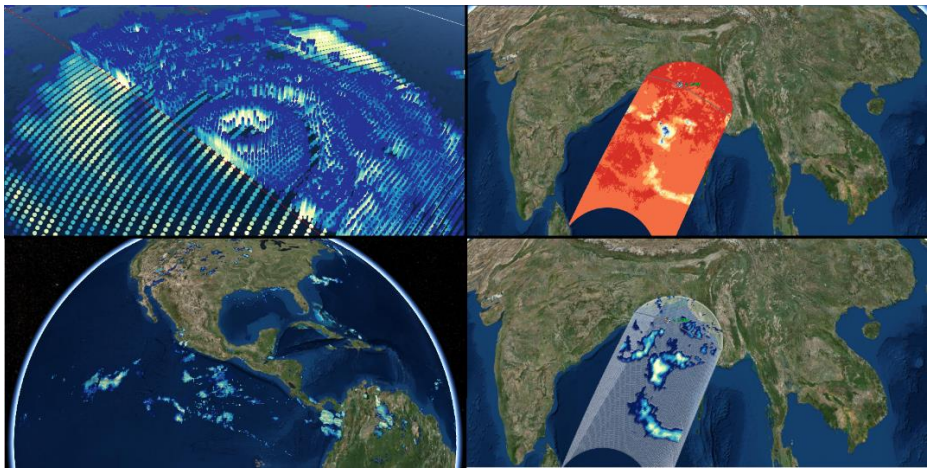
Precipitation Processing System (PPS)



STORM 3D Data Visualization
User Guide

Version 1.2

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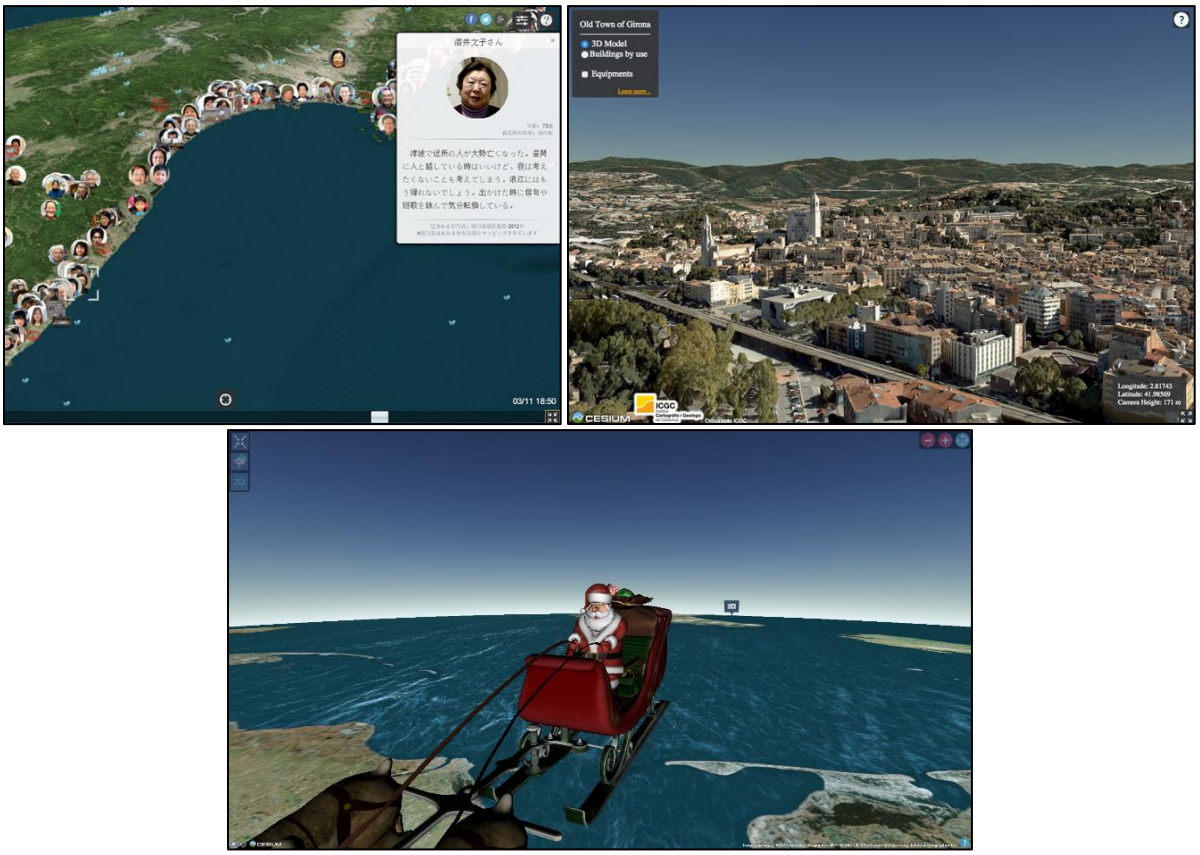
1.0 INTRODUCTION

1.1 3D VISUALIZATION PAGES

STORM (https://storm.pps.eosdis.nasa.gov) is a publicly available Web-based data access interface for the Global Precipitation Measurement (GPM) Mission's Precipitation Processing System (PPS). The goals of the 3D Visualization Pages are threefold. The first goal is to provide a way to visualize near real time data as soon as they become available on the ftp server. This is achieved through both the GPM Near Real Time Viewer and the STORM Event Viewer (EV)/EV Mini pages. The second is to allow users of the STORM data order interface to view products in three dimensions prior to order. For this, STORM Virtual Globe (VG) was created to complement the static images and Tool for High-Resolution Observation Review (THOR) Online tools. The final goal of these pages is to bring attention both to the work of the PPS group and the breadth of data coming from the GPM Core satellite and partner satellites processed by PPS. All three of these pages highlight the importance and visually compelling nature of GPM data.

1.2 ABOUT CESIUMJS

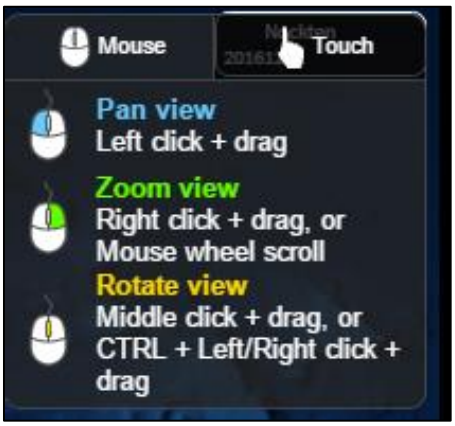
Developed by Analytical Graphics, Inc., CesiumJS is an open-source three-dimensional globe visualization package developed in JavaScript to be run in browsers as part of a Web interface. It is used for such diverse purposes as "tracking" Santa Claus in his travels, providing a user interface to access earthquake survivor stories, and recreating entire cities building by building in three dimensions.



CesiumJS is compatible with a variety of geospatial data formats but is best coupled with a JavaScript Object Notation (JSON)-based format called CZML (Cesium Markup Language). CZML allows for time-dynamic properties, which means that anything that can evolve with time, such as color, opacity, position, or size, can have that change represented easily in the file. CesiumJS comes packaged with a timeline and a set of time controls that enable efficient animation. CZML is used in the GPM Near Real Time (NRT) Viewer.

1.3 USING CESIUMJS

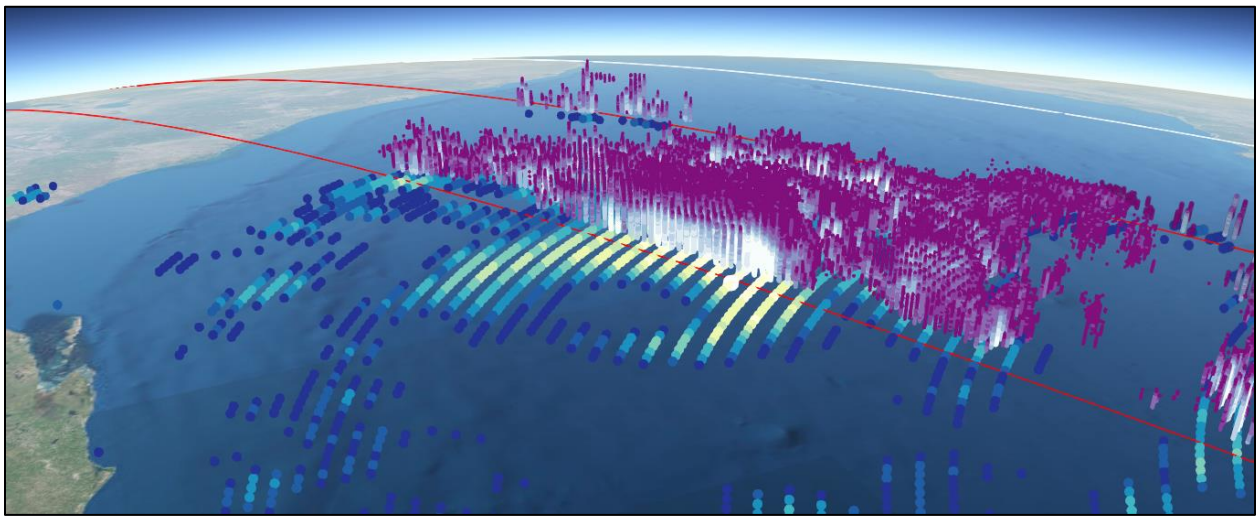
While navigating using CesiumJS might initially seem difficult, the controls are similar to other three-dimensional interfaces and are generally intuitive. There are three directions of movement: towards/away from Earth (also known as zooming in and out), parallel with the surface (aka panning), and around a fixed point (rotating the camera). There are multiple ways of achieving each of these motions, outlined in the "?" popup window shown below.



All of the products allow for universal movement except the mobile version of the Event Viewer (EVMini), which by focusing on a single point disables view rotation and only allows panning in a circle around the focal point. Another thing to note is that though a left click and drag pans around the surface of the globe when the click is on the globe itself, a left click and drag not on the globe (in the atmosphere or "space") will rotate the view.

Some of the interfaces feature mouse-over based inquiry of individual data points. Integrated Multi-Satellite Retrievals for GPM (IMERG) in the NRT Viewer and all products in the STORM VG/EV can be moused-over. Two-dimensional products (gridded data and anything from GPM Microwave Imager (GMI)) will give precipitation rate values. Three-dimensional products will give precipitation rate values and altitude. The exception is in the Event Viewer with "Storm Top Height" as the color, in which case only altitude will be shown.

Other methods of interacting that are specific to the individual interfaces will be discussed in their sections. All of the interfaces allow full-screen by clicking the “Expand” button in the bottom right corner. One other universal is the ability to take a screen capture by pressing the “p” key. This will automatically dump the contents of the CesiumJS window to a PNG image, named by the file name and an integer that increments through the session.



2.0 GPM NEAR REAL TIME VIEWER

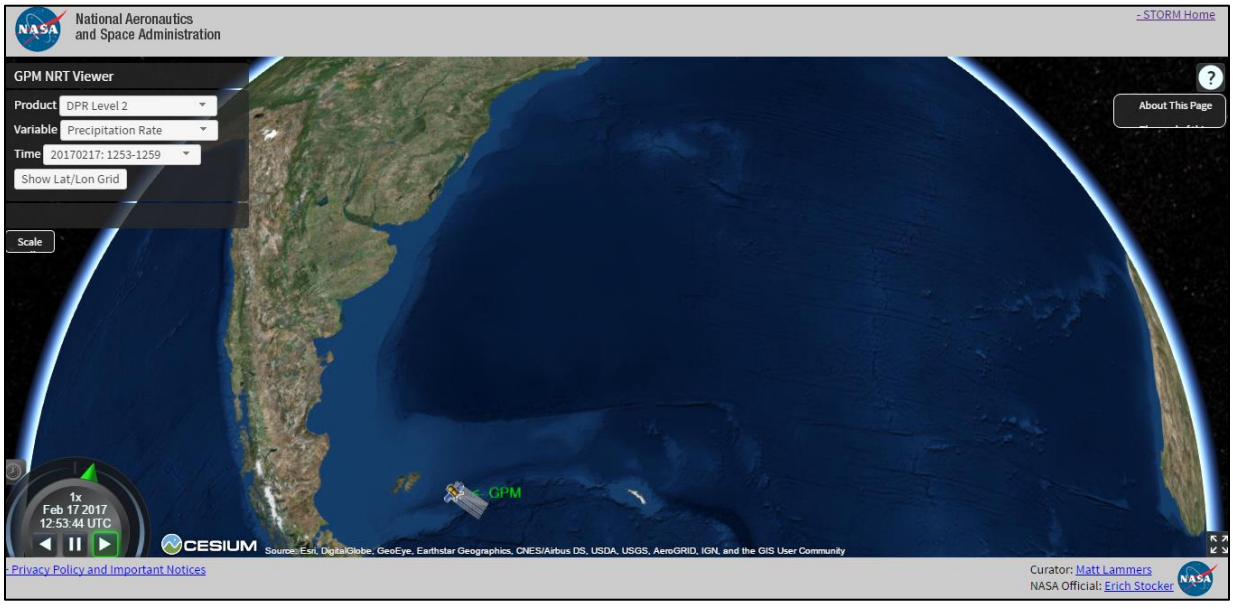
2.1 INTRODUCTION

The GPM Near Real Time Viewer, found at https://storm.pps.eosdis.nasa.gov/storm/cesium/GPMNRTView.html, was the first product developed for CesiumJS by the PPS Data Visualization Team. Prior to this, the only way of visualizing Near Real Time GPM data was to download the file and display it in THORViewer. There was no way to see the data before downloading it, even if many of the Near Real Time users pulled the data using automated systems.

The GPM Near Real Time Viewer enables the visualization of various variables within Level 1 GMI; Level 2 GPM Profiling Algorithm (GPROF), Dual-Frequency Precipitation Radar (DPR), and Combined (CMB); and Level 3 IMERG Half Hour products. It animates the progress of the GPM Core satellite over the Earth's surface in virtual real time and will continue to animate as data are acquired for as long as the browser window is open. Between 15 and 30 minutes of data are visible at any given time. Twenty-four hours of files are available at any given time, and the interface enables efficient switching between time intervals within that day of data.

One of the challenges in developing a viewer was that the data are kept on a different ftp server from the interface. This provided an opportunity to test the suitability of CZML as a post-processed format for two-dimensional GPM data. Every 6 minutes, GMI files are generated. Every half hour, DPR and IMERG files are generated. Files are created for each imaged variable for each of the Level 2 and 3 products. For the Level 1C product, files are made for all of the imager channels for both polarizations.

For the swath-based products, data points appear in virtual real time, as the satellite orbits the globe. The progress of the satellite can be slowed or sped up using the controls in the bottom left, although increasing speed too much can cause scans to be skipped. Speeds 4x and below should be fine, however.

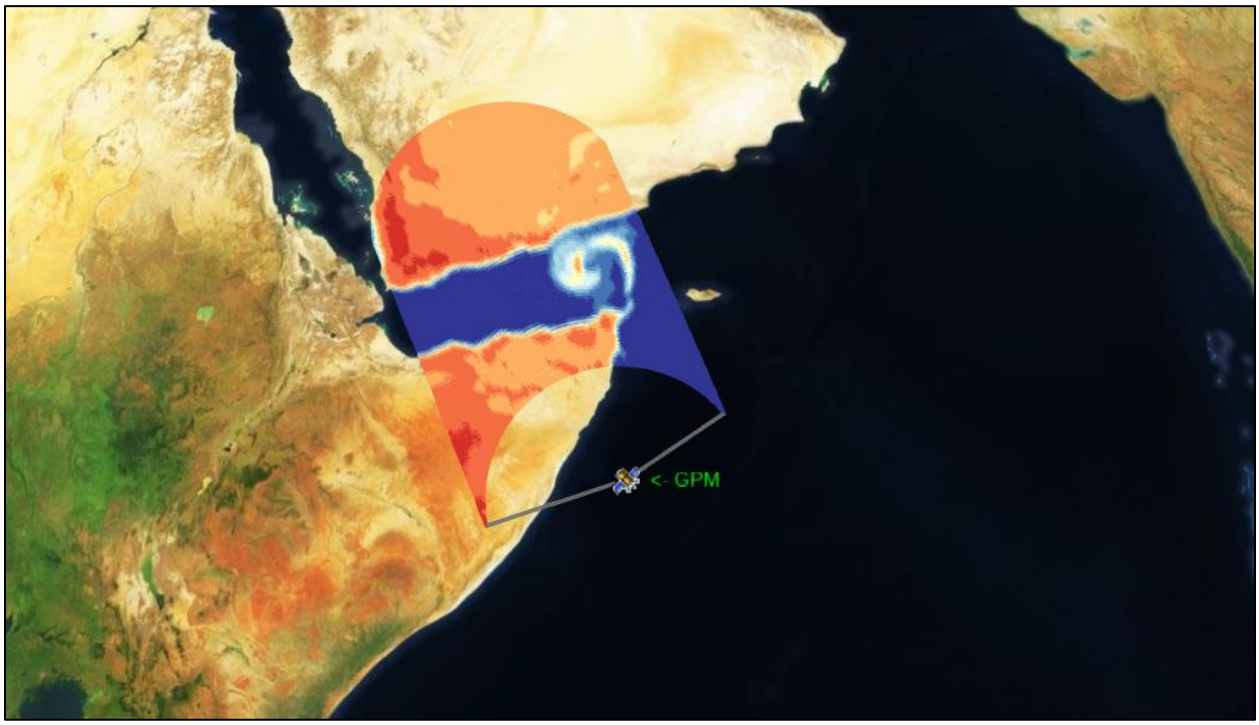


There are a few options to note. Both the color table window and the "About This Page" window can be closed by clicking the "Close" button in the bottom right. They can then be opened by clicking on the white-outlined text labeled box that replaces them. The user can also add a labeled latitude-longitude grid to the globe by clicking on the "Show Lat/Lon Grid" button.

When the page is initialized, the first granule loaded will be the most recent Level 2 DPR Precipitation Rate acquired. The swath may start off the bottom of the screen because of the automated initial camera position, so it might be necessary to scroll down slightly to see the first few scans. If the "Loading" bar stays visible and no data load, there may be an issue with the page. In this case, users may notify the development team at matthew.r.lammers@nasa.gov.

2.2 LEVEL 1C GMI

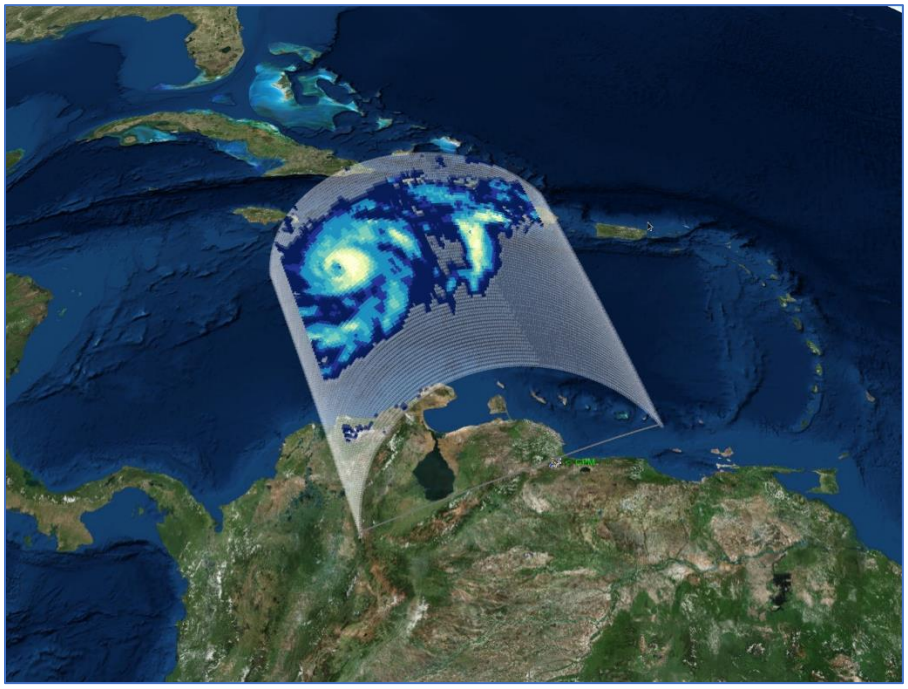
There is a great deal that even casual scientists can glean from brightness temperature calculations provided by GMI. The 10 GHz channels appear warmer during rough seas, providing a good proxy for high wind speeds over open ocean. The 23 GHz channel shows water vapor transport. 89 GHz channels illustrate cloud top height, with cooler temperatures reflecting deep convection. Elaborate algorithms aggregate these values to generate Level 2 products.



The GPM NRT Viewer makes available the last 24 hours of Level 1C brightness temperatures from GMI for the following channels: 10 GHz horizontal and vertical (H/V from now on), 19 GHz H/V, 23 GHz V, 37 GHz H/V, and 89 GHz H/V. The data are available in 5-minute intervals, which is how they are broken into HDF5 files in the ftp archive. For each channel, the temperature scale steps from blue to yellow to red in 20 K intervals from 120 K to 300 K.

2.3 LEVEL 2A GPROF

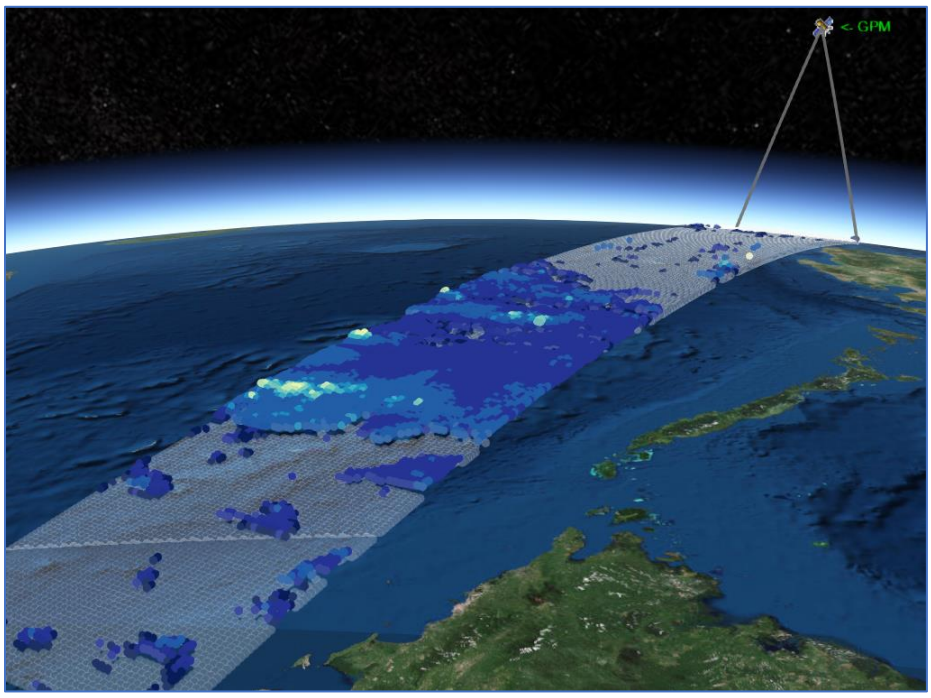
GPROF is the algorithm developed at NASA Goddard for converting brightness temperature data from GPM into various precipitation-related values. In the GPM NRT Viewer, four variables are available for visualization: Precipitation Rate, Liquid Precipitation Rate, Convective Precipitation Rate, and Probability of Precipitation. As with Level 1C, Level 2A GPROF is available in 5-minute intervals. For each variable, the color table is from blue (low values) to yellow (high values).



2.4 LEVEL 2B DPR

With the GPM Dual-Frequency Precipitation Radar, three-dimensional information about precipitating clouds can be acquired. In the GPM NRT Viewer, three variables are available from the DPR instrument: Surface Precipitation Rate, Storm Top Height, and Precipitation Type. To acknowledge the 3D nature of the DPR returns, all of the points are rendered at the storm top height level. This combines the overall structure of the scanned clouds with the precipitation fields to get an overall sense of intensity and evolution.

At PPS, DPR data are received in 30-minute intervals. These files are divided into 6-minute segments to ease access to specific times in the interface. For Precipitation Rate and Storm Top Height, the color table is identical to the one in 2A GPROF. With Precipitation Type, four disparate colors are used to identify “transition,” “convective,” “stratiform,” and “other” precipitation.

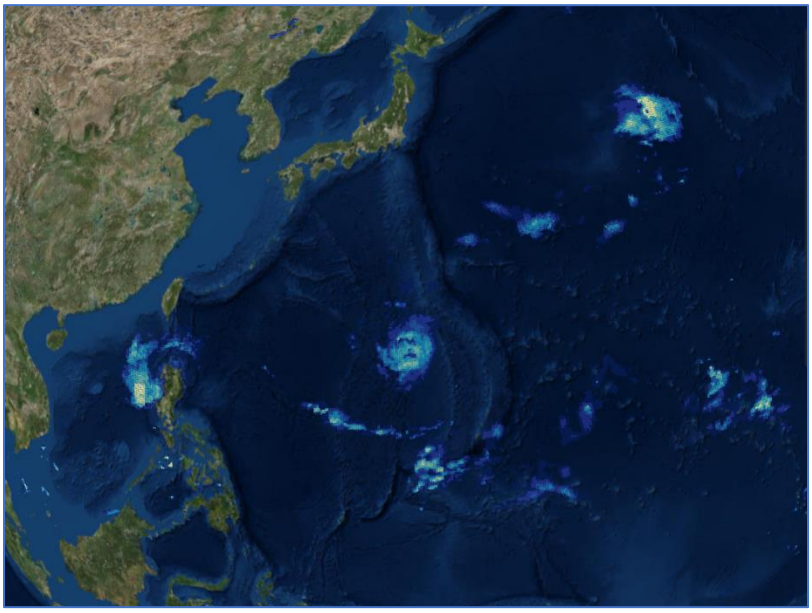


2.5 LEVEL 2B CMB

The DPR/GMI Combined product combines the three-dimensional information from DPR with the versatile imagery from GMI. The output aligns with the DPR product, and as such the same variables are represented here as with 2A DPR: Surface Precipitation Rate, Storm Top Height, and Precipitation Type.

2.6 LEVEL 3 IMERG

The version of IMERG featured in the GPM NRT Viewer is the "early" run of the Half-Hour incremented product. IMERG aggregates information from the entire constellation of microwave imaging/sounding satellites as well as infrared data to generate a consistent product on a 0.1 x 0.1-degree latitude-longitude grid. There is also a morphing mechanism that attempts to simulate what microwave imagery would have looked like between scans when only infrared data are available.



The only variable available is Surface Precipitation Rate, which uses the same color table as Precipitation Rate in 2A GPROF, 2A DPR, and 2B CMB. Because not all points are represented in the visualization of IMERG, the threshold for precipitation rate represented is 0.5 mm/hr rather than 0.01 mm/hr. There is no time mechanism for IMERG, because it is representative of a single span of time. Switching between different IMERG runs is efficient, but returning from IMERG to the swath-based products remains time consuming because of the process of removing the IMERG points.

3.0 STORM VIRTUAL GLOBE

3.1 INTRODUCTION

Upon realizing how useful a tool the GPM NRT Viewer was, it made sense to take the technology and apply it to the data order interface and production data. Users had the ability to see static preview images of single variables, as well as to explore all of the variables in THOROnline's viewer tool. Neither could represent the three-dimensional data from DPR, nor could they combine satellite imagery with a seamless mouse-over driven interface. Admittedly, STORM Virtual Globe (STORM VG) remains a single-variable driven visualization, only showing precipitation rate. In that sense, it is more limited than THOROnline.

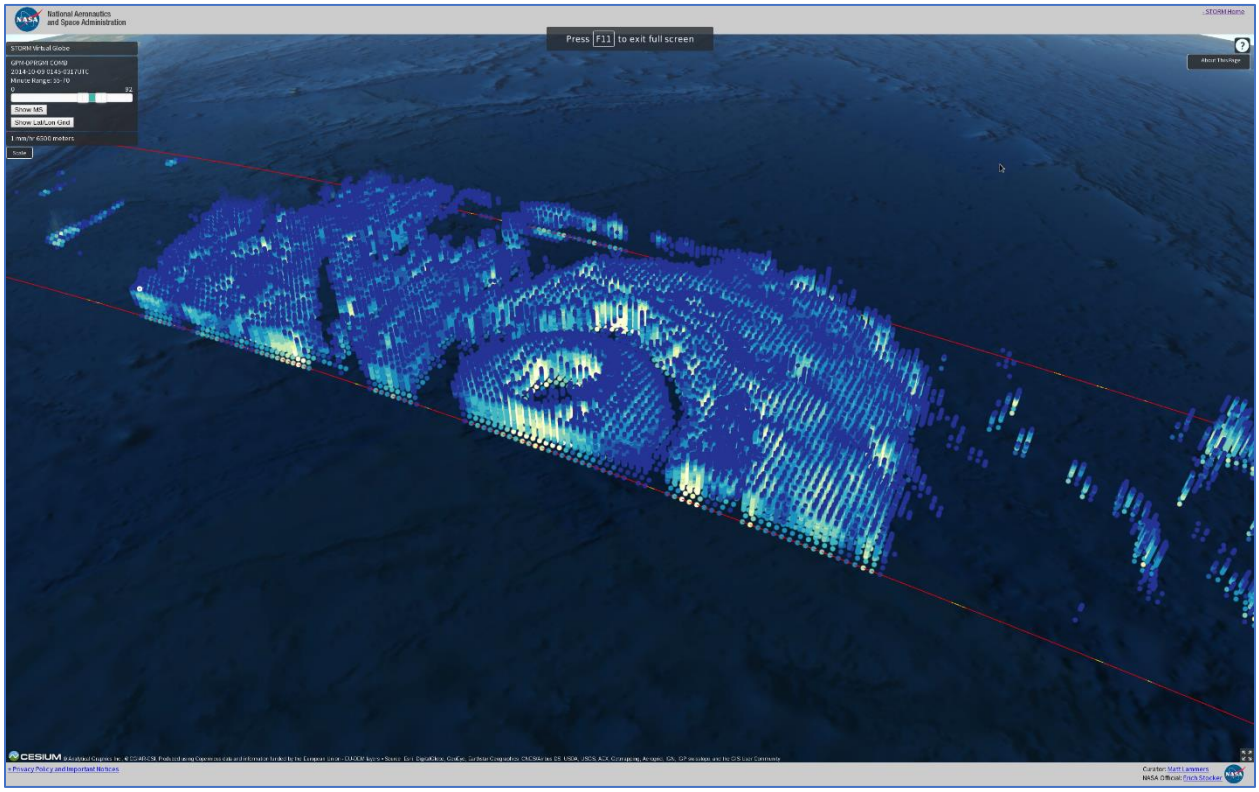
2A	2ADPR	2015-01-31 23:22:21	2015-02-01 00:54:54	5264	hdf5
3A	3GPROF	2015-02-01 00:00:00	2015-02-01 23:59:59	32	hdf5
3B	3IMERGHH	2015-02-01 00:00:00	2015-02-01 00:29:59	1	hdf5
3B	3IMERGHH	2015-02-01 00:30:00	2015-02-01 00:59:59	2	hdf5
2A	2ADPR	2015-02-01 00:54:55	2015-02-01 02:27:27	5265	hdf5
3B	3IMERGHH	2015-02-01 01:00:00	2015-02-01 01:29:59	3	hdf5
3B	3IMERGHH	2015-02-01 01:30:00	2015-02-01 01:59:59	4	hdf5
3B	3IMERGHH	2015-02-01 02:00:00	2015-02-01 02:29:59	5	hdf5
2A	2ADPR	2015-02-01 02:27:28	2015-02-01 04:00:01	5266	hdf5
3B	3IMERGHH	2015-02-01 02:30:00	2015-02-01 02:59:59	6	hdf5
3B	3IMERGHH	2015-02-01 03:00:00	2015-02-01 03:29:59	7	hdf5
3B	3IMERGHH	2015-02-01 03:30:00	2015-02-01 03:59:59	8	hdf5
3B	3IMERGHH	2015-02-01 04:00:00	2015-02-01 04:29:59	9	hdf5
2A	2ADPR	2015-02-01 04:00:02	2015-02-01 05:32:34	5267	hdf5
3B	3IMERGHH	2015-02-01 04:30:00	2015-02-01 04:59:59	10	hdf5
3B	3IMERGHH	2015-02-01 05:00:00	2015-02-01 05:29:59	11	hdf5

Along with only having one variable per product, there are several differences between STORM VG and GPM NRT Viewer. One involves the way data are represented. With the GPM NRT Viewer, post-processed files are generated in CZML format to take advantage of its time-dynamic capabilities. For STORM VG, even if there is only one variable for each product, post-processing a whole parallel set of CZML files is unrealistic. As such, this interface leverages the server-side Java code and HDF5 bindings to automatically generate JSON objects containing the necessary information to generate the points in CesiumJS.

Most Level 2 and Level 3 products can be displayed in STORM Virtual Globe. From Level 2, all of the Level 2A GPROF, Level 2A DPR, and Level 2B CMB can be seen. From Level 3, Level 3A GPROF and Level 3 IMERG Half-Hour are available. For the swath-based products, 15 minutes of data are displayed at a given time, out of a 90- to 105-minute swath. The slider shown below allows navigation through the swath. The position of the camera and an orange rectangle indicate what segment will be loaded while adjusting the slider. For Level 3 gridded products, all of the data are visible upon load.

For all products in STORM VG, the URL contains parameters to save state and share it with others. There are three query string parameters: “fname,” which is the path for the ftp file of the swath, “start,” which is used in swath-based products to set the initial section of swath being loaded, and “height,” which defines the elevation of the camera on initial load. Each of these parameters is dynamically updated as the user navigates the visualization.

The most useful aspect of STORM VG is the ability to mouse over individual data points and discover their raw values. This can be done with any product, swath-based or gridded. Data points from the DPR instrument in the 2A DPR and 2B CMB products will also give their altitude, to allow for three-dimensional reference. Not only can the user inspect the intensity of precipitation, but also its depth, exposing hot towers and other deep convective features. Note that regardless of the product, only precipitation rates greater than 0.5 or 1.0 mm/hr (depending on the product) are shown to prevent too many points from being made visible, slowing down the browser.

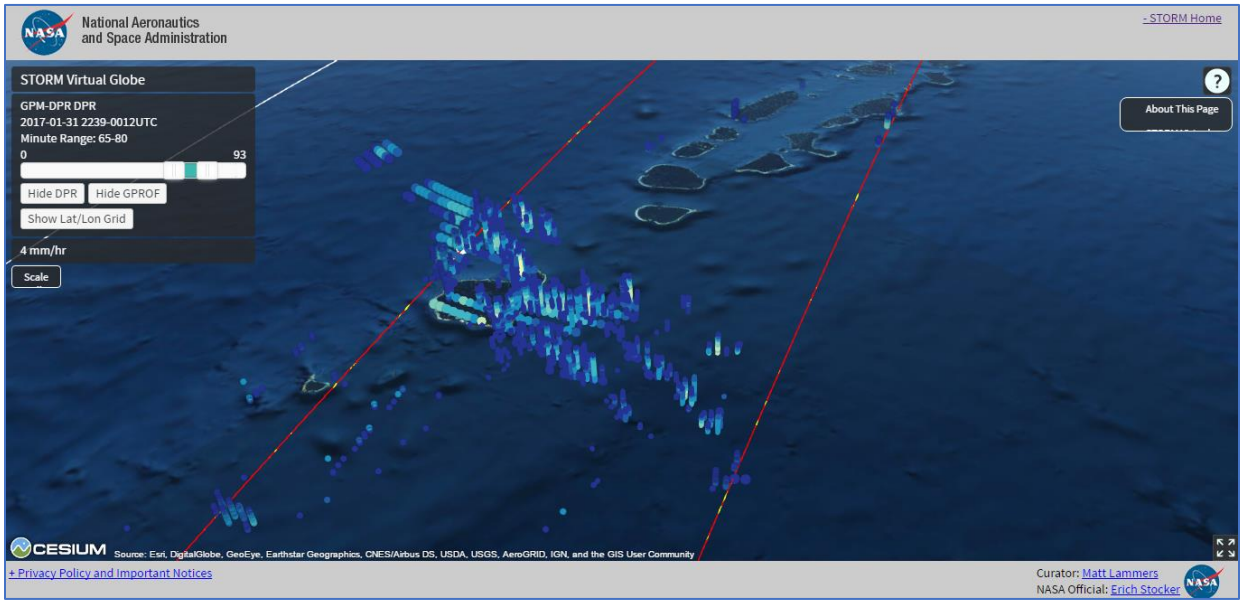


As discussed in the section on CesiumJS controls, STORM VG allows full range of camera motion, including full zoom, camera rotation, and camera pan. The “About This Page” and “Scale” windows can be closed by clicking the “X” button in their bottom right corners, and they can be reopened by clicking on their labels. STORM VG also allows showing/hiding a labeled latitude/longitude grid which can help provide a visual reference for location, especially in the middle of an ocean.

3.2 SWATH-BASED PRODUCTS

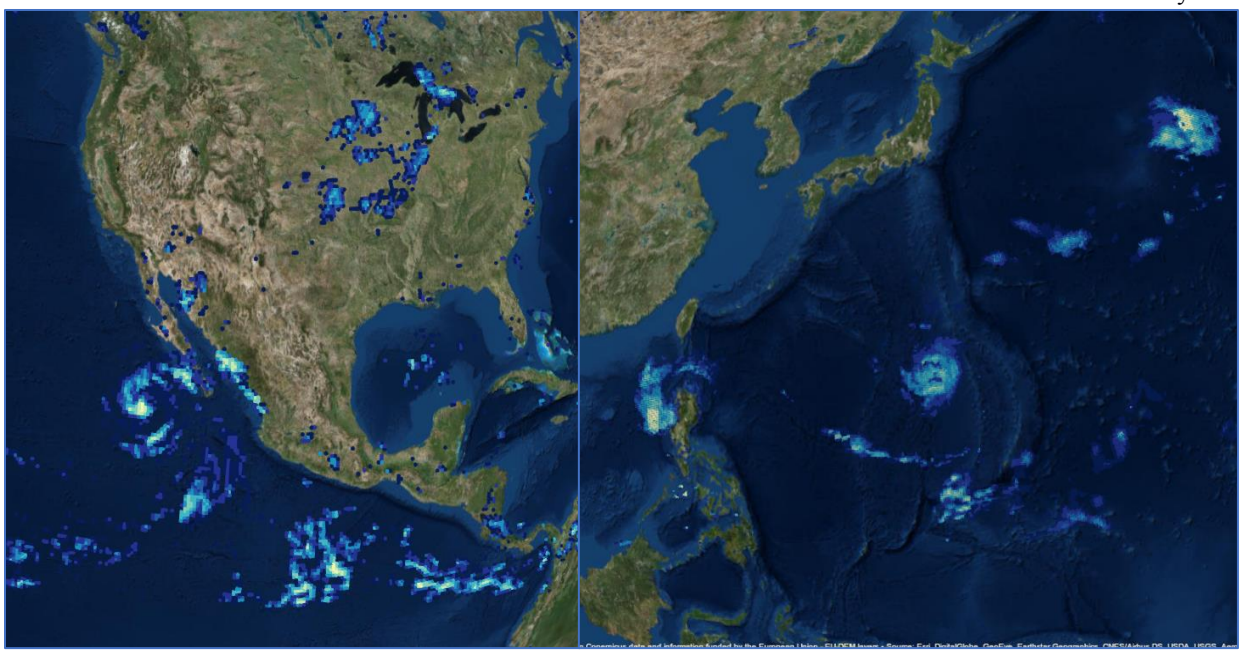
As stated previously, the swath-based products available in STORM VG include all of the Level 2A GPROF, Level 2A DPR, and Level 2B CMB swaths in the STORM data order interface described in the STORM User Guide (https://storm.pps.eosdis.nasa.gov/storm/STORMUserGuide.pdf). Once a list of files is populated in the granule list, any of them can be visualized in STORM VG for preview purposes.

Upon clicking the globe icon (), a new tab or window opens with the CesiumJS globe visible and a "Loading" sign. Once loaded, the camera will pan to near the start of the swath and the initial 15 minutes of data will load. If the selected product is 2A GMI GPROF or 2A DPR, both the GMI and DPR data will load. One swath will be bounded with red lines, the other with white lines. Even though both instruments are loaded, the Hide/Show DPR and Hide/Show GPROF buttons can be used to remove or show one or the other.



3.3 GRID-BASED PRODUCTS

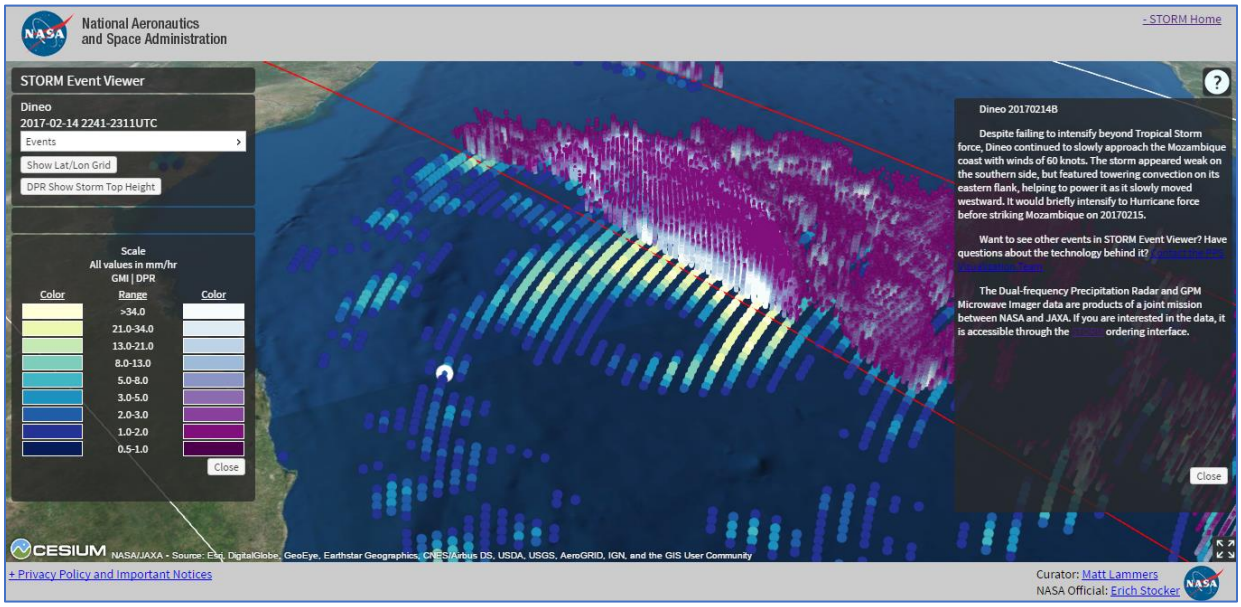
There are two types of grid-based products that can be visualized in STORM VG. One set contains the 3A GPROF Daily grids from each of the constellation satellites. The microwave imager/sounders have their precipitation rate values remapped to a 0.25 x 0.25-degree grid. Regions over which the satellites did not fly do not have any data. The other product is the IMERG Half Hour "final" run, which combines microwave radiometer and infrared satellite data, adjusting based on ground observations available. These grids are available 3-4 months after the observation date. They feature surface precipitation on a 0.1 x 0.1-degree grid and global coverage.



4.0 STORM EVENT VIEWER

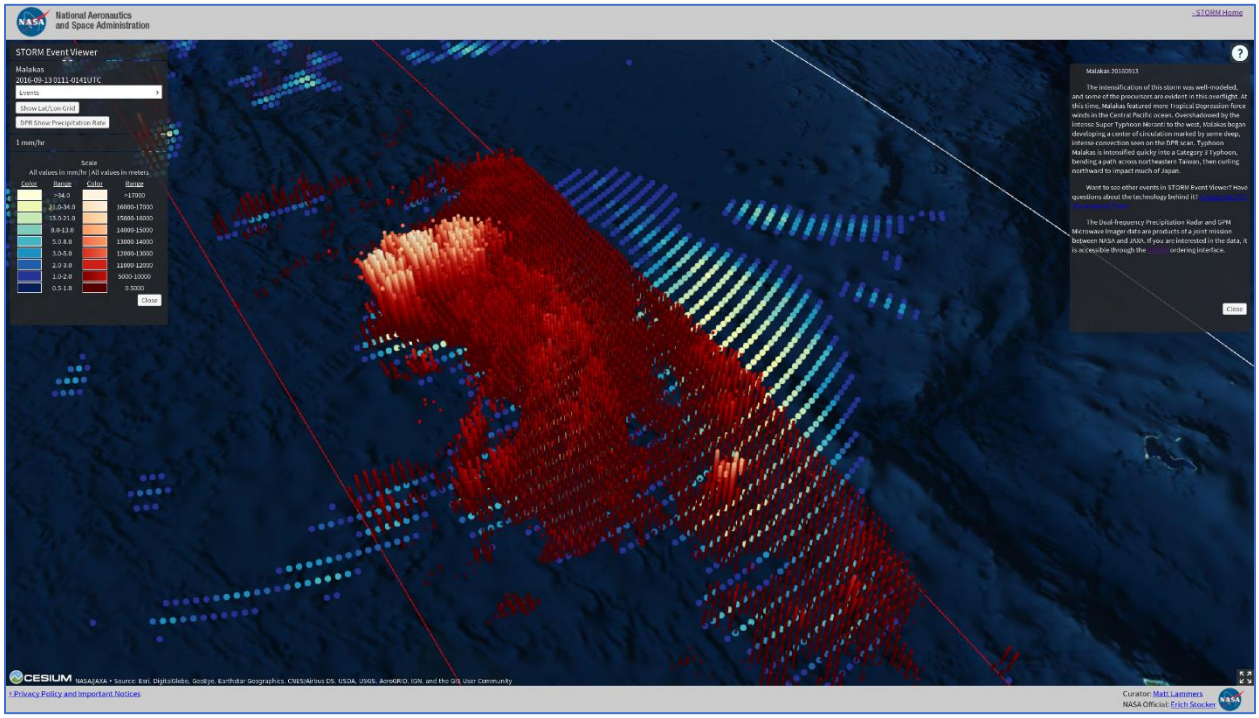
4.1 INTRODUCTION

During the summer of 2016, with the framework for STORM Virtual Globe (STORM VG, found at https://storm.pps.eosdis.nasa.gov/storm/cesium/EventViewer.html) established, work began on a curated set of high-impact overflights combining the DPR and GMI data. These visualizations could be generated from near real time data to avoid delaying the 36-48 hours until production data became available. This product became the STORM Event Viewer, and later the EVMini (https://storm.pps.eosdis.nasa.gov/storm/cesium/EVMini.html).



Like STORM VG, the STORM Event Viewer combines DPR and GMI data to provide both surface and 3D precipitation rate values. In the STORM Event Viewer, GMI maintains the same precipitation rate color scheme used in STORM VG, but DPR is given a different color scale to contrast the vertical values with the surface values. Because it can be difficult given all of the data points to assess verticality within storms, Event Viewer gives users the ability to change the color scheme for DPR from precipitation-based to altitude-based, highlighting deep convection and "hot towers" in tropical systems.

In 2018, a substantial number of tropical cyclones from the TRMM era were added to Event Viewer, including data from TRMM Microwave Imager (TMI) and TRMM Precipitation Radar (PR). These overflights display exactly the same as the GPM overflights, albeit with minor differences in swath width and resolution.



Included in STORM Event Viewer are descriptions of GPM events being highlighted in the overflights (TRMM events do not currently have descriptions). These short paragraphs help to contextualize the overflight, discussing intensification or weakening in tropical systems and how the data help to illustrate these processes to scientists and researchers. The product also includes the ability to display a labeled latitude/longitude grid on the globe to help users better know where the overflight is located. One final thing to note is that STORM Event Viewer, like STORM VG, enables URL state saving. This means that copy-pasting the URL and sharing it with someone will give them the exact view you were using, of the exact overflight you were viewing. Moving the camera or changing the event viewed will automatically update the URL.

4.2 NAVIGATING THE INTERFACE

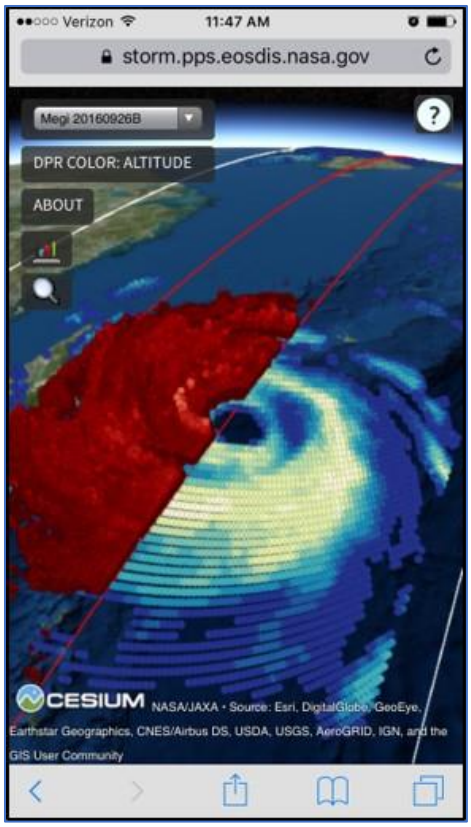
Beyond the standard CesiumJS controls, there are three primary controls in the STORM Event Viewer. The first is the menu controlling which overflight is being shown. These are organized in the following schema: Year -> Region/Basin -> Storm -> Date. Selecting a new event will bring the “Loading” window back up, relocate the camera, and then pull up the new data onto the screen.

There are two other controls. The first shows and hides the labelled latitude/longitude grid, and the button text alternates depending on what is visible. The second changes the DPR color scheme and variable depicted. If the variable shown is precipitation rate, the color scheme is purple-to-white. If the variable is altitude, the color scheme is red-to-white. If the variable is liquid/frozen, the variable shown is precipitation rate, but the color scheme changes depending on whether the values are liquid or frozen. There are two “Close” buttons visible on the page, which minimize the color table and event description, respectively. These windows can be reopened by clicking on their minimized labels.

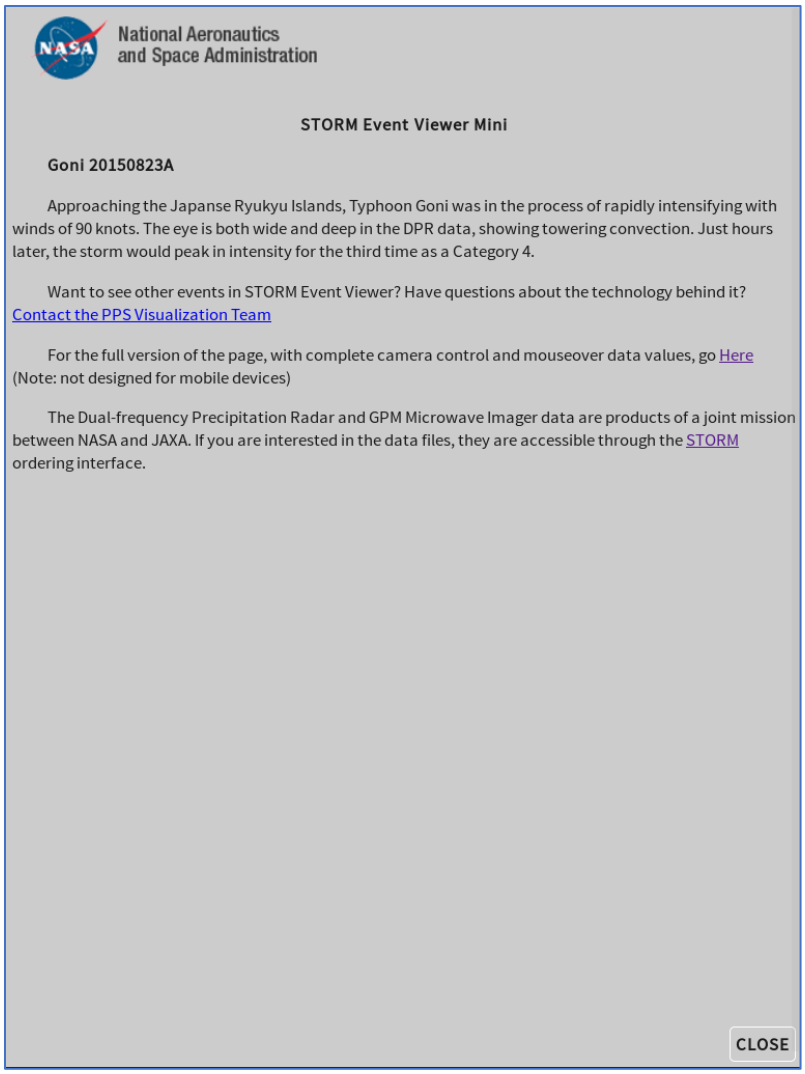
As with STORM Event Viewer, if the user mouses-over a data point, it is highlighted with a white ring and its value appears in a text window below the controls. Depending on whether precipitation rate or altitude is selected as the visible variable for DPR, either precipitation rate and altitude or just altitude is put in the text window. For GMI, surface precipitation rate values are always shown.

4.3 EVMINI

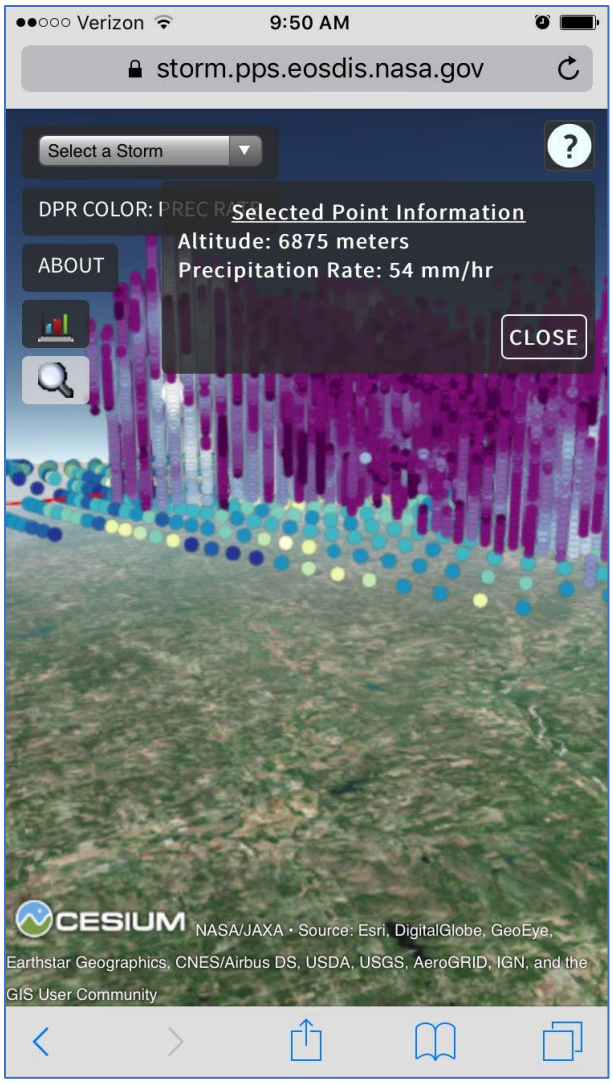
With improvements to CesiumJS and mobile browsers, it became possible to view STORM Event Viewer on phones and tablets. However, the interface is not ideal for small screens, and things like mouse-over events are not possible with a touch screen. This resulted in developing EVMini, which is a reskinned version of Event Viewer better designed for smaller screens and touch-enabled devices. It retains much of the functionality of STORM Event Viewer, apart from the latitude-longitude grid and the ability to roll the camera.



There are numerous differences, however, in the way controls are represented and actions are performed. All of the controls are given their own windows, which line up in the top left of the screen (apart from the CesiumJS control help, which always stays in the top right). The top features the event dropdown, which is organized in reverse chronological order. This is followed by the “DPR Color” button, which when pressed alternates between precipitation rate and altitude. Clicking “About” will hide the CesiumJS window and give information about the event, the data, and how to contact the developers.



The two icon buttons activate the color table and investigate mode, respectively. When pressed, the “Color Table” button pops up the color table on the right side of the screen. The “Investigate Mode” button enables one-click viewing of the raw data values for each point. Because this ability involves a lot of clicking and maneuvering the camera, it is disabled by default, but users can explore the data values even in this modified interface. When a point is clicked, an information window appears on the right side of the screen containing the altitude and precipitation rate values. This window can be closed with the “Close” button. It will also close when the color table pops up (conversely, the color table will close if a user is in investigate mode and clicks on a point). If a different point is clicked, the values will change.



4.4 EVMICRO

A stripped-down version of EVMini, EVMicro is designed as an embeddable Event Viewer for websites and news stories. The interface consists simply of the CesiumJS viewer window and a colorbar. The colorbar is optional and can be disabled with the query string parameter "colorbar=false." The other query string parameters used are "storm" and "date." The values for these parameters are the same as the storm name and date in the selection dropdown in EVMini.

The other difference is the color scheme used for EVMicro as opposed to Event Viewer and EVMini. There is only one way of coloring data in EVMicro, and that contains information about both the precipitation rate and the phase of the precipitation. Frozen precipitation is on a blue scale, while liquid precipitation is on a green scale. This is more in line with the other visualizations released by the Precipitation Measurement Mission (PMM).

APPENDIX A. ACRONYMS AND ABBREVIATIONS

CMB	Combined
CZML	Cesium Markup Language
DPR	Dual-Frequency Precipitation Radar
EV	Event Viewer
GMI	GPM Microwave Imager
GPM	Global Precipitation Measurement
GPROF	GPM Profiling Algorithm
H/V	Horizontal/Vertical
IMERG	Integrated Multi-Satellite Retrievals for GPM
JSON	JavaScript Object Notation
NRT	Near Real Time
PMM	Precipitation Measurement Mission
PPS	Precipitation Processing System
PR	Precipitation Radar
THOR	Tool for High-Resolution Observation Review
TMI	TRMM Microwave Imager
TRMM	Tropical Rainfall Measuring Mission
VG	Virtual Globe