Version 1.0

Beginner's Guide to GOES-R Series Data

How to acquire, analyze, and visualize GOES-R Series data

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Contents

Part 1.

The GOES-R Series

Introduction to the GOES-R Series

- Geostationary Operational Environmental Satellites (GOES) are developed, launched and operated in a collaborative effort by NOAA and NASA, and have been in operation since 1975.
- The latest generation of geostationary satellites, with its first launch in 2016, is the GOES-R Series.
- The GOES-R Series is a four satellite program, which maintains two operational satellites at all times, as well as third standby satellite in "storage mode" on-orbit as a ready spare (currently GOES-14).
    - GOES-R (GOES-16, GOES East) launched in November 2016, replacing GOES-13. It orbits at 75.2º W longitude, with coverage of North and South America and the Atlantic Ocean to the west coast of Africa
    - GOES-S (GOES-17, GOES West) launched in March, 2018, replacing GOES-15. It orbits at 137.2º W, with coverage of western North America and the Pacific Ocean
    - GOES-T and GOES-U, currently scheduled for launch in 2021 and 2024 respectively, will assume operational roles as GOES-16/17 are retired
- The GOES satellites have six different instruments onboard. See Slide 5 for descriptions of each instrument.

Useful links for background information:

- Mission Overview, GOES History, GOES-R Data Book (technical overview of satellite and ground systems)

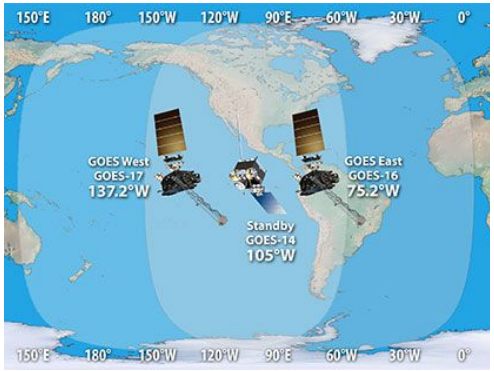


Figure 1. The geographic ranges of GOES-16 and 17 together cover the North American continent.

GOES-R Series Instruments

Earth-pointing:

- Advanced Baseline Imager (ABI) - the primary instrument for imaging Earth's weather, oceans and environment. See Slide 6 for more details.
- Geostationary Lightning Mapper (GLM) - a single-channel, near-infrared optical transient detector that can identify momentary changes in an optical scene, indicating the presence of lightning.

Sun-pointing:

- Extreme Ultraviolet and X-ray Irradiance Sensors (EXIS) - monitors solar irradiance in the upper atmosphere using two primary sensors: the Extreme Ultraviolet Sensor (EUVS) and the X-Ray Sensor (XRS).
- Solar Ultraviolet Imager (SUVI) - a telescope that monitors the sun in the extreme ultraviolet wavelength range, detecting solar flares and solar eruptions, and compiling full disk solar images.

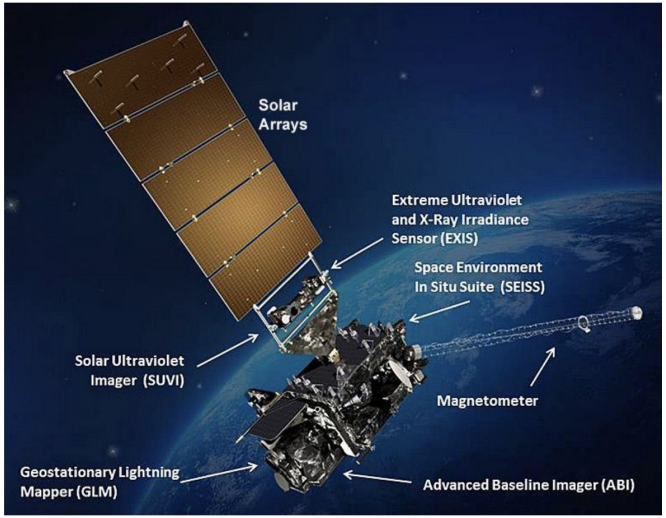


Figure 2. GOES-R Series satellites are composed of 6 instruments, and powered by a solar panel array.

In-situ:

- Magnetometer (MAG) - measures the space environment magnetic field that controls charged particle dynamics in the outer region of the magnetosphere.
- Space Environment In-Situ Suite (SEISS) - monitors proton, electron, and heavy ion fluxes in the magnetosphere using four sensors: the Energetic Heavy Ion Sensor (EHIS), the High and Low Magnetospheric Particle Sensors (MPS-HI and MPS-LO), and the Solar and Galactic Proton Sensor (SGPS).

Advanced Baseline Imager (ABI)

- ABI is a multi-channel passive imaging radiometer that images Earth's weather, oceans and environment with 16 spectral bands (2 visible, 4 near-infrared, and 10 infrared channels).
  - ABI Bands Technical Summary Chart
- Spatial resolution is 0.5, 1, or 2 km, depending on the band (see above-linked chart).
- Geographic coverage
  - Full Disk: a circular image depicting nearly full coverage of the Western Hemisphere (GOES-16 / GOES-17).
  - CONUS/PACUS : a 3,000 (lat) by 5,000 (lon) km rectangular image depicting the Continental US (CONUS) (GOES-16) or the Pacific Ocean including Hawaii (PACUS) (GOES-17).
  - Mesoscale: a 1,000 by 1,000 km rectangular image. GOES-16 and 17 both alternate between two different mesoscale geographic regions (domains). See Slide 7 for a complete description of mesoscale domains.
- ABI has multiple scan modes.
  - Mode 4 - A contingency mode. Produces a full disk image every 5 minutes.
  - Mode 3 - The cooling timeline mode used by GOES-17 during four time periods per year. This operation mitigates the number of saturated images resulting from the loop heat pipe (LHP) temperature regulation anomaly. Mode 3 produces a full disk image every 15 minutes, and images of both mesoscale domains every 2 minutes.
  - Mode 6 - The default operational mode for GOES-East & West. Produces a full disk every 10 minutes, a CONUS/PACUS image every 5 minutes, and images from both mesoscale domains every 60 seconds.

Mesoscale Domains

- Mesoscale domains are 1,000 by 1,000 km movable rectangular regions. The purpose of a mesoscale scan is to frequently revisit an area of interest to monitor regional conditions.
- GOES-16 and 17 each have two default domains (see below), however the domains can be positioned anywhere within the full disk upon request. Requests are placed by National Weather Service (NWS) Weather Forecast Offices (WFOs).
  - See the graph (right) of mesoscale requests by month
- In Mode 6, the ABI on both GOES-16 and 17 scans either the same mesoscale domain every 30 seconds, or two separate mesoscale domains every 60 seconds.

Number of Mesoscale Requests by Month

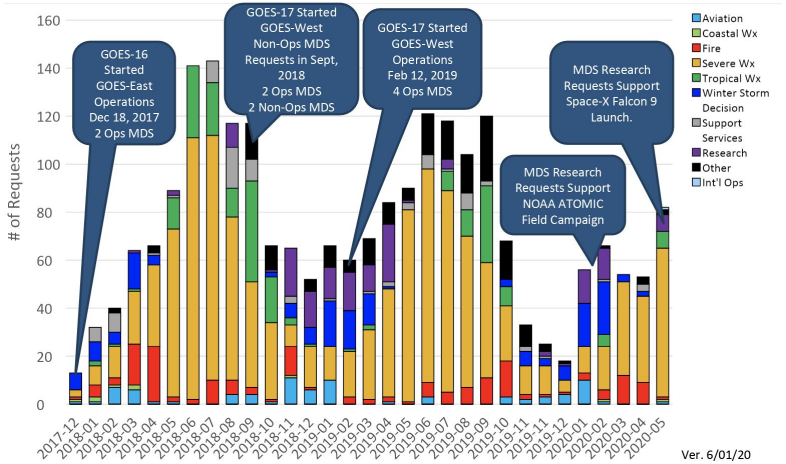


Figure 3. The frequency of mesoscale domain requests varies overtime, peaking during summer months.

Figure 4a. The GOES-16 default mesoscale scan sectors are the East Coast and Midwest.

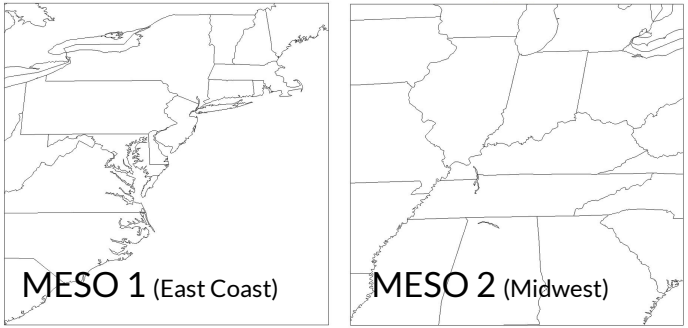
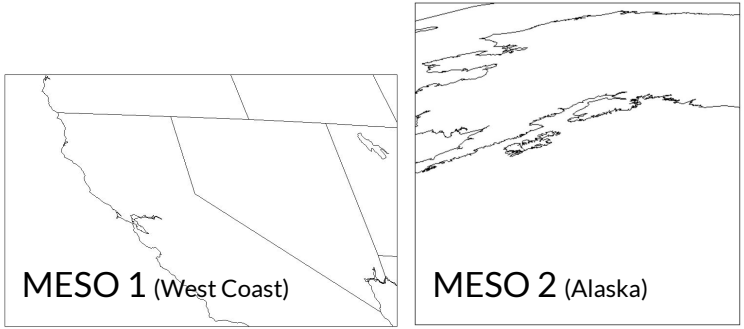


Figure 4b. The GOES-17 default mesoscale scan sectors are the West Coast and Alaska.



GOES-R Data Products

- To visualize GOES-R data, select one of many available products.
  - Here is a list of all the GOES-R products made available to the user community by NOAA.
- Level 0 (L0):
  - L0 products are observation data received directly from the 6 satellite instruments. The data is not meaningful to most users prior to processing by the ground system.
- Level 1b (L1b):
  - L1b products are calibrated and, where applicable, geographically corrected, L0 data. This means that the data has been processed so that its values are in standard units of physical quantities.
  - For ABI, the L1b product is Radiances. This is useful for users who require radiance units, instead of reflectance/brightness (Kelvin) units.
  - All of the instruments have L1b products available except GLM, which is only distributed as an L2+ product.
  - Product User Guide (PUG) Volume 3: L1b Products, Revision 2.2 (for technical information)
- Level 2+ Products:
  - L2+ products contain environmental physical qualities, such as cloud top height or land surface temperature. Aside from the GLM Lightning Detection Product, the data source for these products is the ABI L1b data
  - The mission-critical ABI product is Cloud and Moisture Imagery (CMI), which utilizes all 16 ABI spectral bands, and is used to generate an array of products aiding forecasters in monitoring and predicting all kinds of hazards.
  - PUG Volume 5: L2+ Products, Revision 2.2 (for technical information)

Product Maturity and Data Availability

- Before GOES-R satellites take off, pre-launch verification determines that systems are functioning.
- However, most instrument, L1b, and L2+ product validation is fully realized after launch with post-launch product tests that use actual earth observations. Calibration and characterization also continue after launch to maintain data product quality.
- Product Maturity Levels, *summarized*:
  - **Beta**: Data are preliminary and non-operational; undergoing testing and initial calibration and validation. Beta products have been minimally validated and may still contain significant errors.
  - **Provisional**: Data are ready for operations. Performance has been tested and documented over a subset of conditions, locations, and periods. Validation is still ongoing; known anomalies are documented and available to the user community.
  - **Full**: Product is operational. All known anomalies are documented and shared with the user community. Performance has been tested and documented over a wide range of conditions.
- Data Availability:
  - CLASS and NCEI (see Slide 13) have all data from launch onward available to end-users.
  - Cloud-based platforms (see Slides 14 and 15) typically have only provisional data and onwards available to users. However, the length of time of the data archive may vary between vendors.
  - To determine when a particular product advanced to a certain maturity level, explore the Peer/Stakeholder Product Validation Reviews.

Part 2.

Where Can I Access the Data?

View GOES-R Imagery

- There are several platforms designed for viewing recent GOES-R imagery, but not analyzing the data.
- The GOES Image Viewer provides maximum flexibility to look at recent GOES images. Selection options include the geographic scale and the band/band combination of interest.
    - In addition, for any active storm, a console describes the weather event and provides a real-time animation.
- The CIRA “RAMMB” Slider offers a similar service. This platform has real-time images for all the bands, and many L2+ products including GLM. There is select archived data available for the prior two weeks.
    - The NASA SPoRT website is almost identical, but the archived data only goes back one day.
    - The SSEC Viewer provides the same dates as NASA SPoRT, but has fewer GOES products to choose from.
- NASA Worldview is a great portal for overlaying GOES images with other satellite imagery, for any recent or archived time interval. However, the only GOES data stored on Worldview are band 2 (Red Visible), band 13 (Clean Infrared), and the Air Mass RGB composite imagery.
- For other viewing platforms, check out the "GOES ABI (Advanced Baseline Imager) Realtime Imagery" web page.

View GOES-R Imagery with AWIPS

- AWIPS (Advanced Weather Interactive Processing System) is the software used by the National Weather Service (NWS) to display and analyze meteorological data.
- Unidata developed and supports a modified non-operational version of AWIPS which is a free and open-source software that any user can download to view GOES-R Series data through a similar lens as weather forecasting offices (WFOs).
  - CAVE (Common AWIPS Visualization Environment) is a Java application which runs on Linux, Mac, and Windows. Follow these steps to download CAVE to your device.
  - AWIPS data can be accessed through the cloud using the EDEX Server. When prompted by the Connectivity Preferences Dialog, select the EDEX-cloud server .
  - Read Unidata's CAVE User Manual to learn how to interact with and customize the AWIPS tools. See the GOES 16/17 Section for instructions specific to GOES-R channels, products, and RGB Composites.
    - For more detail, review the entire user manual with particular attention to Section 2.2.
    - See p.56-63 for image display and time cadence options, and p.53-55 for viewing preferences.

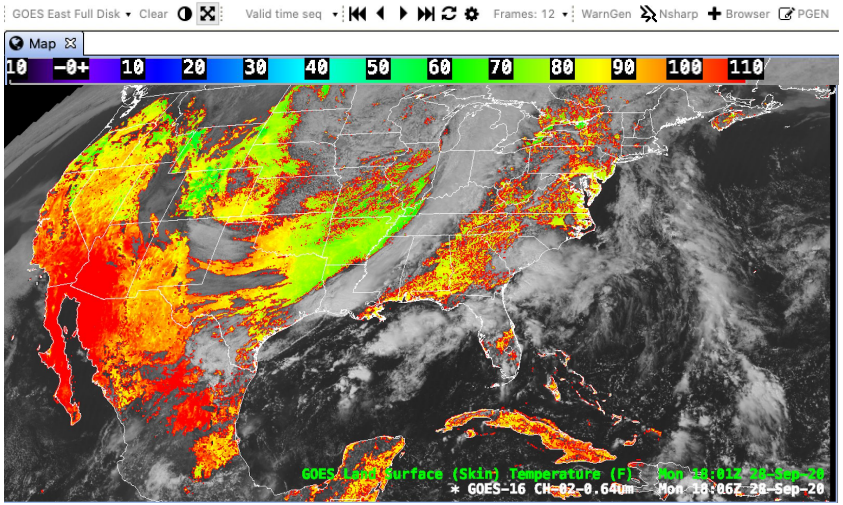


Figure 5. The AWIPS display can overlay L2+ products and visible imagery, such as Land Surface Temperature and Channel 2.

Access Data Files: NOAA CLASS

- The NOAA Comprehensive Large Array-data Stewardship System (CLASS) repository is the official site for accessing all available GOES-R Series Products.
  - Begin by selecting the product of interest from the search bar, such as GOES-R Series ABI Products (GRABIPRD) (partially restricted L1b and L2+ Data Products).
  - Use the Temporal and Advanced Search options to filter the data by time, date, satellite, geographic scale, and product. It is possible to include up to 10,000 files in an order. Click “Quick Search and Order”, then “Register”.
  - Fill in your contact information to create a Guest User Profile. Once you are logged into CLASS as a guest, the option to “Place Order” will appear. If you are a returning CLASS user, log in before beginning your data search.
  - When the order has been processed (up to 48 hours for large order sizes), instructions will be sent to the email address provided. The email will offer two options for accessing the file(s):
    - 1. Authenticate and download from CLASS via FTPS. This requires a robust FTP client. Use “anonymous” as the FTP user ID, and your email address as the password.
    - 2. Download each file individually from the CLASS website.
- A similar but easier website to navigate is NCEI's Archive Information Request System (AIRS).
  - Using the AIRS system, there is no need to set up an account.
  - It is possible to filter, search, and order up to 30 days worth of files, and access up to 1,000 files per order.
  - An email will be sent with download instructions for the processed files, with options for web and FTP downloads.
  - Another interface for downloading NCEI’s archive of GOES data is NCEI Dataset Search.

Access Data Files: Amazon, Microsoft, OCC

- Amazon Web Service (AWS) - ABI L1b and L2+, GLM L2+, and SUVI L1b products are available in an AWS S3 Bucket
  - Objects cannot be accessed from the AWS website. Scripted downloads are necessary to pull data from AWS.
  - An AWS Free Tier Account (12-months free) *may* be necessary for data access, depending on the retrieval method used.
  - Options for scripted downloading include the AWS Command Line Interface, rclone (see rclone tutorial for GOES data access) and the Python s3fs library (see Slide 16 for more information on Python).
  - See the README file under "Documentation" on the AWS page for GOES-specific instructions and file naming.
  - Not interested in coding? The "GOES-16/17 on Amazon Download Page," created by Brian Blaylock, Ph.D. is a bypass that executes file downloads in a few clicks (the page uses rclone to pull data from the AWS S3 Bucket).
    - The clear website interface allows for easy product browsing and filtering.
    - The site provides a good option for retrieving a few particular files, but not bulk downloads.
- Microsoft Azure - One GOES-16 L2+ Product (CMI Full-Disk) is stored in a Azure blob container.
  - This Azure Notebook shows how to retrieve a file from blob storage and visualize the image with Python.
- Open Commons Consortium (OCC) - Stores a 100 TB rolling archive of GOES-16 data (~ 8 months), the products stored are ABI L1b and ABI L2+ CMI and MCMI.

  OCC recommends using the AWS CLI or the python boto library, to access the data.

Access Data Files: Google Cloud

- Google Cloud Platform (GCP) - ABI L1b and L2+ products are available in two buckets for GOES-16 and GOES-17.
  - Unlike AWS, GOES data can be browsed and pulled directly from the GCP website (up to 1TB/month).
  - The website can filter by product name and date, but be prepared with the product abbreviation and the day-of-the-year of interest, because there are few descriptors on the GCP website.
  - Downloading the data requires authentication with a Google account (not Google Cloud specific).
    - Without a Google account, data access is still possible using a Cloud Storage API link.
  - Set up Google Cloud Platform Free Tier service to gain $300 in credit, and benefit from a 12-month free trial.
    - Follow the "How to process weather satellite data in real-time in BigQuery" tutorial to visualize GOES using GCP and the gsutil command-line utility.
- Google Earth Engine (GEE) - A cloud-based platform for geospatial analysis. This service runs through Google Cloud, and pulls GOES datasets from the GCP buckets.
  - Only two GOES L2+ products are currently available in the GEE Data Catalog. The products are Multispectral Cloud and Moisture Imagery (MCMI) and Fire Detection and Characterization (FDC).
  - Apply for a free GEE account to use this platform. It may take one-to-two days for the account to get approved.
  - See Slide 20 for more information on how to use GEE as a tool for image analysis and visualization.

Use Python to Retrieve Data from AWS

- To pull data from AWS, it's necessary to use account credentials and scripted file transfers.
- Use AWS Free Tier Account credentials
  - Sample Script #1: "Visualize GOES-16 Data from S3" by Hamed Alemohammad. This script bypasses downloading data to a local device by loading a file directly into Python. Recommended edits follow.
  - Adjust information to reflect the specific product/date/file of interest. Be wary that **not** all products have data for multiple bands (if not, remove "band" attribute), or have images for every date.

    How do I find my AWS credentials? Go to AWS > My Account > Security Credentials > Access Keys
  - Change "M3" to "M6" (mode 3 to mode 6) if the imagery of interest was collected after April 2, 2019
    - This reflects the switch in ABI's default scan mode. See Slide 6 for more information on scan modes.
  - Change "Rad" to other variable name, if the product of interest is not an ABI L1b Radiance Product.
- Use AWS anonymous credentials
  - Sample Script #2: "Download GOES AWS" by Brian Blaylock. This script demonstrates how to do a scripted download from the AWS, without setting up a Free Tier Account.
  - Edit the script to use the correct prefix for the file intended for download. For GOES-R file naming conventions, see the AWS README documentation.
    - For example: "noaa-goes17/ABI-L2-MCMIPC/2019/240/00/"

Part 3.

How Can I Display the Data?

Visualize GOES Using Python (Part 1)

- Import data to Python directly from AWS (follow Script #1, Slide 14), or from a local directory (instructions included in the scripts on Slide 16).
- Visualize GOES-R imagery using xarray and pyplot
  - Most scripts utilize the module xarray to process GOES images (multidimensional arrays).
  - For simple visualizations, use the matplotlib.pyplot module to generate an image (Script #1).
    - Pyplot was used to generate this GOES-16 Full Disk image of Channel 3 Radiances, a title and legend (Figure 6).
  - For more advanced display capabilities, such as georeferencing the image and adding state boundaries, the module Cartopy is necessary.
  - Many guides for GOES visualization rely on the module Basemap, such as the five-part GEONETClass tutorial, or the Maker Portal GOES-R Projection Algorithm. Unfortunately, Basemap has been deprecated and replaced with Cartopy for Python 3.0.

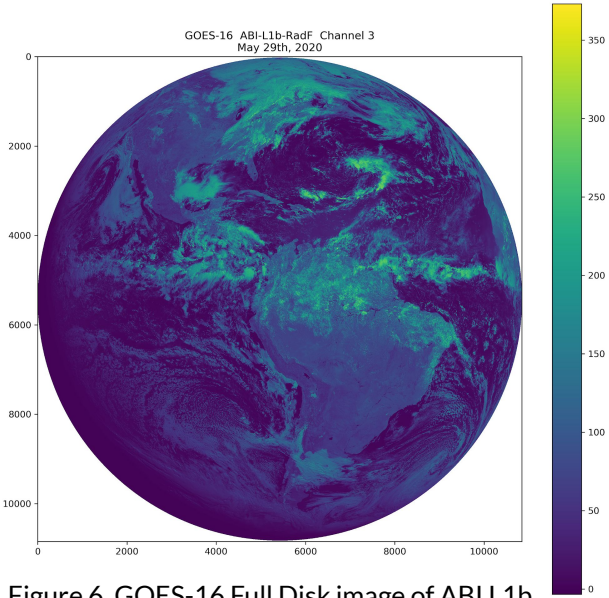


Figure 6. GOES-16 Full Disk image of ABI L1b Channel 3 Radiances on May 29th, 2020, visualized using Python.

Visualize GOES Using Python (Part 2)

Visualize GOES-R imagery using Cartopy

- Script #3: “Mapping GOES-16 True Color” by Brian Blaylock
  - This is an excellent tutorial with step by step explanations for how to render a GOES -16 true color image (CONUS, Mesoscale or Full Disk), how to georeference the image, and how to add features (i.e. state boundaries).
  - The resulting image is pictured in Figure 7.
  - This script takes advantage of the L2+ MCMI product, a single file which contains all 16 bands, resampled to the same resolution. For handling raw radiances, see Slide 21.
- Script #4: “Accessing GOES-16 data on Azure”
  - A nearly identical script, which includes commands to access GOES-16 data from blob storage on Azure, and then renders a true color image with the same technique.

A Python alternative: use GDAL to convert a GOES netCDF file into a png image (Sample Script #5).

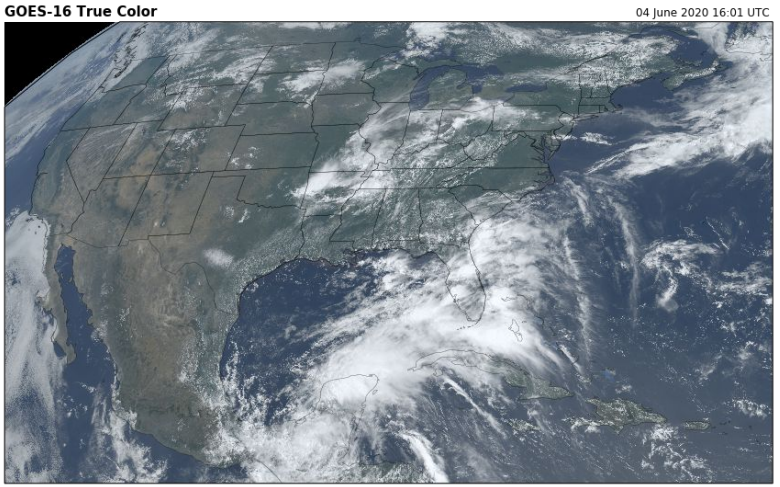


Figure 7. GOES-16 CONUS True Color image on June 4th, 2020, visualized using Python.

Visualize GOES Using Earth Engine

- Google Earth Engine (GEE) is a cloud-based platform for geospatial data analysis. The following list summarizes the advantages of imagery processing using GEE:
  - The GOES imagery stored in the GEE Data Catalog is already georeferenced. Therefore, it only requires a few lines of script to display an image accurately (Figure 8).
  - GEE provides advanced image processing tools designed for satellite imagery analysis, offered through several APIs
  - The GEE Data Catalog stores many datasets, including imagery from MODIS, Landsat, and Sentinel, which are updated daily. Synthesizing dissimilar satellite products is possible in GEE.
  - GEE takes advantage of Google's infrastructure to execute high speed parallel processing. This is helpful for handling large collections of images, without using local computing resources.
  - For an introduction to GEE, check out the GEE Community Tutorials.

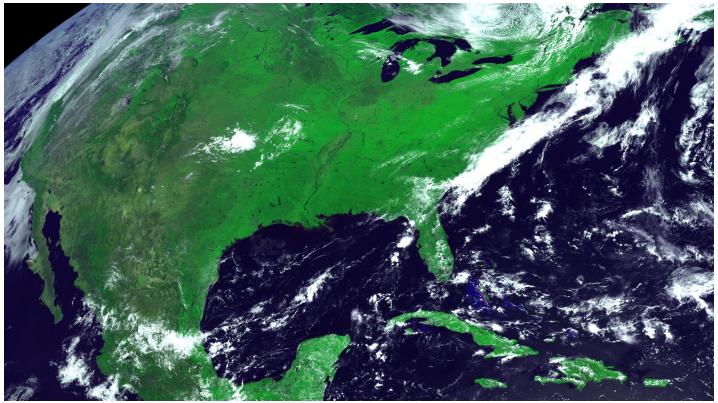


Figure 8. GOES-16 CONUS False Color image on June 12th, 2020, visualized using GEE.

- Be aware of the following:
  - To use this platform, it is necessary to apply for a free GEE account, which may take a day or two to get approved.
  - Two GOES-R Series L2+ products are currently available in the GEE Data Catalog: Multispectral Cloud and Moisture Imagery (MCMI) and Fire Detection and Characterization (FDC). Sample scripts available for products at links.

Technique: Radiance to Reflectance

- When using the L1b Radiance product, it may be beneficial to convert from the unit radiance, which takes into account the solar irradiance and Earth-Sun distance. For the reflective bands (1-6), convert to reflectance. For the emissive bands (7-16), convert to brightness temperature (Kelvin).
- Reflectance conversion equation: reflectance ρf_v = kappa factor κ * radiance L_v
  - The kappa factor is included in the metadata for every L1b file, stored as the variable `'kappa0'`
  - For more information on the reflectance conversion, or how to convert to brightness temperature, see the PUG: Volume 3: L1b Products, Revision 2.2, pages 27-28.
- Sample Script #6: "True-Color Image: GOES-R ABI L1b Radiances" by Danielle Losos
  - This Jupyter Notebook demonstrates several useful techniques for processing and visualizing the L1b Radiance product
  - Compare to the Script #3 methodology for creating true color images from the L2+ MCMI product.
    - See Slide 22 for background on using multiple bands to generate true-color composite images.
  - Alternative approach for converting radiance to reflectance values is documented in the tutorial: "Jupyter Notebook for Working with GOES-16 Data" by OCC . However, this script errs in using constant values to convert between radiance and reflectance. It is recommended to always use the coefficients embedded in that particular image's metadata for conversion to reflectance or brightness temperature.
    - A section of the OCC script shows how to visualize Geostationary Lightning Mapper (GLM) point data.

Technique: Band Stacking

- "Band stacking" is the process of overlaying certain bands to create composite imagery. Composite imagery often yields unique value for user applications.
- A popular composite image type is an RGB True-Color, which uses red, green, and blue wavelengths to mimic the appearance of the Earth to the human eye.
  - GOES-R has both a blue and red visible channel (bands 1 and 2), but not a green visible channel.
  - Band 3, the vegetation band, detects near infrared (NIR) wavelengths, and can serve as a proxy for the green band.
  - Script #3 details how to create an RGB true color image from bands 1, 2 and 3 of a L2+ MCMI file. The MCMI Product has 2 km resolution for every band. Since all the bands have the same resolution, it is easier to perform multi-band operations, however higher resolution on certain bands is lost.
  - Using three separate CMI files for the three bands is less data intensive, and achieves a higher resolution. However, band 2 (the red band) is at 0.5 km resolution while bands 1 and 3 are at 1 km resolution. Therefore, it is necessary to resample band 2. Script #6 demonstrates how to do so using a Rebin function.
- Another common composite is NDVI (normalized difference vegetation index). This index determines vegetative health by finding a the difference between a pixel's reflectance in red and NIR wavelengths.
  - Script #7: shows how to easily calculate NDVI of a Landsat image in Python using the module Earthpy. To calculate NDVI using a GOES image, substitute band 2 as the red band and band 3 as the NIR band.

Part 4.

Frequently Asked Questions

How are GOES-R Series files formatted?

- GOES-R Series product files use the netCDF-4 format, a general-purpose scientific data file format.
- More details on netCDF files:
  - GOES products may have any of the following types of attributes.
    - **title** : a global attribute that is a character array providing a succinct description of what is in the dataset.
    - **Conventions** : a global attribute that is a character array for the name of the conventions followed by the product.
    - **long_name** : long descriptive name for each variable.
    - **_FillValue** : a scalar value that identifies missing data.
    - **Valid_range** : a delimited vector of two numbers specifying the minimum and maximum valid values for the variable to which it is attached.
    - **scale_factor** and **add_offset** : these attributes are used together to provide simple data compression to store floating-point data as small integers in a product data file.
    - **units** : a character string that specifies the units used for the variable's data.
  - A netCDF file also includes the dimensions that are used to size dimensional variables.
  - The netCDF ABI L1b/L2+ gridded product files are compressed to reduce the file size. For information on how to unpack data, see Slide 25. For more details on netCDF files, refer to the PUG Volume 1, Revision 2.2, pages 8-14.
- Other file formats:
  - Flexible Image Transport System (FITS) format is used alongside netCDF for the SUVI Solar EUV Imagery product.
  - Unix text file format is used in a small subset of the Level 1b and 2+ semi-static source data files.
  - Hierarchical Data Format (HDF) is used for several Level 1b semi-static source data files.

How do I pre-process GOES-R Series data?

- GOES-R Series data are packed in compressed files, which must be “unpacked” for integer analysis. Images can be visualized without unpacking, since scaled integers are still proportional to each other.
- What is packed data?
  - In order to minimize file size, many of the ABI L1b/L2+ products use 16-bit **scaled** integers for physical data quantities rather than 32-bit floating point values.
  - To convert data back to the actual value associated with the physical quantity, the user must multiply by a scale factor and add an offset to the 16-bit scaled integer.
- How do I unpack data?
  - To unpack the data, apply the attributes using the following equation:
    unpacked_value = packed_value * scale_factor + add_offset
  - The variables ‘scale_factor’ and ‘add_offset’ are included in the metadata for each file. The scale factor is calculated with the formula (Max Value - Min Value)/65530, and the offset is the product’s expected minimum value.
  - Here is a sample conversion for band 8: Brightness temperature(Kelvin) = (2,305.05 * 0.04225) + 138.05 = 235.44 K
  - Before unpacking, check to ensure that the program in use is not automatically applying the scale factor and offset.
- How do I remove data that is fill, out of range, or missing, from the image?
  - These faulty data types can be masked using data quality flags (DQFs), convention attributes which associate integer values with a categorization of the data quality.
  - For more information on packed data or DQFs, see the PUG Volume 1, Revision 2.2, pages 21 or 16, respectively.

How are ABI L1b products georeferenced?

- The ABI uses a fixed grid whose native coordinate values are the East/West scanning angle and North/South elevation angle in units of radians relative to the location of the satellite.
  - The ABI fixed grid is a projection based on the viewing perspective of the idealized location of a satellite in geosynchronous orbit. This allows the same data points in every product to be at the same location on Earth.
  - The fixed grid is rectified to an ellipsoid defined by the Geodetic Reference System 1980 (GRS80) earth model.
  - For all ABI gridded L1b/L2+ products, the names of the coordinate variables are x (E/W scanning angle) and y (N/S elevation angle) (Figure 9).
  - Additionally, there is a "grid_mapping" attribute which is attached to data variables whose values are associated with specific earth locations.
  - For ABI L1b/L2+ gridded products, the grid mapping attribute specifies the projection (GRS80), the lat/lon origin of the projection, and a parameter that identifies the ABI scanning pattern.
- Grid mappings coupled with the coordinate variables provide the means to determine the latitude and longitude of a data point.
  - See the PUG Volume 3: L1b Products, Revision 2.2, pages 8-26, for a explanation in greater depth.

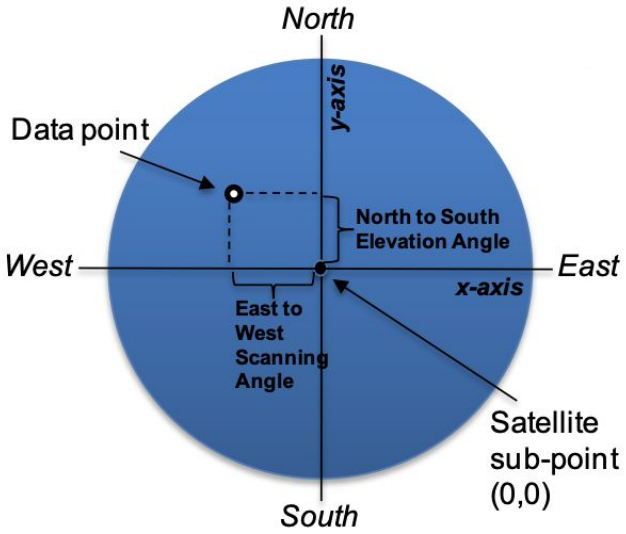


Figure 9. Every data point is plotted on the ABI fixed grid as a distance from the (0,0) origin, in units x (East to West Scanning Angle) and y (North to South Elevation Angle).

Why are data not available on a given date?

- Cloud-based platforms have select L2+ Product availability.
  - Once a GOES-R Series product has reached provisional status, cloud-based platforms may release the product.
  - When there is demonstrated user interest in a product, vendors may backfill their archive to include the dates requested. This may include beta maturity levels of the product.
  - If there is no demonstrated user interest in the product, vendors may choose not to release the entire available collection. For this reason, collection length may vary between products on cloud-based platforms.
- To retrieve pre-provisional GOES-R Series products, search on NOAA CLASS to access the entire archive of products made available to users. CLASS stores products with beta, provisional, and full status.
- Occasionally, there is missing GOES-R Series data on select dates and times.
  - To investigate whether data is missing due to issues with data reception, check out the SSEC's Monitoring Web Page. Follow these instructions for tips on how to navigate this website:
    1. First, select either GOES-16 or 17, then choose a date of interest at the top of the page.
    2. Each row represents the data quality of full disk, CONUS, and mesoscale images for every hour of the day.
    3. The "DB SSEC" section reports missing data due to GOES Rebroadcast (GRB) reception issues.
       KEY- light green: 100% received, yellow: 96 -100% received, light red: < 96% received, dark red: missing
    4. The "PDA via STAR" section reports missing data due to errors with Product Distribution and Access (PDA).
       KEY (same as above with two more categories)- blue & orange: data available from PDA but missing or late
  - Also, check out General Satellite Messages to see if there were any outages reported on that day (Search the date, i.e. "July 10, 2020").

Other Questions

- For unanswered questions, try browsing the GOES-R Series FAQ Page or NCEI's FAQ Page.
- For technical details on the satellites or products, the GOES-R Series Documents page has links to many helpful GOES-R resources, including the Product Definition and Users' Guides (Volumes 1-5) and the Product Algorithm Theoretical Basis Documents (ATBDs).

How could this GOES-R beginner's guide be more helpful?

- For ideas, or concerns, please reach out to the Satellite Products and Services Division (SPSD) User Services at SPSD.UserServices@noaa.gov.

Appendix A: Acronym List

ABI - Advanced Baseline Imager
AIRS - Archive Information Request System
ATBD - Algorithm Theoretical Basis Documents
AWIPS - Advanced Weather Interactive Processing System
AWS - Amazon Web Service
CAVE - Common AWIPS Visualization Environment
CONUS - Continental U.S. (geographic coverage)
CLASS - Comprehensive Large Array-data Stewardship System
CMI - Cloud and Moisture Imagery (Level 2+ Product)
EHIS - Energetic Heavy Ion Sensor
EUVS - Extreme Ultraviolet Sensor
EXIS - Extreme Ultraviolet and X-ray Irradiance Sensors
FDC - Fire Detection and Characterization (Level 2+ Product)
FITS - Flexible Image Transport System
FTP - File Transfer Protocol
GCP - Google Cloud Platform
GEE - Google Earth Engine
GLM - Geostationary Lightning Mapper
GOES - Geostationary Operational Environmental Satellite
GRB - GOES Rebroadcast
GRS80 - Geodetic Reference System 1980
HDF - Hierarchical Data Format
L0/L1b/L2+ - Level 0/ Level 1b/ Level 2+
MAG - Magnetometer
MCMI - Multispectral Cloud and Moisture Imagery (Level 2+ Product)
MESO 1/2 - Mesoscale Domain Sector 1/2
MPS-HI/LO - Magnetospheric Particle Sensor - High/Low
NASA - National Aeronautics and Space Administration
NCEI - National Centers for Environmental Information
NDVI - Normalized Vegetation Index
NetCDF - Network Common Data Format
NIR - Near-infrared
NOAA - National Oceanic and Atmospheric Administration
NWS WFO - National Weather Service Weather Forecast Office
OCC - Opens Commons Consortium
PACUS - Pacific U.S. (geographic coverage)
PDA - Product Distribution and Access
PUG - Product User Guide
RGB - Red-Green-Blue (a true-color image)
SEISS - Space Environment In-Situ Suite
SGPS - Solar and Galactic Proton Sensor
SPSD - Satellite Products and Services Division
SSEC - Space Science and Engineering Center
SUVI - Solar Ultraviolet Imager

Additional acronyms defined on the GOES-R Series Acronym Page.