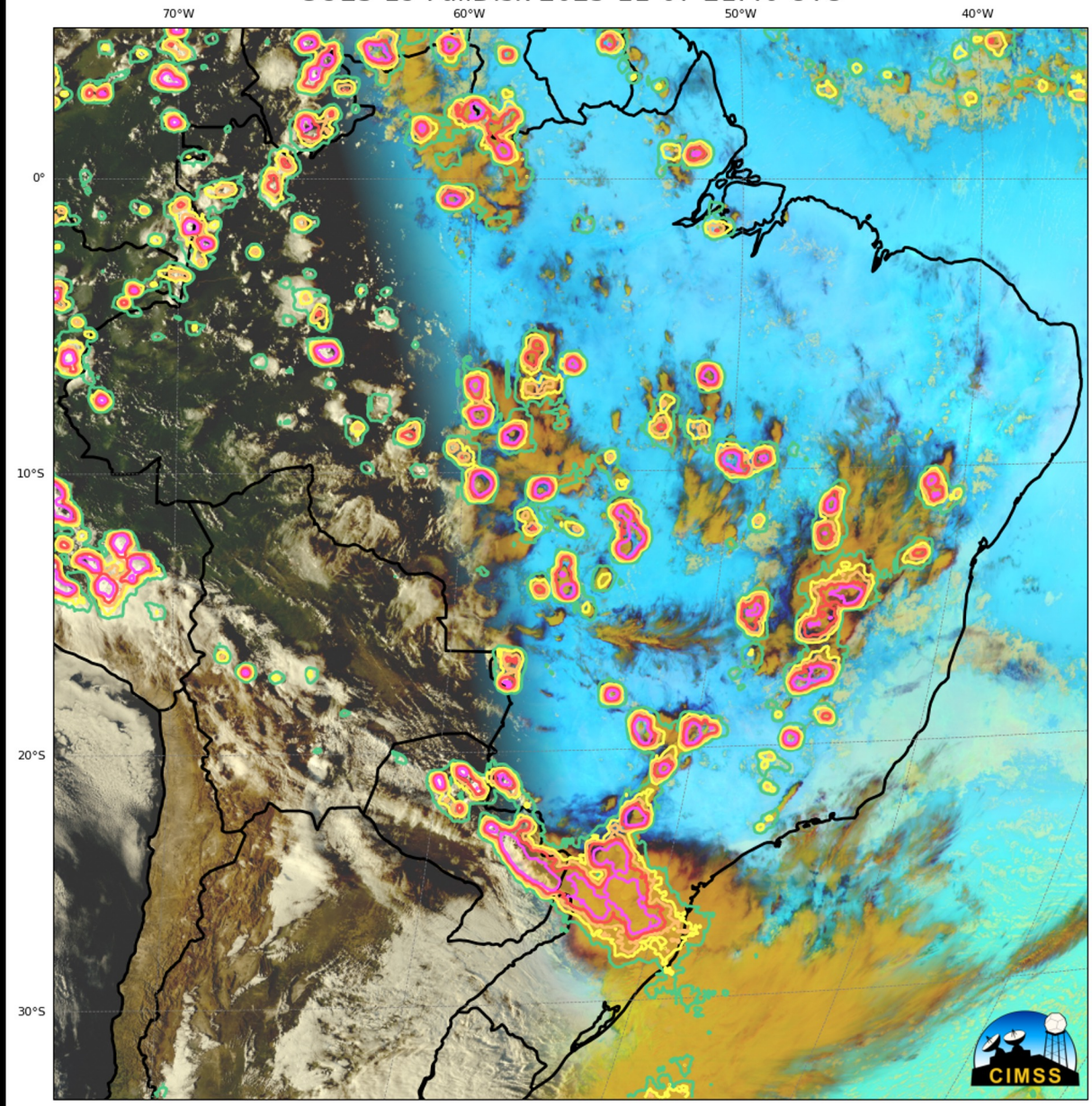
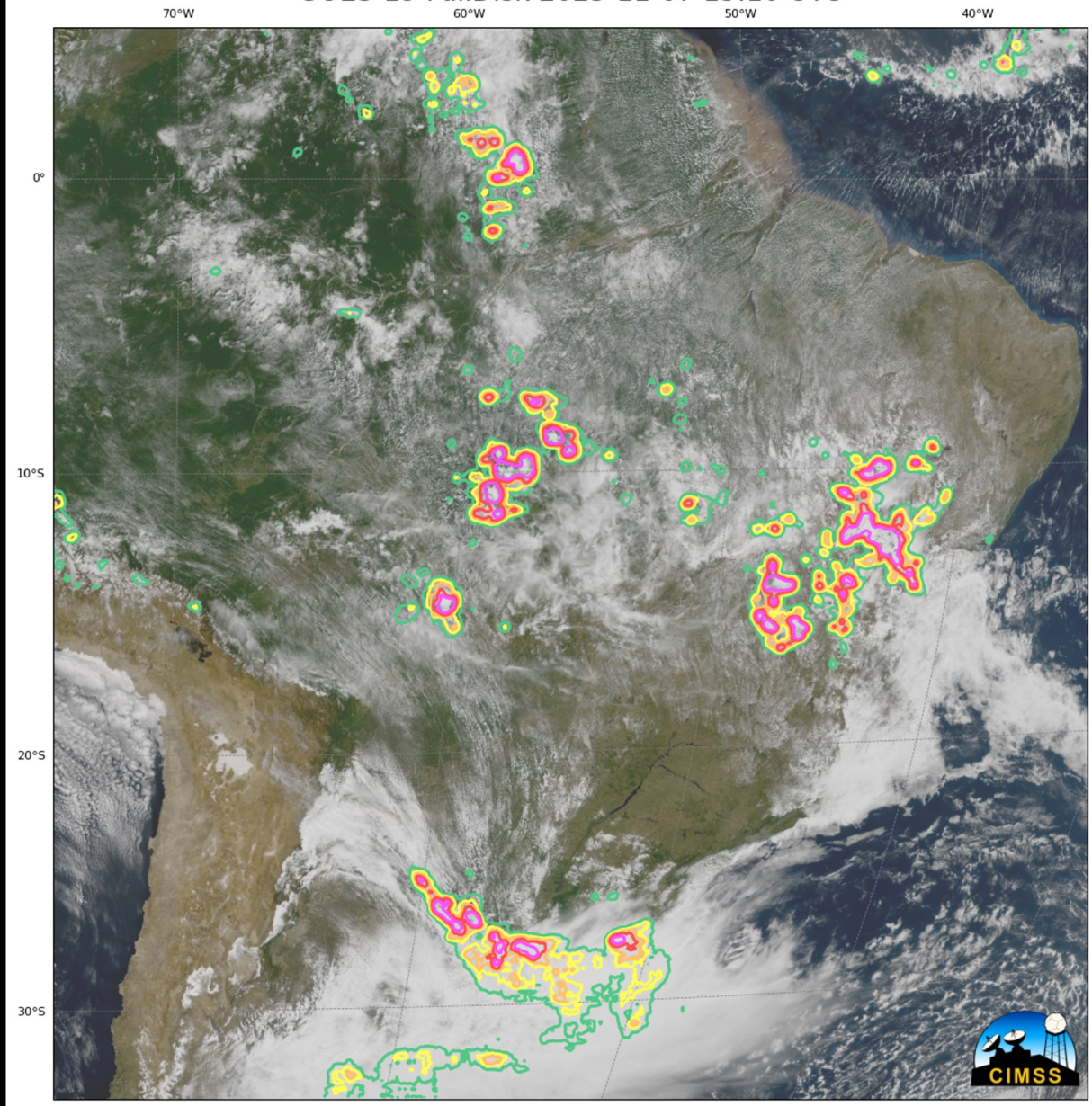
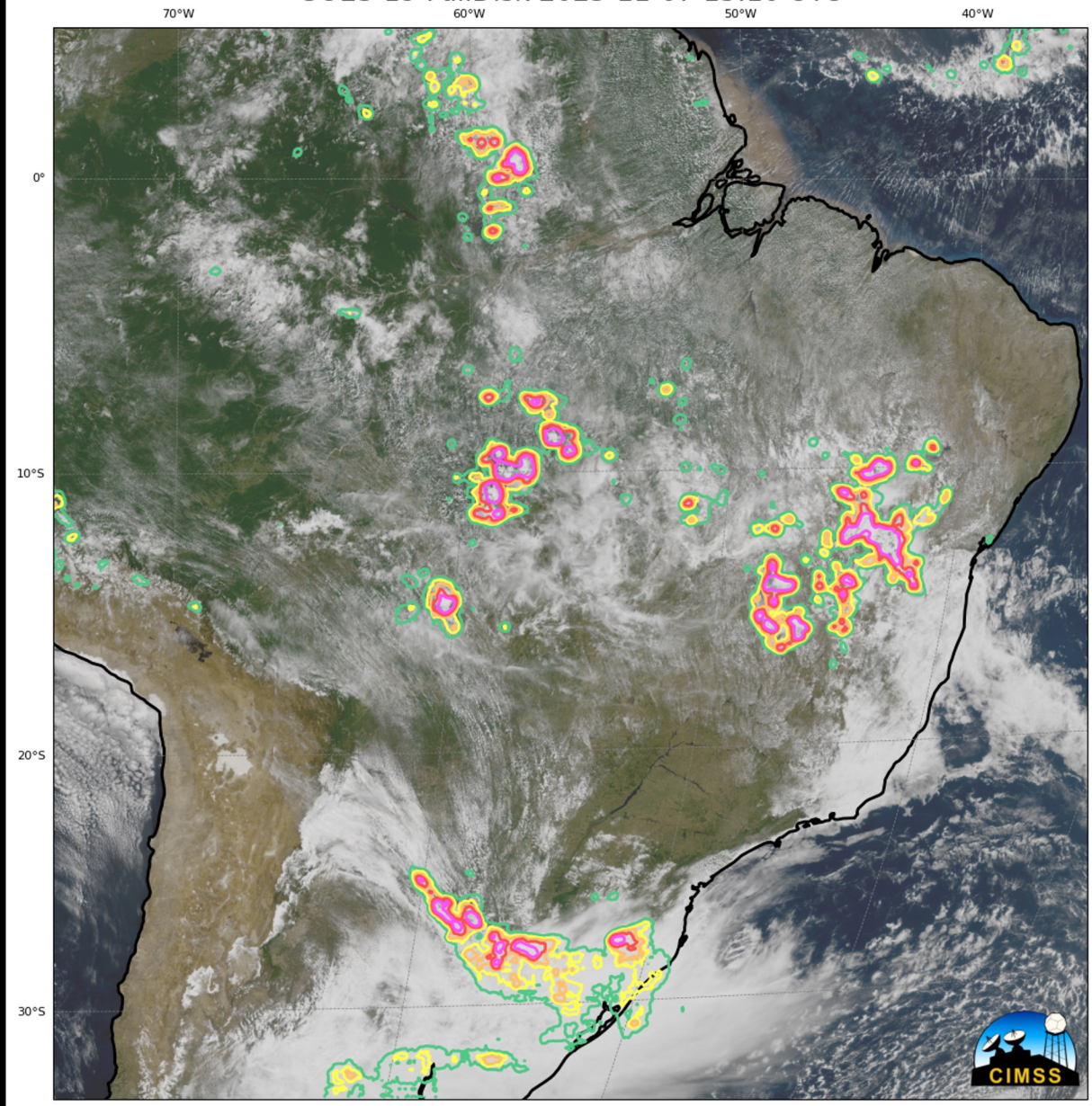

GOES-19 FullDisk 2025-11-07 21:40 UTC
70°W
60°W
50°W
40°W
0°
10°S
20°S
30°S
CIMSS
10%
30%
50%
70%
90%
Probability of lightning in 60 min

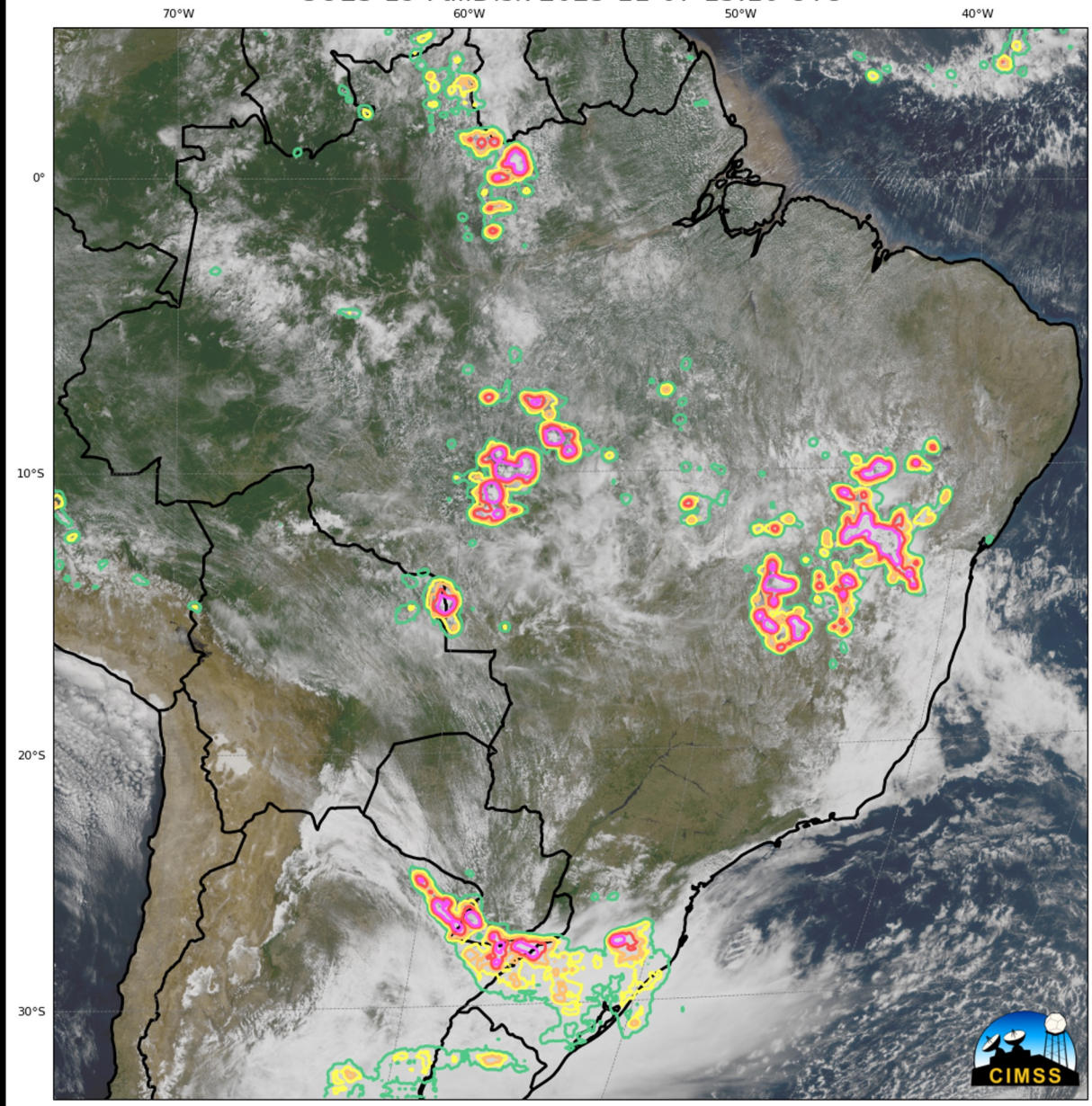
Image Border Levels

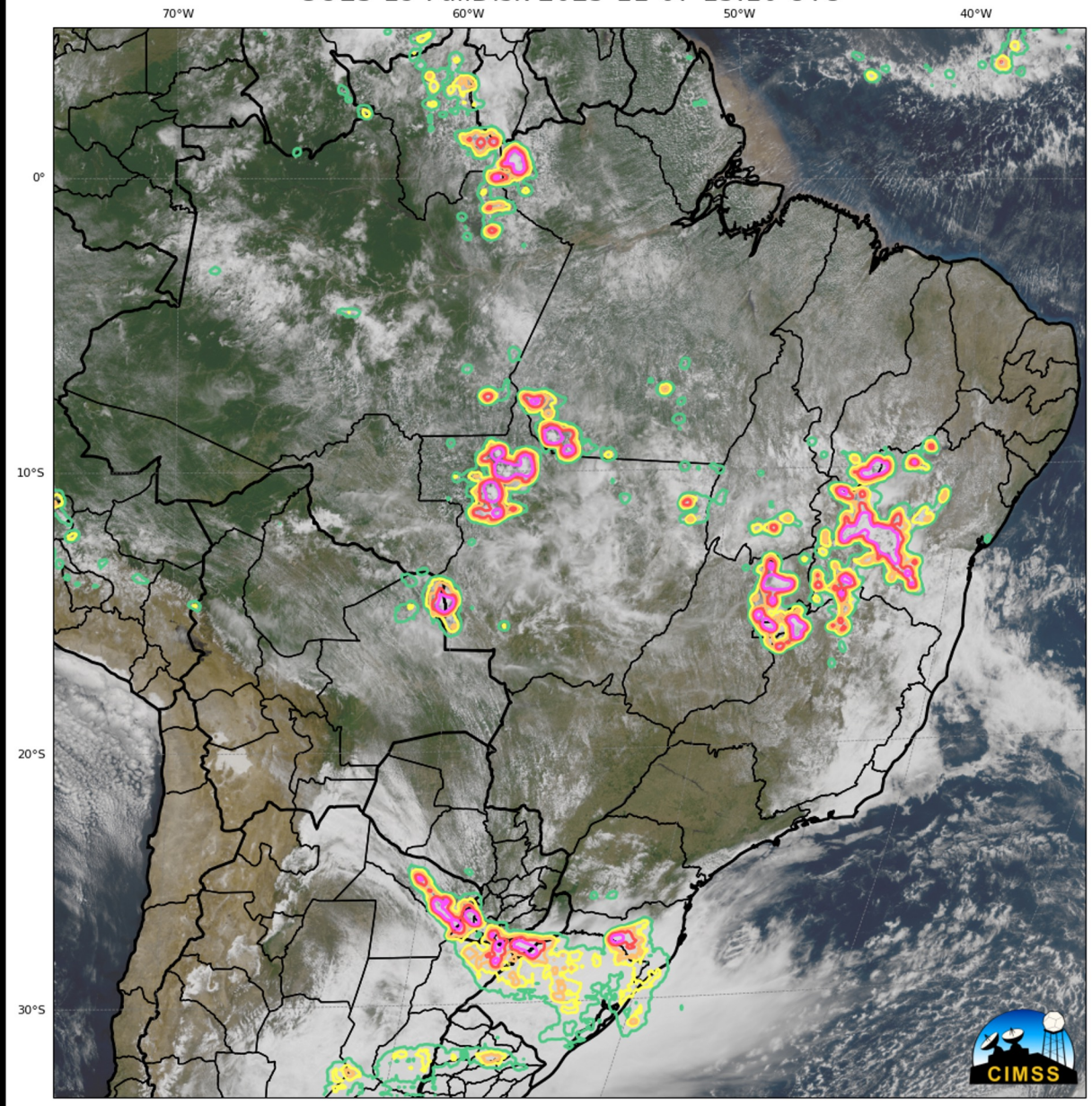
- Available on any Image type
- Configurable to different levels:
  - **0:** No borders
  - **1:** Coastlines
  - **2:** Country borders (default)
  - **3:** States / provinces
  - **4:** US counties (US only)
- **Example command**

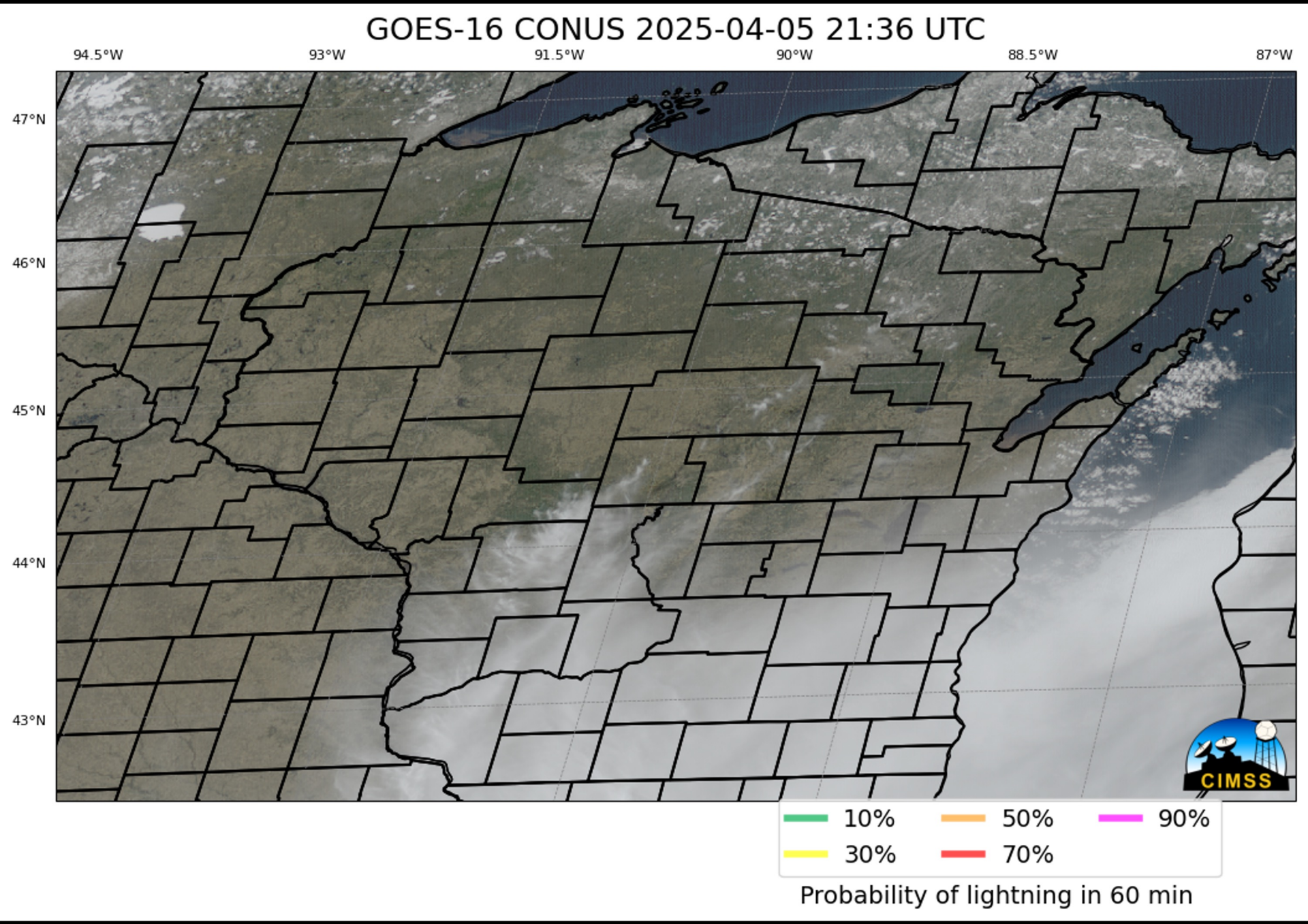
```
./lightningcast --border-level $BORDER_LEVEL --make-tcirp-image --ll-
bbox -74.0 -34.7 -33.8 5.3 $INPUT_FILE_PATH
```


GOES-19 FullDisk 2025-11-07 15:10 UTC
70°W
60°W
50°W
40°W
0°
10°S
20°S
30°S
CIMSS
10%
30%
50%
70%
90%
Probability of lightning in 60 min


GOES-19 FullDisk 2025-11-07 15:10 UTC
70°W
60°W
50°W
40°W
0°
10°S
20°S
30°S
CIMSS
10%
30%
50%
70%
90%
Probability of lightning in 60 min


GOES-19 FullDisk 2025-11-07 15:10 UTC
70°W
60°W
50°W
40°W
0°
10°S
20°S
30°S
CIMSS
10%
30%
50%
70%
90%
Probability of lightning in 60 min

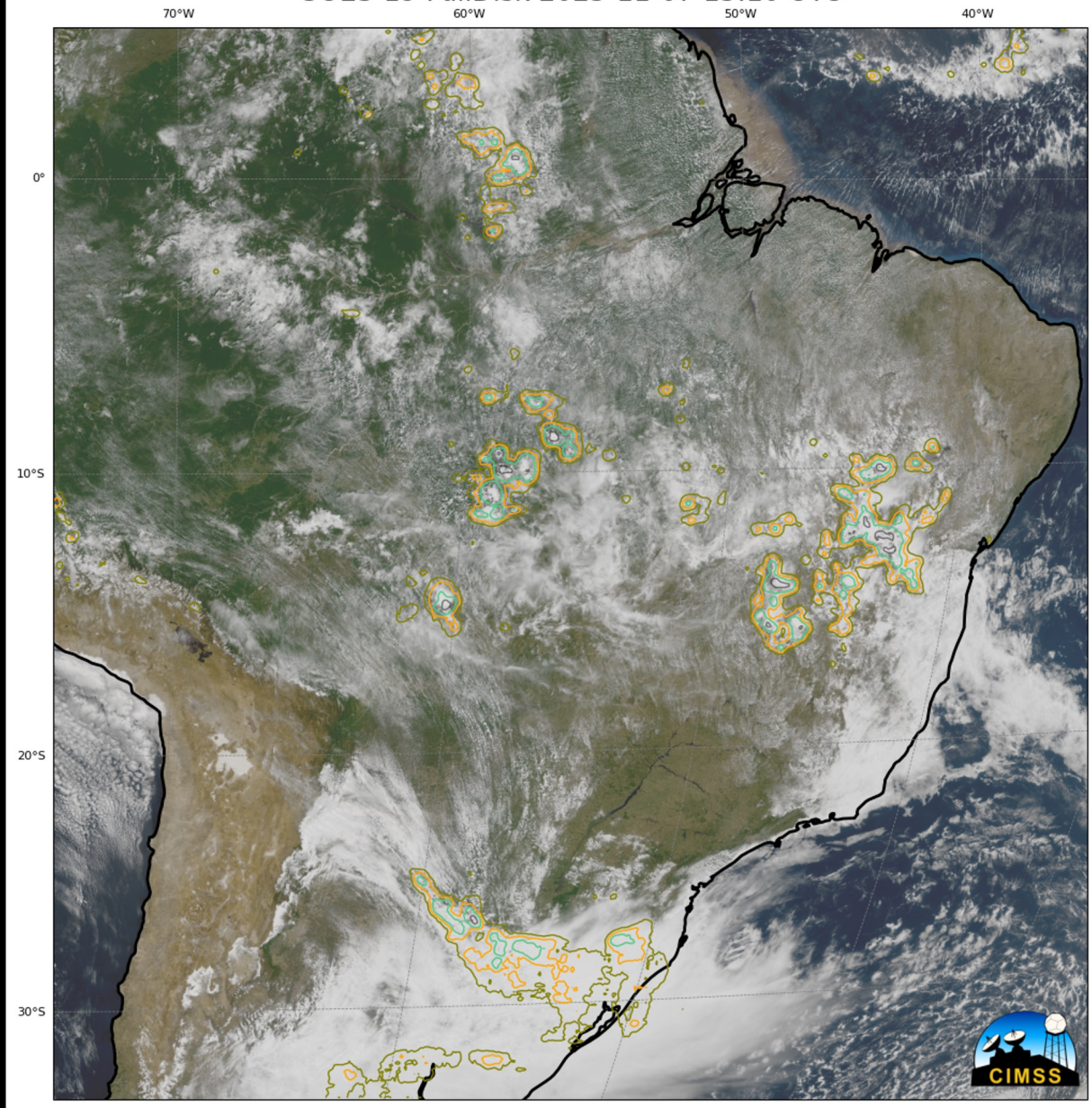

GOES-19 FullDisk 2025-11-07 15:10 UTC
70°W
60°W
50°W
40°W
0°
10°S
20°S
30°S
CIMSS
10%
30%
50%
70%
90%
Probability of lightning in 60 min


GOES-16 CONUS 2025-04-05 21:36 UTC
94.5°W
93°W
91.5°W
90°W
88.5°W
87°W
47°N
46°N
45°N
44°N
43°N
CIMSS
10%
30%
50%
70%
90%
Probability of lightning in 60 min

Contour Probability Customization

- Default probability levels can be customized
  - Requires 1 - 8 values
  - Affects GeoJSONS and images
  - Allows arbitrary numbers
  - Defaults to 10%, 25%, 50%, 75%
  - Defaults to 10%, 30%, 50%, 70%, 90% (upcoming)
- Colors can be adjusted on images using hex values or strings
- **Example command:**

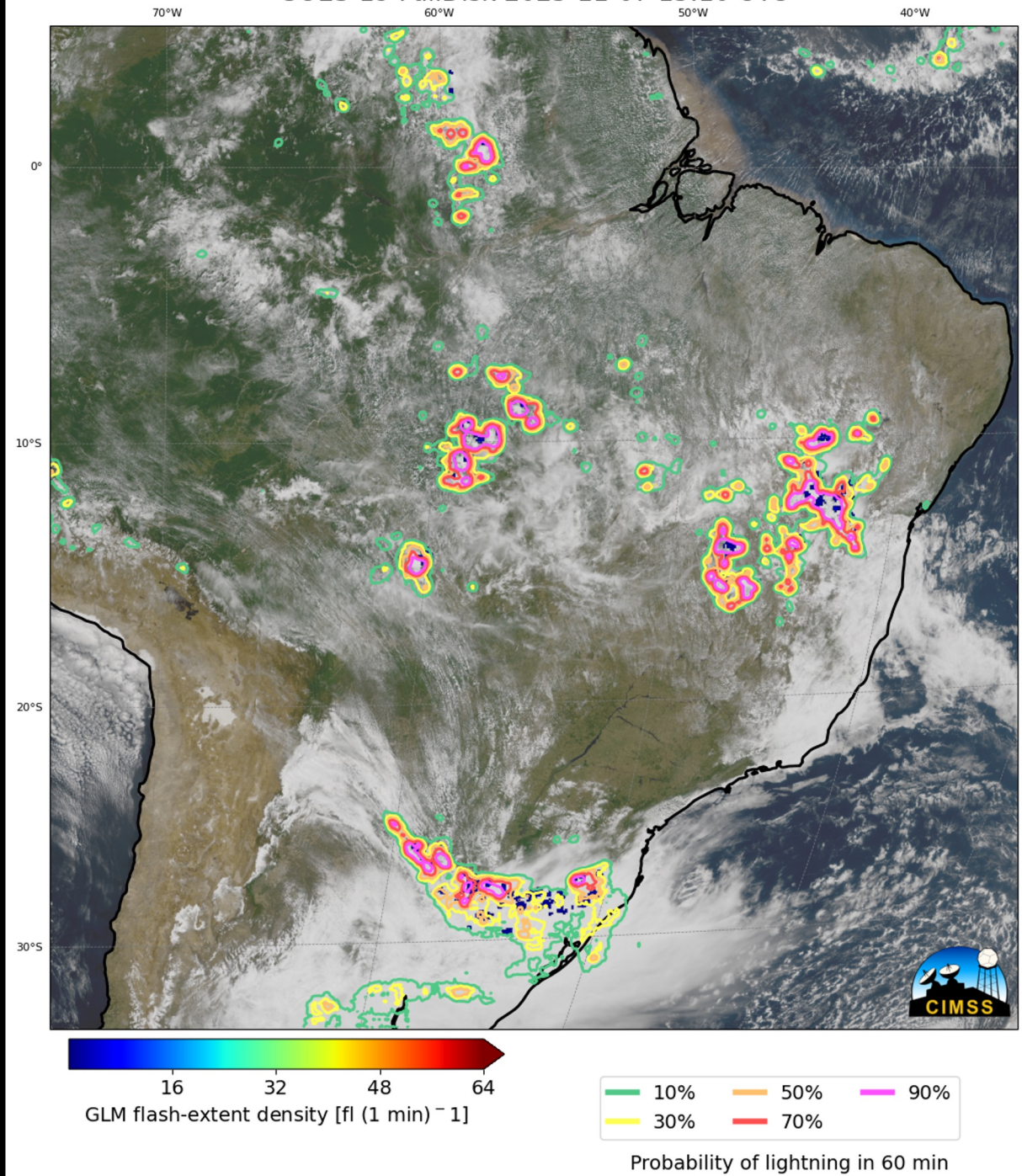
```
./lightningcast --probability-contours 13 42 78 99 --image-probability-colors "olive" "orange" "#50c986" "#0f0f0f80" --ll-bbox -74.0 -34.7 -33.8 5.3 --make-tc-image $INPUT_FILE_PATH
```


GOES-19 FullDisk 2025-11-07 15:10 UTC
70°W
60°W
50°W
40°W
0°
10°S
20°S
30°S
CIMSS
13%
42%
78%
99%
Probability of lightning in 60 min

Geostationary Lightning Mapper (GLM) Overlay

- Gridded GLM output from the CSPP Geo Gridded GLM package may be overlaid on image output
- Allows visualizing lightning from within the last minute alongside lightning prediction
- Shows how lightning activity may change from present
- **Example command**:

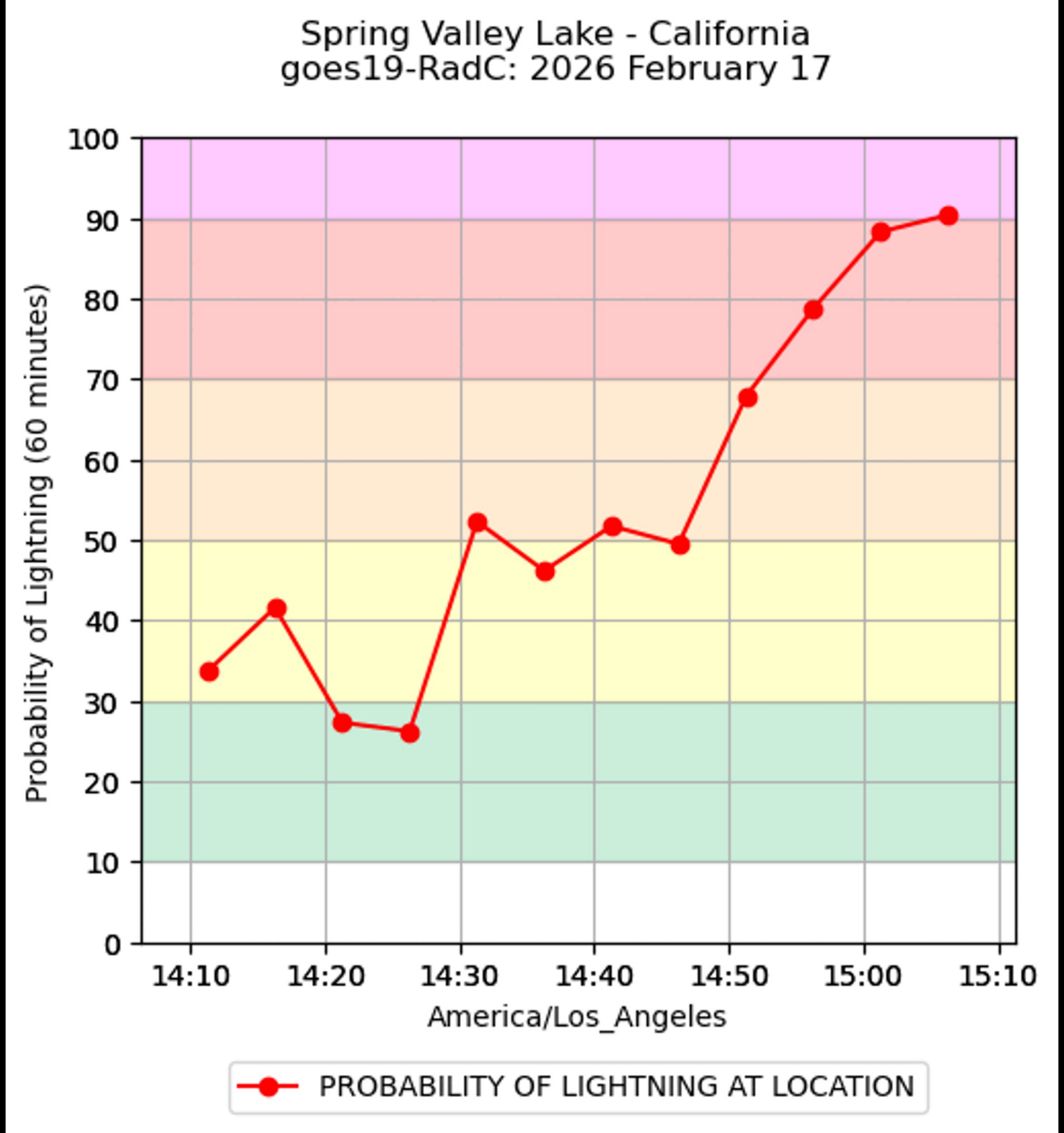
```
./lightningcast --gridded-glm $GGLM_PATH  --ll-bbox -74.0 -34.7 -33.8
5.3 --make-tc-image $INPUT_FILE_PATH
```

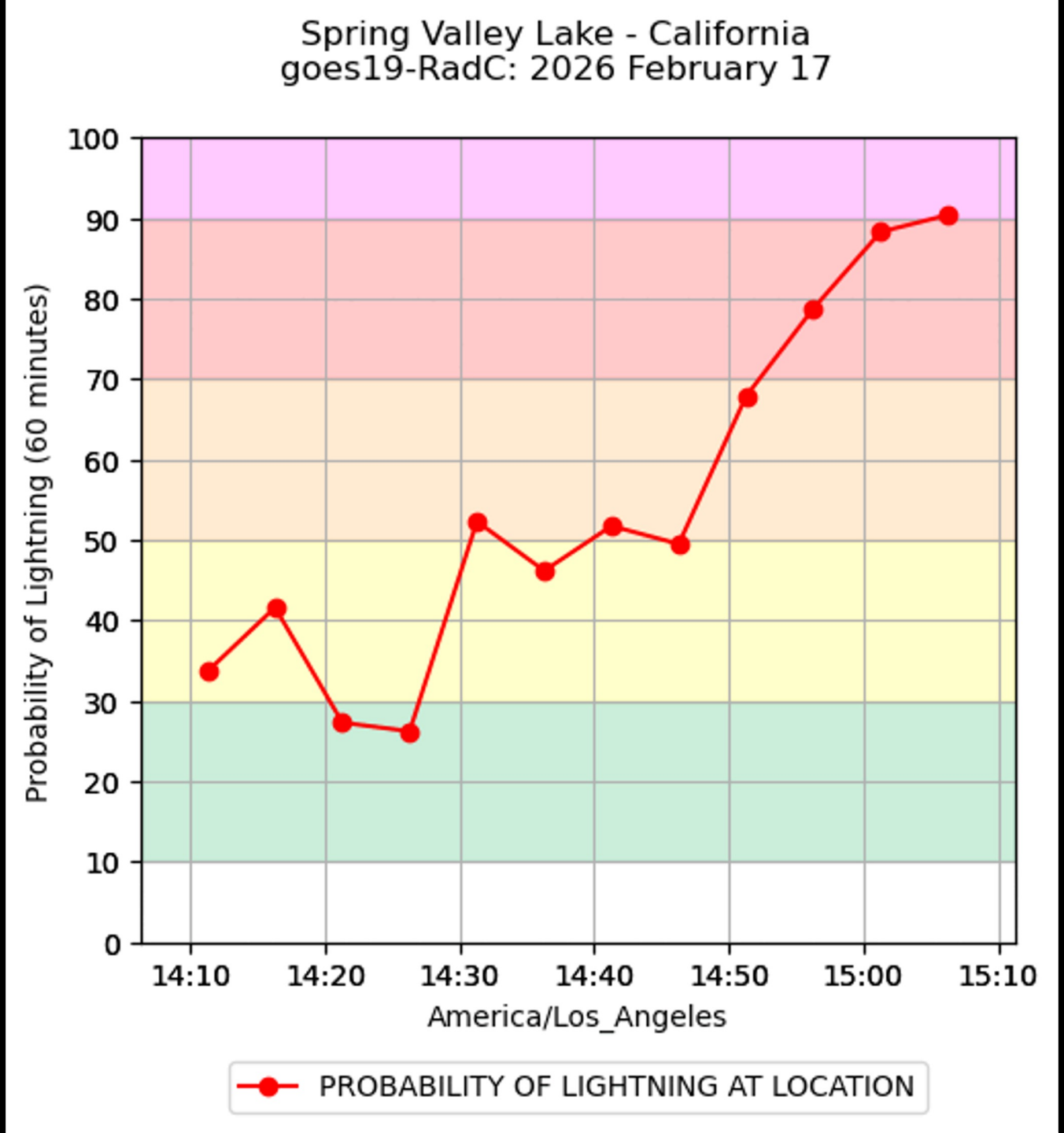

GOES-19 FullDisk 2025-11-07 15:10 UTC
70°W
60°W
50°W
40°W
0°
10°S
20°S
30°S
CIMSS
16
32
48
64
GLM flash-extent density [fl (1 min)⁻¹]
10%
30%
50%
70%
90%
Probability of lightning in 60 min

Meteograms

- Uses output of past runs to graph change in probability in a given area over time
- Takes in a CSV with locations to meteogram generation
- Helpful for recognizing trends
- Configurable timezone
- **Example command:**

```
./lightningcast --meteogram-locations $CSV_PATH --meteogram-timezone
America/Los_Angeles $INPUT_FILE_PATH
```


Spring Valley Lake - California
goes19-RadC: 2026 February 17
Probability of Lightning (60 minutes)
100
90
80
70
60
50
40
30
20
10
0
14:10
14:20
14:30
14:40
14:50
15:00
15:10
America/Los_Angeles
PROBABILITY OF LIGHTNING AT LOCATION


Spring Valley Lake - California
goes19-RadC: 2026 February 17
Probability of Lightning (60 minutes)
100
90
80
70
60
50
40
30
20
10
0
14:10
14:20
14:30
14:40
14:50
15:00
15:10
America/Los_Angeles
PROBABILITY OF LIGHTNING AT LOCATION

GeoTIFF Output

- TIFF image file with additional geographic information
- Useful for specific geo-processing software such as QGIS, ArcGIS, etc.
- **Example command**:

```
./lightningcast --geotiff $INPUT_FILE_PATH
```


Visualized by QGIS

NetCDF Output

- Supports both AWIPS and non-AWIPS systems (including built-in AWIPS sectors)
- Supports parallax correction set to on, off, or both (multiple variables in files)
- **Example command for non-AWIPS:**

```
./lightningcast --parallax both --netcdf $INPUT_FILE_PATH
```

- **Example command for AWIPS:**

```
./lightningcast --parallax both --awips-mode --netcdf $INPUT_FILE_PATH
```

GeoJSON Output

- Lightweight and widely supported JSON based format
- Supports parallax correction set to on, off, or both (creates multiple files)
- On by default
- **Example command (to turn off):**

```
./lightningcast --parallax both --skip-geojson $INPUT_FILE_PATH
```

GR PlaceFile Output

- Easy to use alongside radar data
- Used by US National Weather Service
- Requires Parallax correction
- **Example command:**

```
./lightningcast --parallax both --gr-placefile $INPUT_FILE_PATH
```

Contacts / Resources

- Levi Pfantz (lpfantz@wisc.edu)
- John Cintineo (john.cintineo@noaa.gov)
- https://cimss.ssec.wisc.edu/csppgeo/lightningcast.html
- https://forums.ssec.wisc.edu
- Access this presentation: