

GOES-R Risk Reduction Bi-Annual Report

Reporting Period: January 2019 – June 2019 (2nd half of FY18 / Year 2 funding cycle)

Team Lead: Steven Miller (CSU/CIRA)

Team Members: CIRA: Curtis Seaman, Jason Apke, K. Hilburn, Jeremy Solbrig, Yoo-Jeong Noh, Matthew Rogers, Natalie Tourville
RAMMB: Don Hillger, Deb Molenaar

Project Title: Developing an Environmental Awareness Repertoire of ABI Imagery ('DEAR-ABII') to Advise the Operational Weather Forecaster

Project Number: 476

Executive Summary

The Himawari-8 Advanced Himawari Imagery (AHI) provided a golden opportunity to develop multispectral and data-fusion imagery products tailored to an assortment of operational forecaster situational awareness needs in advance of GOES-R Advanced Baseline Imager (ABI). Value-added applications such as Rayleigh-corrected true color, GeoColor (a data fusion product), fire temperature, 'blue-light' and background-reduced dust, snow/ice, and other enhancements have been crafted to provide context and a sanity check for the suite of quantitative (Level-2) products supported by the GOES-16 and GOES-17 ABI. Several of these applications have followed the natural progression from polar-orbiting platforms (based on the MODerate-resolution Imaging Spectroradiometer (MODIS) leading into the Visible/Infrared Imaging Radiometer Suite (VIIRS).

This DEAR ABII project aims to transition, further refine, and demonstrate through established Satellite Proving Ground channels these AHI-based imagery applications to first-light ABI data. The products are made available to operational centers and National Weather Service (NWS) forecasters in the AWIPS-II display environment.

Special Achievements:

1. On 12 February 2019, examples of CIRA's GOES-17 GeoColor imagery were shared with the media to celebrate the declaration of GOES-17 (GOES-West) as operational. **The director of the National Weather Service, Louis Uccellini, posted an animation of CIRA's GOES-17 GeoColor product, highlighting the utility of GOES-17 to monitor weather for Alaska and the West Coast of the U.S.**

2. On 12 February 2019, the **NESDIS homepage** posted an article titled “It’s official: GOES-17 is now operational as NOAA’s GOES West satellite” which came with a large **GOES-17 GeoColor imagery of the Northern Hemisphere** (from 9 February 2019).
<https://www.nesdis.noaa.gov/content/goes-17-now-operational-here’s-what-it-means-weather-forecasts-western-us>
3. Work on a **publication of the GOES-R synthetic true color product** began during this reporting period and a manuscript was submitted to *J. Atmos. Ocean. Tech.*
4. CIRA GOES-16/17 DEAR-ABII products are being depicted as the main satellite image example in three different **GOES-R Program Office “Fact Sheets”**, which were published in June 2019.
5. **GOES-17 CONUS GeoColor RGB product was made available in AWIPS2 D2D.**
6. WFO forecaster Glenn Coin (NYup.com) used a **GOES-16 GeoColor imagery** from 20 February 2019 15:36 UTC to post a warning about “*A massive winter storm.*”
7. Work on “**Optical Flow in GOESR ABI GeoColor**” continued – which is a brand-new research application for GOES-R ABI products being explored by the DEAR-ABII Team.
8. **GOES-16 and GOES-17 GeoColor imagery continues to be heavily used for the GOES-R Program Office Quarterly Newsletter**, including on the cover pages.
9. **GOES-16 and GOES-17 GeoColor imagery is regularly tweeted by @NOAASatellites.**
10. As evidenced in the items above, and countless others not mentioned here, *GOES-16 and GOES-17 GeoColor Imagery continues to be used extensively by the media and science community like, and represents in many ways a “flagship product” of the NOAA and the GOES-R Program.*

Progress toward FY18 Milestones

FY18 (Year 2) Milestones (1 July 2018 – 30 June 2019)

1. Begin conducting near real-time demonstrations of core products, distributed on AWIPS/NAWIPS and on the web working with liaisons to monitor performance.
(1 July 2018 – 30 June 2019)
2. Begin development of augmented DEBRA algorithm with 1.38 μm + blue band.
(1 July 2018 – 30 June 2019)

3. Begin development of augmented GeoColor with new layers (lightning, dust, fog, fire).
(1 July 2018 – 30 June 2019)
4. Begin development of custom products as defined via Liaison/forecaster interactions.
(1 July 2018 – 30 June 2019)
5. Begin preparing and supplying materials (product descriptions, representative case studies) to training partners. (1 January 2019 – 30 June 2019)
6. Prepare/submit a publication on GOES-R synthetic true color. (1 March – 30 June 2019)

PROJECT ACCOMPLISHMENTS

(during January 2019 – June 2019)

Milestone 1: Begin conducting near real-time demonstrations of core products, distributed on AWIPS/NAWIPS and on the web working with liaisons to monitor performance.

❖ Core Product: GeoColor

GOES-17 ABI GeoColor (true color day, blended IR, low-cloud enhancement and city lights at night) has been running with no problems since it was implemented in late 2018.

The GOES-R Program Office continues to use CIRA's GeoColor imagery product for GOES-16 and GOES-17 ABI on a daily basis, on its webpages, GOES-R Program Office Newsletters, Fact Sheets, twitter, and other promotional materials. GeoColor imagery and imagery loops are part of most GOES-R management presentations.

Work continued on refining the LUTs which resulted in improved characterization of specific true color scenes that are not always well represented within the AHI/ABI domains. Daily GOES-16 and GOES-17 GeoColor were closely examined for any problems. GOES-16/17 Loops of the Day are available to operational forecasters as well as the public at:

http://rammb.cira.colostate.edu/ramdis/online/loop_of_the_day/

As mentioned in our previous semi-annual report, GOES-16 and GOES-17 GeoColor products are available to the public on our SLIDER web application:

<https://rammb-slider.cira.colostate.edu/>

In addition, a variance-encoded half-kilometer (HKM) resolution GeoColor was developed for the SLIDER CONUS sector of GOES-17 ABI GeoColor. CIRA's SLIDER web application uses the HKM version for its GOES-17 GeoColor CONUS sector, if 0.5 km resolution is selected. The difference between the HKM 0.5 km and the non-HKM 0.5 km version is very noticeable, as can be seen in **Figure M1-1** below.

GOES-16 and GOES-17 ABI GeoColor imagery became both available on the NESDIS GOES-East and on the NESDIS GOES-West Viewer websites (see **Figure M1-2** below)

<https://www.star.nesdis.noaa.gov/GOES/conus.php?sat=G16>

and

<https://www.star.nesdis.noaa.gov/GOES/conus.php?sat=G17>

A GOES-R Program Office published three “Fact Sheets” in June 2019, which each include GeoColor imagery as a baseline reference product (see Milestone 5 for more details).

Following a webinar on GOES-17, presented by Dan Lindsey on 11 February 2019, CIRA received several requests for access to the RAMMB/CIRA AWIPS2 tiled GOES-17 CONUS GeoColor RGB product. D. Molenaar (NESDIS/StAR/RAMMB) worked with Western Region Headquarters (WRH) to implement LDM data access at WRH, which then disseminates the data to individual Western Region forecast offices. An additional request for data access came from the DoD Dugway Proving Ground Meteorology Division in Dugway, UT. LDM data access for that site has also been implemented. Instructions to ingest and display the products in AWIPS2 D2D have also been sent to requesting individuals.

❖ **Core Products: Snow/Cloud Discriminator and the Snow/Cloud Layer products**

After **CIRA’s Snow/Cloud Discriminator and the Snow/Cloud Layer products** were transitioned to GOES-17. Both GOES-16 and the GOES-17 version of this product started to be evaluated regularly. Both products were also introduced to CIRA’s SLIDER web display application page at <http://rammb-slider.cira.colostate.edu/> as well as in AWIPS2. This has become a popular product to look at after a snow storm, because it so clearly and intuitively (snow = white) discriminates between the snow on the ground and low/high clouds.

❖ **Core Product: GOES-16/17 Fire Temperature RGB and Natural Color-Fire products**

CIRA’s **Fire Temperature RGB** was first developed at CIRA for VIIRS and has since been applied to ABI with much positive feedback from the user community. Both, **CIRA’s GOES-16 Fire Temperature** and **CIRA’s GOES-16 Natural Color-Fire** products were transitioned to GOES-17 during the past reporting period. The products have been standardized for use in AWIPS and are easily displayed through the “on-the-fly” RGB capability available to all AWIPS users.

The **Fire Temperature RGB product** became quite famous within the operational NWS/WFO forecaster group after a quickly growing wildfire on the Great Plains suddenly changed directions, after a cold front moved through the area, and forecasters in that area noticed that change first by watching a Fire Temperature RGB animation of this event:

http://rammb.cira.colostate.edu/ramdis/online/loop.asp?data_folder=loop_of_the_day/goes-16/20170310000000&number_of_images_to_display=130&loop_speed_ms=100

This Fire Temperature RGB imagery loop was presented by the Director of the NWS, Louie Uccellini, as part of the presentation he gave at the 2019 Joint AMS-EUMETSAT Satellite Conference in Boston, MA, on 30 September 2019.

Even far out near the limb of the satellite Field of Regard (FOR), the GOES-17 Fire Temperature RGB detected the hot spot and GOES-17 GeoColor detected the fire smoke from the Pigeon Valley Fire near Nelson, New Zealand on 7 February 2019 (see **Figure M1-3**). An imagery loop of both RGB products can be seen at:

http://rammb.cira.colostate.edu/ramsd/online/loop.asp?data_folder=loop_of_the_day/goes-16/20190207000000&number_of_images_to_display=100&loop_speed_ms=150

In April 2019, the **Swedish Meteorological and Hydrological Institute (SMHI)** contacted Curtis Seaman to inquire about the recipe for the Fire Temperature RGB:

“We really like that RGB at the Swedish Met Service and plan to have it operational soon and hopefully before the summer-fire-season. It may also be handy for other (Pytroll) users as well.”

❖ **Other RGB products**

During this reporting period the GOESR DEAR ABII Team transitioned many more GOES-GOES-17 core Multispectral Imagery products and Multispectral RGB Composite Products to SLIDER for real-time demonstration purposes:

Multispectral Imagery

- GeoColor (CIRA)
- Shortwave Albedo (CIRA)
- Dust DEBRA (CIRA)
- Snow/Cloud (CIRA)
- Snow/Cloud-Layers (CIRA)
- Split Window Difference (10.3 μm – 12.3 μm)

Multispectral RGB Composites

- Natural Color (EUMETSAT)
- Airmass (EUMETSAT)
- Day Cloud Phase Distinction (JMA)
- Nighttime Microphysics (EUMETSAT)
- Day Snow/Fog (EUMETSAT/NASA SPoRT)
- Dust (EUMETSAT)
- Fire Temperature (CIRA)
- Natural Color-Fire (CIRA)
- Ash (EUMETSAT)
- SO₂ – Sulfur Dioxide (JMA)

❖ **Snow/Cloud Discriminator and the Snow/Cloud Layer products:**

The Binary Snow/Cloud Discriminator and Snow/Cloud-Layers products are being produced in real time from both GOES-16 and 17. The “Binary” version highlights all clouds in yellow and snow in white. The “Snow/Cloud-Layers” product uses additional information provided by the 1.38 μm channel to further distinguish high clouds in magenta from the yellow low clouds. Demonstration of the products on SLIDER led to a request from the NWS WFO in Buffalo, NY for us to make the Snow/Cloud-Layers product available in AWIPS. Through collaboration with Eastern Region Headquarters, the Snow/Cloud-Layers product is now being sent to the NWS Eastern Region via the LDM. Training on this product has commenced, and a Quick Guide has already been posted to the VISIT website:

http://rammb.cira.colostate.edu/training/visit/quick_guides/

- ❖ **Optical Flow in GOESR ABI GeoColor:** The CIRA DEAR-ABII Team continued to explore a new research and development application for GOES-R ABI products: “*Optical Flow in GOESR ABI.*” Different types of Optical Flow algorithms are currently being tested (LK, Affine LK, 8-Parameter LK, and Fanreback). During this reporting period, we began with running optical flow on GeoColor imagery using a pre-packaged code called *Butterflow*. For the initial validation thus far, we are not using GeoColor; instead, we are using the red band and Channel 07. Efforts are currently underway to validate and tune optical flow produced with 1-min ABI data to render a dense field atmospheric winds.

Milestone 2: Begin development of augmented DEBRA algorithm with 1.38 μm and the blue band.

On 1 November 2018, a version of DEBRA began to run on CIRA’s public-facing SLIDER satellite product demonstration web page. This allows for the forecasters to observe fall/spring dust storms which are often kicked up by the descending storm track.

Further progress was made in the development and analysis of **cloud-cleared background to be used for DEBRA**. Cloud-cleared backgrounds are currently produced by taking the warmest 10.35 μm brightness temperature for a given pixel during a 21-day period, and then using the date/time index of the warmest pixel location as an index to provide the likeliest cloud-free location for all other ABI channels. An analysis performed, which located areas of large standard deviation in the monthly-mean cloud-cleared background surface brightness temperatures and reflectance values, suggested improvements to the product by incorporating 10.35 μm - 3.9 μm information into the cloud-clearing index method described above.

Another very important step for the DEBRA development was achieved by **transitioning the existing DEBRA code from Terascan over to IDL**. This transition will expedite future revisions, debugging, and innovations on DEBRA by coupling it to the powerful IDL toolkit.

Milestone 3: Begin development of augmented GeoColor with new layers

- ❖ **GOES-R GeoColor with GLM overlays** were made available for GOES-16 and for GOES-17 GeoColor Imagery. The two GLM overlay products, generated in real-time, are “CIRA’s Group Energy Density” and “CIRA’s Group Flash Count Density.” The products are being demonstrated in SLIDER.

GLM Detects Asteroid Flash: At the CIRA Weather Briefing on 1 February 2019, while looking at convection over the Gulf of Mexico, a curious flash was seen over Cuba (**Figure M3-1**). The flash occurred in clear skies, causing suspicion that it was a “false” flash, but it was unusually energetic and large for a false feature. It had no obvious explanation related to sun reflection or cloud edges. The flash was seen on just one image, which accumulates GLM observations over the corresponding 15-minute ABI Full Disk period. Later it was reported (<https://earthsky.org/space/small-meteorite-asteroid-cuba-feb-2019>) that an asteroid was seen over Viñales, Cuba around 1:16 p.m. EST. It was described as extremely bright, yellow-orange in color, and lasted at least four seconds. The event was also visible to residents of southern Florida, and pieces of the meteorite were retrieved in Cuba. Astronomers estimated that before entering Earth’s atmosphere, the rock had been “van-sized”, much smaller than the “house-sized” asteroid that exploded over Chelyabinsk, Russia in February 2013.

- ❖ **GeoColor with Multi-Radar/Multi-Sensor (MRMS) overlay:**

During the reporting period, work continued on a new overlay product of GeoColor with radar products, specifically with Multi-Radar/Multi-Sensor (MRMS) fields. When viewing the GOES-16 CONUS sector on SLIDER, the following MRMS products are now available:

- Merged Base Reflectivity (Quality Controlled)
- Reflectivity at Lowest Altitude
- 1-hour Precipitation Accumulation
- Surface Precipitation Type
- Precipitation Rate

For the GOES-17 CONUS sector, only the Merged Base Reflectivity product is available at present. In addition, we have added two National Lightning Detection Network (NLDN) lightning products that are made available in the MRMS product suite. These products are: 0-30 minute Lightning Probability and 5-min. CG Lightning Density. The NLDN products are currently only available for the GOES-16 CONUS view on SLIDER.

Milestone 4: Begin development of custom products as defined via Liaison/forecaster interactions.

In July 2017, GOES-16 GeoColor imagery started to be provided to forecasters in AWIPS/NAWIPS. During this reporting period, GOES-17 products were added to AWIPS as well. GeoColor is heavily used by NWS WFOs and National Centers. We have heard many voices of NWS forecasters who were asking for GeoColor to become a “Baseline Product”.

Here is an example of **GeoColor imagery directly being used by forecasters (NYup.com)**:

On 20 February 2019, Glenn Coin (NYup.com) posted GOES-16 GeoColor imagery loop from 20 February 2019 15:36 UTC with a text warning about “*A massive winter storm hitting every state in the eastern U.S. will just graze Upstate New York. The storm is expected to bring 1 to 3 inches of snow to Upstate today, with a potential for a light coating of ice tonight before temperatures warm. Winter weather advisories are in place for much of Upstate through Thursday morning. Heavy snow is expected from Oklahoma through the Northeast, according to the National Weather Service.*”

<https://www.newyorkupstate.com/weather/2019/02/massive-winter-storm-will-just-graze-upstate-ny.html>

As mentioned under Milestone 1, the **Fire Temperature RGB** was added to AWIPS through the “on-the-fly” RGB module developed at NASA SPoRT, and all NWS WFOs throughout CONUS have access to it. The “on-the-fly” RGB module was a solution in response to requests from operational forecasters for access to this product. This “simple” RGB is created from the operational GOES data feed and, as such, is not delivered through the LDM.

On 11 February 2019, Ronald Brogan, from ENSCO (<https://www.ensco.com/>), contacted CIRA and requested a **GOES16 animated loop of the Volcanic Ash Microphysics (EUMETSAT) product** for a 40-minute time period on January 14th. Brogan had seen the loop on CIRA’s SLIDER. CIRA replied to Brogan on the same day - the requested imagery loop was made available on a publicly accessible ftp directory

We also successfully **adapted the Binary Snow/Cloud Discriminator and the DEBRA** products in order to successfully convert the algorithms for AWIPS/NAWIPS. These products are being tested on AWIPS. Forecasters are also using SLIDER whenever needed.

Milestone 5: Begin preparing and supplying materials (product descriptions, representative case studies) to training partners.

1. **GOES-16 and GOES-17** GeoColor, RGB Fire Temperature, Snow/Cloud Discrimination, and the other RGB products (see list under Milestone 1) were all made available in real-time on the CIRA RAMMB SLIDER website (<http://rammb-slider.cira.colostate.edu>).

The following email about usage of CIRA’s GeoColor product was received by CIRA’s Director on 16 January 2019:

From: "Stull,R.S. Roland" <rstull@eoas.ubc.ca>

Subject: kudos for GOES-17 fog product

Date: January 16, 2019 at 6:46:18 PM MST

To: "Christian.Kummerow@colostate.edu" <Christian.Kummerow@colostate.edu>

Christian,

Please forward my congratulations to the developers of the GOES 16/17 fog product, and for its excellent display in the RAMMB-CIRA slider. It is a game changer in meteorology.

Cheers, -Roland

Prof. Roland Stull, CCM, CFII
Dept. of Earth, Ocean & Atmos. Sciences
University of British Columbia
2020 - 2207 Main Mall
Vancouver, BC, V6T 1Z4

2. The **CIRA/RAMMB real-time SLIDER website continues to be the principal public-facing demonstration utility for GOES-16 and GOES-17 DEAR-ABII products**. Case studies can be found on the **CIRA-RAMMB's GOES-16/17 "Loop-of-the-Day"** page at: http://rammb.cira.colostate.edu/ramsdis/online/loop_of_the_day/
3. CIRA GOES-16/17 DEAR-ABII products are being depicted as the main satellite image example in **GOES-R Program Office "Fact Sheets"**, which were published in June 2019:
 - **GeoColor:** Fact Sheet on "Hurricane Monitoring"
https://www.goes-r.gov/education/docs/fs_hurricane.pdf
 - **Fire Temperature RGB:** Fact Sheet on "Fire Detection and Characterization"
https://www.goes-r.gov/education/docs/fs_fire.pdf (**Figure M5-1**)
 - **Volcanic Ash (EUMETSAT) RGB:** Fact Sheet on "Volcanic Ash Detection"
https://www.goes-r.gov/education/docs/Factsheet-Volcanic_Ash.pdf (**Figure M5-2**)
4. Many CIRA GOES-16/17 DEAR-ABII products, especially GeoColor imagery, are regularly used in **GOES-R Program Office Quarterly Newsletters**:
 - **January – March 2019 Newsletter (Figure M5-3):**
<https://www.goes-r.gov/downloads/multimedia/newsletters/GOES-RQ1-2019NewsletterFinal.pdf>
 - **April - June 2019 Newsletter:**
<https://www.goes-r.gov/downloads/multimedia/newsletters/GOESRQ22019.pdf>
5. Satellite Training Quick Guides:
 - **The RGB Fire Temperature Quick Guide** was posted on-line at:
http://rammb.cira.colostate.edu/training/visit/quick_guides/Fire_Temperature_RGB.pdf

- **The Day Land Cloud Fire RGB Quick Guide** is available here:
http://rammb.cira.colostate.edu/training/visit/quick_guides/QuickGuide_GOESR_DayLandCloudFireRGB_final.pdf
 - **The Snow/Cloud-Layers Quick Guide** is available here:
http://rammb.cira.colostate.edu/training/visit/quick_guides/GOES_Cloud_Snow_Discriminator_Quick_Guide_20190814.pdf
6. GOES-16/17 DEAR ABII products were presented frequently to forecasters and training partners at **workshops and conferences**. See list of conferences/workshops below in Section V under “Additional Information.”
 7. GOES-16/17 DEAR ABII products were presented as part of the **VISIT Satellite Chats**, which were held during this reporting period:
http://rammb.cira.colostate.edu/training/visit/satellite_chat/
 8. GOES-17 GeoColor was presented as part of a **GOES-17 Webinar** session presented by Dan Lindsey on 11 February 2019.
 9. GOES-16/17 DEAR ABII products are demonstrated to trainers and forecasters via **Blogs**:
 - **GOES-16 DEBRA product**: Blog on “**Blowing Dust associated with 10-11 April 2019 Central US Strong Cyclone**” was posted on 12 April 2019 by CIRA Trainings expert Dan Bikos (**Figure M5-4**)

http://rammb.cira.colostate.edu/research/goes-r/proving_ground/blog/index.php/blowing-dust-detection-split-window-technique/blowing-dust-associated-with-10-11-april-2019-central-us-strong-cyclone/
 - **GOES-16 GeoColor** imagery loop was used in a Blog on “**Rapid ice cover development over the eastern Great Lakes in late January 2019**”, posted by on 1 February 2019 by CIRA Trainings expert Dan Bikos.

http://rammb.cira.colostate.edu/research/goes-r/proving_ground/blog/index.php/geocolor-imagery/rapid-ice-cover-development-over-the-eastern-great-lakes-in-late-january-2019/
 - The **GOES-16 Snow/Cloud-Layers** product was featured on several blog posts on the **VISIT Meteorological Interpretation Blog**, including “Polar-orbiting and geostationary lake ice monitoring” (10 March 2019) and “Low cloud / fog over snow covered ground on 25 February 2019” (25 February 2019).

<http://rammb.cira.colostate.edu/training/visit/blog/index.php/2019/02/25/low-cloud-fog-over-snow-covered-ground-on-25-february-2019/>

<http://rammb.cira.colostate.edu/training/visit/blog/index.php/2019/03/10/polar-orbiting-and-geostationary-lake-ice-monitoring/>

Milestone 6: Prepare/submit a publication on GOES-R synthetic true color

Work on a publication of the GOES-R synthetic true color product began during this reporting period and a manuscript was submitted to *J. Atmos. Ocean. Tech.*,

Miller, S. D., D. T. Lindsey, C. J. Seaman, and J. E. Solbrig, 2019: GeoColor: Illustrating a Dynamic Blending Technique for Multivariate Satellite Imagery. *J. Atmos. Ocean. Tech.*, Submitted.

Plans for Next Reporting Period

Work will continue on all listed milestones during the first half of Year 3 (July 2019 – December 2019)

Additional Information

I. Interaction with Operational Partners

- On 12 February 2019, the NESDIS News & Articles webpage reported on the fact that GOES-17 was declared to be “operational”. The webpage used four different GOES-17 GeoColor imagery (3 loops) for that announcement.
<https://www.nesdis.noaa.gov/content/goes-17-now-operational-here's-what-it-means-weather-forecasts-western-us>
- On 12 February 2019, examples of CIRA’s GeoColor imagery were shared with the media to celebrate the declaration of GOES-17 (GOES-West) as operational. The director of the National Weather Service, Louis Uccellini, posted an animation of CIRA’s GOES-17 GeoColor product, highlighting the utility of GOES-17 to monitor weather for Alaska and the West Coast of the U.S. (**Figure M6-1**).
- National Centers which receive CIRA GeoColor imagery: **National Hurricane Center, Aviation Weather Center, Ocean Prediction Center, Weather Prediction Center, the Anchorage Volcanic Ash Advisory Center.**
- CIRA continued to work closely with **NWS partners** to make sure the GOES-16/17 imagery is displaying properly in their **AWIPS and NAWIPS** systems. GeoColor Imagery is now flowing to numerous NWS offices (via LDM) to be viewed in AWIPS (for evaluation).

- As mentioned above, under the Project Accomplishment section Milestone 1, GOES-16/17 **GeoColor imagery is very frequently used by NWS forecasters** to visualize wildfire smoke events, dust, severe storms, low cloud/fog at night, and other hazardous events.
- By now all NWS/WFOs are receiving the **GOES-16 and the GOES-17 Fire Temperature** and Natural Color-Fire (aka **Day Land Cloud Fire RGB**) product. These products are easily displayed using the “on-the-fly” RGB capability within AWIPS.

The RGB Fire Temperature Quick Guide and the Day Land Cloud Fire RGB Quick Guide were both posted on-line at http://rammb.cira.colostate.edu/training/visit/quick_guides/

- The **Japan Meteorological Agency (JMA)** has adopted CIRA’s AHI true-color algorithm to display their version of GeoColor.
- The **South Korean Air Force** sent one of their Lead Air Force Aviation Weather Forecasters to CIRA with the goal to learn as much as possible about Satellite Meteorology applicable to Aviation Hazards and Aviation Weather Forecasting. Major Hyekyong Kim visited CIRA from 1 August 2018 – 30 January 2019. The CIRA Meteorological Satellite Application Team worked closely with Major Kim during her visit. Training of Major Kim on GOESR DEAR ABII aviation-related products was one of the highest priorities during her time at CIRA.

II. **Support of true color real-time production at NOAA and NESDIS for Outreach and Communication**

- GOES-16 GeoColor image is now on the new webpage banner of NOAA CLASS at <https://www.bou.class.noaa.gov/saa/products/welcome;jsessionid=50E06D5A0319104DEB13BA14A3E44EFE>
- CIRA GOES-16 and GOES-17 GeoColor imagery is used regularly by **NESDIS News** <https://www.nesdis.noaa.gov/news-articles-archive?page=1>
- NOAA Satellites (@ **NOAASatellites**) tweets show CIRA’s GOES16/17 ABI GeoColor imagery daily to highlight special weather events.
- GOES-16 and GOES-17 True Color/GeoColor imagery is heavily used in the **GOES-R Program Office Quarterly Newsletters**, including on the cover pages. (see Milestone 5)
- **NWS WFO Offices and National Centers** frequently use CIRA’s GeoColor to publish/cover special weather events.
- **Daily CIRA GOES-16/17 ABI product loops** are being **posted on CIRA’s webserver** and are frequently downloaded by NESDIS for their use.
- The majority of the “ABI Loop-of-the-Day” which are posted almost daily, are GeoColor loops, which can be viewed by the public:

http://rammb.cira.colostate.edu/ramsdis/online/loop_of_the_day/

III. GeoColor imagery used to support CAMP₂Ex Field Experiment planning

CIRA's GeoColor imagery is being used regularly in preparation for the "The Cloud, Aerosol and Monsoon Processes Philippines Experiment (CAMP₂Ex)". CAMP₂Ex is a response to the need to deconvolute the fields of tropical meteorology and aerosol science at the meso-b to cloud level. The operations will be based at Clark International Airport (Philippines). <https://espo.nasa.gov/camp2ex/content/CAMP2Ex>. The campaign is scheduled for mid-August to October 2019. An example of a typical briefing slide can be seen below. (Figure M6-2)

IV. GeoColor imagery used by @NOAAResearch to congratulate CSU on being selected to host the re-competed CIRA

On 22 May 2019, @NOAAResearch congratulated CSU for being selected to host CIRA. The tweet came with a GeoColor image loop of the solar eclipse event from 21 August 2017. <https://twitter.com/NOAAResearch/status/1131236028965052421> (Figure M6-3)

V. Conference / Workshops / Presentations

- 6-10 January 2019: Micke, K., 2019: Exciting New Features, Products, and Satellites Added to SLIDER Satellite Imagery Looper. AMS 35th Conference on Environmental Information Processing Technologies, Phoenix, AZ, 6-10 January 2019.
- 26 March 2019: Mike Stringer (Assistant System Program Director - GOES-R Program Office) and Kevin Fryar (Chief of Staff - GOES-R Program Office) at CIRA:

Miller, S. D., et al.: 2019: Developing an Environmental Awareness Repertoire of ABI Imagery ('*DEAR-ABII*') to Advise the Operational Weather Forecaster.

- 26 April 2019: Dr. Jeff Reid, NRL Monterey, visiting CIRA
 - GeoColor was part of the satellite imagery presented during this visit.
- 29 April 2019: Pam Sullivan (GOES-R System Program Director), Alexander Krimchansky (GOES-R Program Systems Engineering Lead), and Mike Clark (NOAA Office of Management and Budget), visited CIRA. StAR/RAMMB Federal Employees and CIRA Research Scientists presented "Research Highlights" during this visit, which included a variety of different GeoColor imagery.
- 20 May 2019: John Pace, Director of University of Alaska-Fairbanks GINA, visited CIRA.
 - As part of a series of CIRA research presentations, Curtis Seaman presented GOES-R and JPSS imagery on SLIDER to John Pace.

- 23 May 2019: CIRA Fellows Meeting: Steve Miller, presented “CIRA Major Project Updates”

IV. Outside Project Publicity / Examples of GeoColor in the Media

- **PHYSICS TODAY** from May 2019 published an article on “Meteorologists predict better weather forecasting with AI” by Alex Lopatka, using a high-resolution GeoColor image depicting Hurricane Harvey over the Texas coastline in August 2017. Lopatka writes about how “*more advanced estimates of atmospheric conditions depend on merging the knowledge gained from humans and computers.*”

Physics Today **72**, 5, 32 (2019); <https://doi.org/10.1063/PT.3.4201>

- **NCAR/UCAR** used a GeoColor image for the cover page of their report on climate change on 23 January 2019: <https://news.ucar.edu/132649/major-northeastern-snowstorms-expected-continue-climate-change>
- 27 June 2019: An **ABC7 eyewitness** broadcast showed a CIRA/RAMMB GeoColor loop of the eruption of Ulawun on the island of New Britain in Papua New Guinea as seen by Himawari:
- <https://abc7.com/science/satellite-view-of-papua-new-guinea-volcano-erupting/5366996/>
- 7 June 2019: **THE WATCHERS** (Watching the world evolve and transform) used CIRA’s GeoColor imagery for their article about an extreme rain event which hit the U.S. Gulf Coast on 5-6 June 2019. <https://watchers.news/2019/06/07/months-worth-of-rain-in-24-hours-hits-parts-of-us-gulf-coast-at-least-one-person-killed/>
- 20 May 2019: **National Public Radio (NPR)** used a GeoColor image depicting “Andrea, the first named storm of the 2019 Atlantic season, formed late on Monday, May 20th, according to a special bulletin from the National Hurricane Center: <https://www.npr.org/2019/05/20/725039576/first-named-storm-of-atlantic-hurricane-season-could-develop-monday-night>
- 22 April 2019: On 22 April 2019, the **New York Post** reported that “*in a new announcement from the National Oceanic and Atmospheric Administration (NOAA), Hurricane Michael, which made landfall in Florida last October, has been upgraded from a Category 4 storm to a Category 5. This makes the storm the first Category 5 hurricane to make landfall in the United States since 1992’s Hurricane Andrew.*” A GOES-16 GeoColor imagery (provided by AP) was used for this story:

<https://nypost.com/2019/04/22/scientists-say-hurricane-michael-was-actually-a-category-5-storm/>

- 11 April 2019: **National Public Radio (NPR)** used a GeoColor image depicting the “Bomb Cyclone” which hit the Central U. S. on 11 April 2019.

<https://www.npr.org/2019/04/11/712307810/bomb-cyclone-shutters-schools-makes-roads-impassable-in-central-u-s>

- 4 April 2019: The Washington Post used a GeoColor image of Hurricane Michael in an article written by Phil Klotzbach, who summarized the prognosis about the 2019 Atlantic Hurricane season which was released on 4 April 2019 by the Colorado State University’s hurricane research team.

- 3 April 2019: On 3 April 2019, **FOX35 Orlando** news used a GeoColor Image of Hurricane Michael from 10 Oct 2018 to broadcast the list of names for the 2019 Atlantic hurricane season which was released by the National Hurricane Center (NHC). The NHC re-cycles its list of names ever six years.

<http://www.fox35orlando.com/weather/national-hurricane-center-releases-list-of-2019-hurricane-names>.

- 14 March 2019: Andrew Freedman (**Axios**) used CIRA’s GeoColor product from 15 UTC 13 March 2019 to discuss the high-impact lee cyclogenesis event that crippled portions of Eastern Colorado and the Plains with blizzard conditions and set record low minimum sea-level pressures.

<https://www.axios.com/bomb-cyclone-blizzard-plains-ccfcb758-1d44-4ee8-97ef-75dc47a7741b.html>

- 14 March 2019: **National Public Radio (NPR)** online used a GOES-16 GeoColor imagery for their report on the ‘Bomb Cyclone’ which paralyzed the Central U.S.

<https://www.npr.org/2019/03/14/703352564/bomb-cyclone-paralyzes-central-u-s-bringing-snow-floods-and-dangerous-winds>

- 6 March 2019: A GOES-17 loop of GeoColor with GLM overlaid over the east Pacific Ocean was provided to **ABC News** upon request. The loop highlighted lightning associated with an Atmospheric River event. The request originated from John Leslie from NESDIS.

- 10 February 2019: **CBS News** broadcasted a report by Jeff Berardelli (CBS News Climate & Weather Contributor) on “Hurricanes are intensifying more rapidly and it may be our fault.”

<https://www.cbsnews.com/news/hurricanes-are-intensifying-more-rapidly-and-it-may-be-our-fault/>

- 30 January 2019: **The Atlantic** used a GeoColor imager of a Polar Vortex from 30 January 2019 for an article about how accurate modern weather forecast has become.

<https://www.theatlantic.com/science/archive/2019/01/polar-vortex-weather-forecasting-good-now/581605/>

IV. **Relevant Journal Publications**

Miller, S. D., D. T. Lindsey, C. J. Seaman, and J. E. Solbrig, 2019: GeoColor: Illustrating a Dynamic Blending Technique for Multivariate Satellite Imagery. Submitted to *J. Atmos. Ocean. Tech.*

Broomhall, M., L. Majewski, V. Villani, I. Grant, and S. D. Miller, 2019: Correcting Himawari-8 Advanced Himawari Imager data for the production of vivid true colour imagery. *J. Atmospheric Ocean. Technol.* In Press.

Lindsey, D. T., S. Nam, and S. D. Miller, 2018: Tracking oceanic nonlinear internal waves in the Indonesian seas from geostationary orbit. *Rem. Sens. Environ.*, **208**, 202-209, <https://doi.org/10.1016/j.rse.2018.02.018>.

Miller, S. D., R. L. Bankert, J. E. Solbrig, J. M. Forsythe, and Y.-J. Noh, 2017: A Dynamic Enhancement with Background Reduction Algorithm: Overview and Application to Satellite-Based Dust Storm Detection. *JGR-Atmospheres*, **122**(23), 12,938–12,959, doi.org/10.1002/2017JD027365.

Note: the DEBRA publication (Miller et al. 2017, listed above) was designated as a “Journal Highlight” by JGR:Atmospheres handling Editor Zhanqing Li. **JGR Highlight Title:** “Addition by Subtraction: Raising the Bar for Satellite Imagery”. Full JGR highlight text: <https://eos.org/editor-highlights/addition-by-subtraction-raising-the-bar-for-satellite-imagery>

Miller, S. D., T. L. Schmit, C. J. Seaman, D. T. Lindsey, M. M. Gunshor, R. A. Kors, Y. Sumida, and D. W. Hillger, 2016: A Sight for Sore Eyes: The Return of True Color Imagery to Geostationary Satellites. *Bull. Amer. Meteor. Soc.*, **97**(10), 1803-1816, [doi:10.1175/BAMS-D-15-00154.1](https://doi.org/10.1175/BAMS-D-15-00154.1).

NOTE: *BAMS* Cover Article



Figure M1-1: Comparison between half-kilometer (HKM, on top) and 1-km (bottom) resolution versions of GeoColor from GOES-17 (23:30 UTC, 30 June 2019).

 **GOES Image Viewer**

Home CONUS ▾ Full Disk ▾ North America ▾ Caribbean ▾ Pacific ▾ South America ▾ M

GOES-West PACUS - GeoColor

1 hour loop - 12 images - 5 minute update

To enlarge image, pause animation & click images; hover over popups to zoom; use slider to navigate.

Band: Loop:

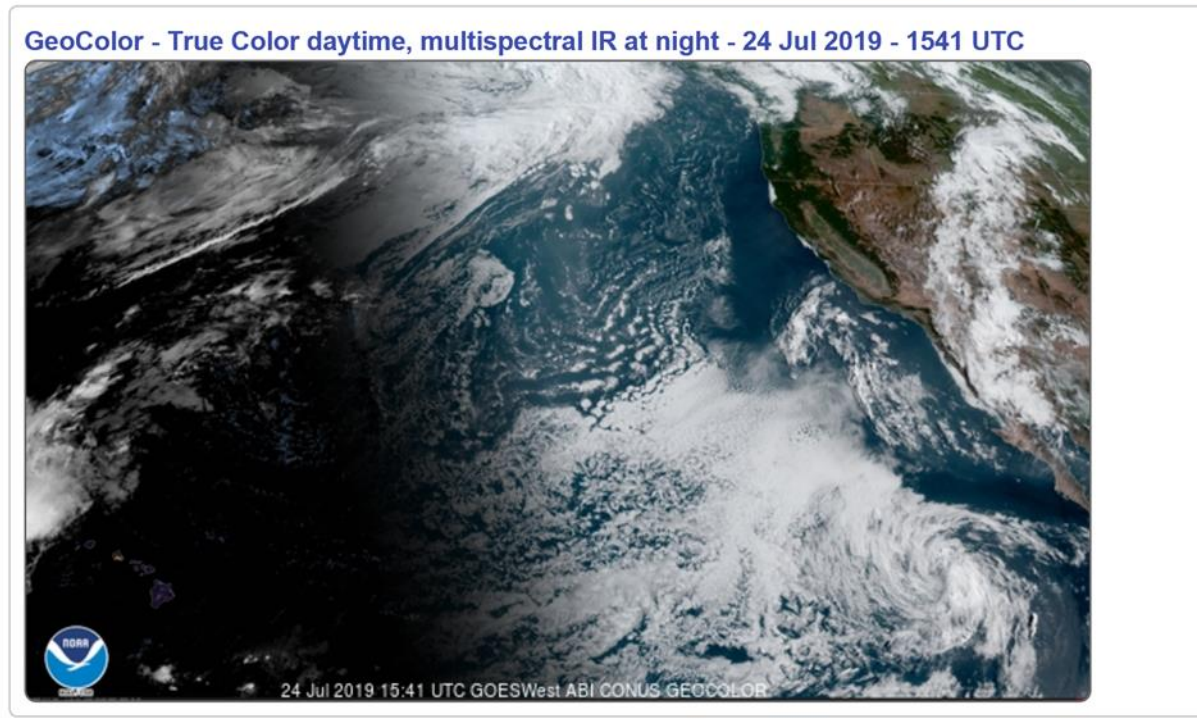


Figure M1-2: NESDIS GOES Image Viewer: GOES-West PACUS- GeoColor seen at: <https://www.star.nesdis.noaa.gov/GOES/conus.php?sat=G17>

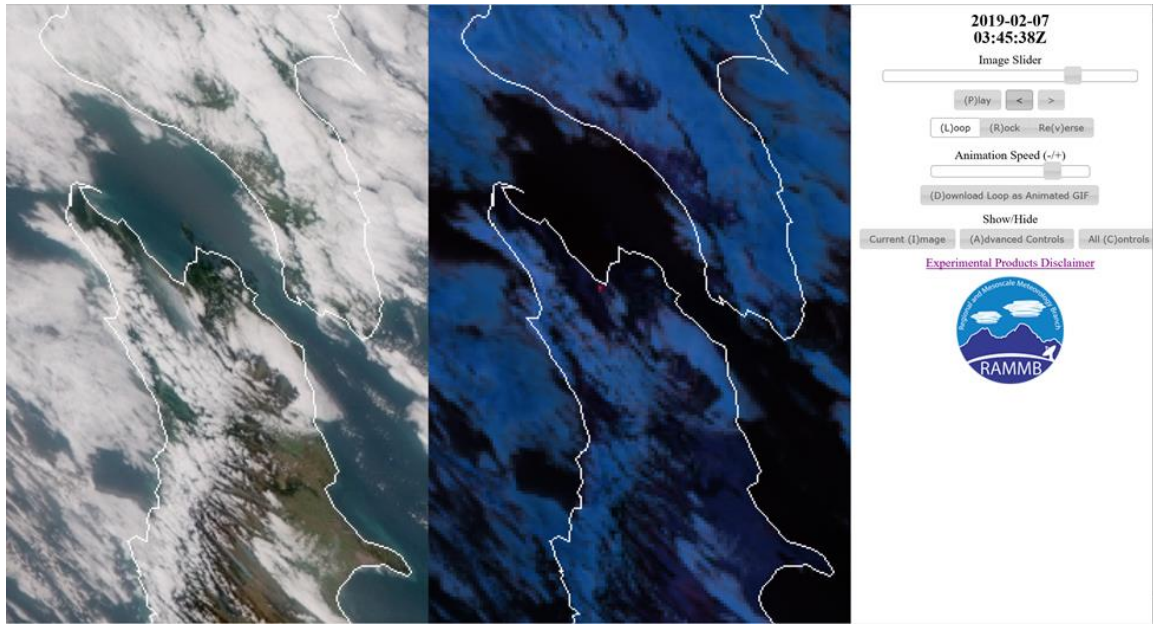


Figure M1-3: 2019-02-07 - Even out near the limb, GOES-17 detects the hot spot and smoke from the Pigeon Valley Fire near Nelson, New Zealand - GeoColor (left) and Fire Temperature RGB (right).

http://rammb.cira.colostate.edu/ramdis/online/loop.asp?data_folder=loop_of_the_day/goes-16/20190207000000&number_of_images_to_display=100&loop_speed_ms=150



Figure M3-1: GLM-detected asteroid flash over Cuba, as shown by RAMMB/CIRA SLIDER on 1 February 2019 at 18:15:32 UTC. The image is GOES-16 ABI GeoColor with the GLM Group Energy Density overlay.



Fire hot spots and a large plume of smoke are seen in this GOES-16 fire temperature RGB imagery with GeoColor enhancement of the Camp Fire in northern California on November 8, 2018.
 Credit: NOAA/CIRA

fires. Once a fire is detected, fire size and temperature can be estimated. Radiative power is also calculated for the fire. Fire radiative power is directly related to fire size and temperature, but the different characteristics can be used in various applications.

Fire temperature red-green-blue (RGB) imagery is used to manually locate and monitor fire hot spots. This imagery is created using three shortwave and near-infrared ABI bands. Active hot spots show up as red, yellow and white as the fire grows increasingly hotter. Fire temperature RGB imagery can be made partially transparent and placed over a **GeoColor** enhancement, so both the fire's hot spots and smoke plumes are visible. GeoColor imagery combines data from multiple ABI bands to approximate how the human eye would see Earth from space. GeoColor imagery helps forecasters easily identify smoke from a fire.

What benefits do GOES-R fire applications provide?

New ABI channels provide more information to forecasters and improved resolution and rapid scanning deliver high-definition images as often as every minute. This means a much more detailed look at fire conditions, faster detection of hot spots, and the ability to track fire progression and spread in real time to detect changes in a fire's behavior and predict a fire's motion. **GOES-R Series satellites frequently detect fires before they are spotted on the ground – often before emergency notifications to 911.** The satellites are also used to pinpoint the exact location of a fire after reports of smoke.

GOES-R Series observations are not just valuable for detecting wildfires but are also critical to observing and monitoring smoke from those fires. The ability to monitor smoke plumes in near real-time is particularly useful in directing firefighting efforts from the air. Deploying airplanes and helicopters to spray fire retardant is often hampered due to poor visibility. GOES-R satellites can help guide decisions for deploying flights by providing information on the exact location and motion of smoke from a fire. The smoke detection and monitoring information also enable better air quality forecasts.

The benefits from GOES-R Series satellites aren't just seen during a fire but are also important in monitoring burn scars and predicting flash flood events from rain events after a fire. The satellites provide critical data for the entire lifecycle of a fire disaster – from drought to fire to floods and landslides.

Contributor: Chris Schmidt (CIMSS)

Related links:

FDC product information: <https://go.usa.gov/xmsCV>

FDC validation and data access: <https://go.usa.gov/xmsCd>

National Weather Service fire weather page: <https://www.weather.gov/fire/>

Figure M5-1: Page 2 of the GOES-R Program Office “Fact Sheet” on “Fire Detection and Characterization” (published in June 2019).

https://www.goes-r.gov/education/docs/fs_fire.pdf

FACT SHEET

Why are volcanic eruptions hazardous?

Volcanic ash is a significant health, aviation, infrastructure, and economic hazard. When ingested into aircraft engines, volcanic ash can lead to engine damage or failure. Volcanic ash is extremely abrasive and even small concentrations can severely damage the exterior of aircraft. In addition, ash falls pose substantial health and infrastructure threats to those on the ground. Breathing volcanic ash can result in serious illness or death and ash falls can also pollute water supplies and damage or destroy buildings. Volcanic eruptions also often produce a noxious gas, sulfur dioxide (SO₂). Inhaling SO₂ is associated with increased respiratory symptoms and disease.

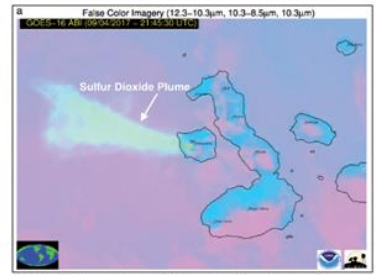


An ash plume rises from the Kilauea volcano in Hawaii on May 15, 2018. Credit: U.S. Geological Survey

Why is it important to monitor volcanoes from space?

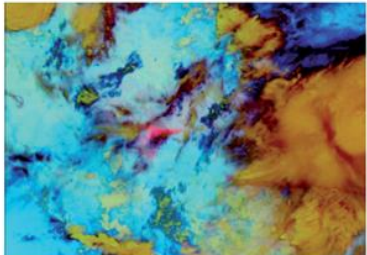
Volcanic emissions generate complex clouds that can affect local, regional, or, in the case of very large eruptions, global weather and climate. Given the remote location of most volcanoes and the rapid formation and expansion of volcanic clouds, geostationary satellites are the primary tool for identifying, tracking and characterizing volcanic clouds. GOES East and GOES West observe a significant fraction of the most volcanically active region on Earth, known as the "Pacific Ring of Fire," which includes the western portions of North and South America, East Asia, Indonesia, Micronesia, and New Zealand.

How do GOES-R Series satellites monitor the hazards from volcanic eruptions?



GOES-16 false color ash RGB image of the Fernandina volcano in the Galapagos Islands on September 4, 2017. This volcanic plume was rich in SO₂, depicted as a green plume in this imagery. Credit: NOAA/CIMSS

The GOES-R Series **Advanced Baseline Imager (ABI)** has several channels (or bands) that are sensitive to volcanic ash. ABI also has significantly improved resolution and faster coverage than previous GOES imagers, allowing for better identification of volcanic clouds. ABI is also sensitive to SO₂. **Sulfur dioxide detection** is a new capability offered by the ABI, due to new infrared channels that previous GOES imagers lacked. Even more so than volcanic ash, geostationary satellite-based volcanic SO₂ detection is revolutionized with the ABI.



Volcanic ash from the September 27, 2017, eruption of the Popocatepetl volcano in Mexico was detected by GOES-16. The reddish pink colors indicate ash. The other colors denote the following: yellowish/brown colors are thick clouds, the dark blues are thin cirrus clouds, and the pale blue indicates the surface (land and water) of the Earth. Credit: NOAA/CIRA

Visible and infrared ABI channels can be combined to create RGB (red-green-blue) imagery that allows for better discernment of features like ash and hot spots. In **volcanic ash RGB** imagery, ash is shown as reddish pink, thick clouds as yellowish brown, thin cirrus clouds as dark blue, and surface (land and water) of the Earth as pale blue. **Fire temperature RGB** imagery is used to detect hot spots from volcanic fire. Active hot spots show up as red, yellow and white as the fires grow increasingly hotter.

The advanced capabilities from GOES-R Series satellites also allow for new detection tools. The **VOLcanic Cloud Analysis Toolkit (VOLCAT)** is an artificial intelligence application developed by NOAA, in partnership with the

Figure M5-2: GOES-R Program "Fact Sheet" from June 2019 depicting CIRA's Volcanic Ash RGB composite imagery (using the EUMETSAT recipe).

https://www.goes-r.gov/education/docs/Factsheet-Volcanic_Ash.pdf



**A Note from Pam Sullivan,
GOES-R System Program Director:**

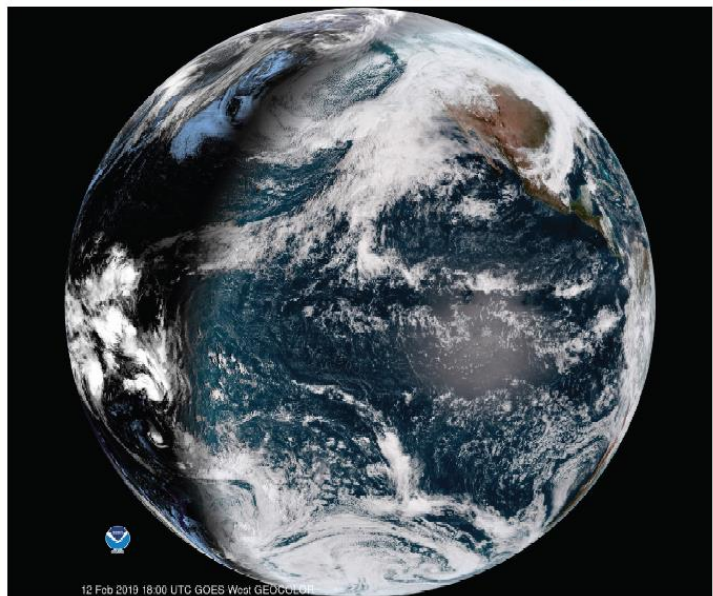


GOES-17 is now operational as GOES West! On February 12, GOES-17 joined GOES-16 in operational service, making

the advanced capabilities of this series available from sea to shining sea! Together, NOAA's most advanced weather satellites provide unprecedented data to forecasters and help save lives and property across more than half the globe. This is a remarkable achievement, made possible by the hard work and dedication of the entire GOES-R team. We remain as busy as ever, with our team continuing to work on GOES-16 and 17 data product validation, the ground system server refresh, the GOES-T/U Advanced Baseline Imager cooling system redesign, and the build of our next two satellites in order to ensure continuity of GOES-R Series operations for many years to come.

PROGRAM HIGHLIGHTS

GOES-17 is now operational as NOAA's GOES West. In its new role, GOES-17 is providing faster, more accurate, and more detailed observations [for detecting and monitoring Pacific storm systems, fog, wildfires, and other weather phenomena that affect the western United States, Alaska, and Hawaii.](#) Located at 137.2 degrees west longitude, GOES-17 replaces GOES-15 as the operational GOES West satellite. GOES-17 joins GOES-16, in operation as NOAA's GOES East, in delivering high-resolution visible and infrared imagery and lightning observations of more than half the globe – from the west coast of Africa to New Zealand and from near the Arctic Circle to the Antarctic Circle. [View GOES-17 operational imagery.](#)



GOES-17 full disk GeoColor imagery from 1:00 p.m. EST on February 12, when the satellite was officially declared operational. Credit: NOAA/STAR

Figure M5-3: Title page of the GOES-R Program Office quarterly Newsletters, from January – March 2019:

<https://www.goes-r.gov/downloads/multimedia/newsletters/GOES-RQ1-2019NewsletterFinal.pdf>

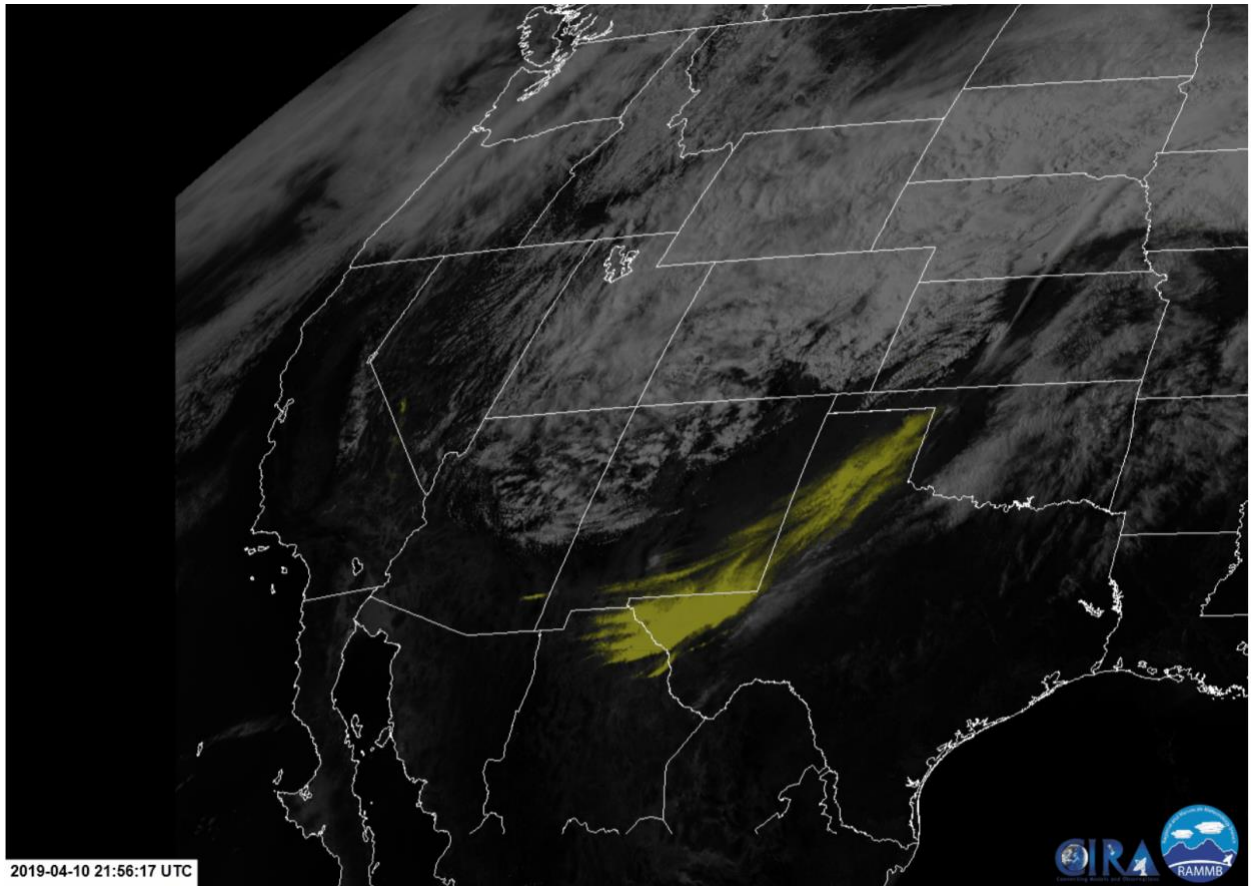


Figure M5-4: *Blowing Dust associated with 10-11 April 2019 Central US Strong Cyclone seen in the above GOES-16 DEBRA imagery from 10 April 2019 21:56 UTC. This DEBRA imagery is part of a blog on “Blowing Dust associated with 10-11 April 2019 Central US Strong Cyclone”, which was posted on 12 April 2019 by CIRA Trainings expert Dan Bikos.*

http://rammb.cira.colostate.edu/research/goes-r/proving_ground/blog/index.php/blowing-dust-detection-split-window-technique/blowing-dust-associated-with-10-11-april-2019-central-us-strong-cyclone/



Figure M6-1: Tweet by the director of the National Weather Service, Louis Uccellini, on 12 February 2019, celebrating that GOES-17 is now operational.

Analysis 00Z June 7th, 2019

Current Obs.

- Convective activity along Palawan and SCS. Clear sky with broken low level clouds N/NE of Luzon. Isolated disorganized convection West of Luzon
- Upper level shear around 400hpa at 5kts from the N just above ML
- GMAO: Manila plume propagating westward. Possible aerosol from SE China and Taiwan north of Luzon
- Wind: LL Easterly to Southerly flow consistent with cleaner air and minimal aerosol.
- Flight: Cold Pool sampling west of Luzon, minimal high clouds North of Luzon good for aerosol/radiation
- Past 48 hr. Verification: Numerous CB/TCU south/southeast of Luzon. Cloud streets East of Luzon both verified.

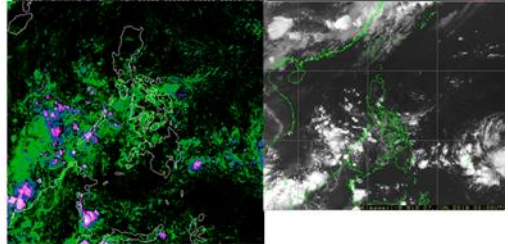
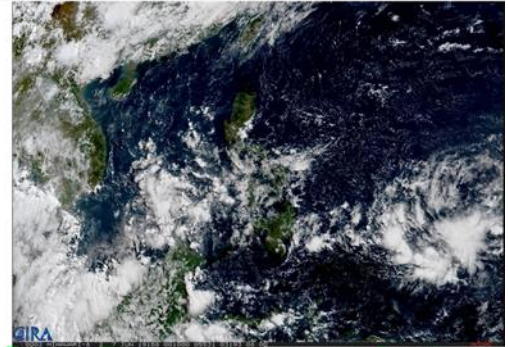
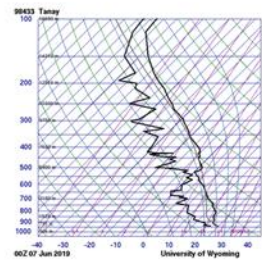
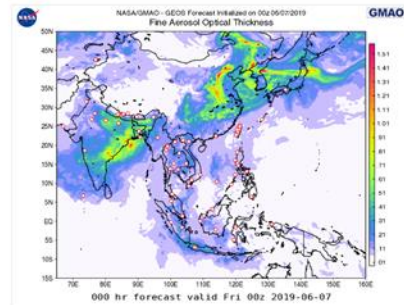


Figure M6-2: CAMP₂Ex weather briefing slide from 7 June 2019. The weekly briefing material shows GeoColor imagery from the CAMP₂Ex field experiment area.



NOAA Research
@NOAAResearch

NOAA Research provides the research foundation for understanding our planet and technological innovation and scientific advances that improve our lives.

US
research.noaa.gov
Joined September 2011

NOAA Research ✓
@NOAAResearch

Follow

Congratulations to @ColoradoStateU for being selected to host NOAA's Cooperative Institute for Research in the Atmosphere (CIRA)!

CIRA is focused on developing new satellite products and models designed to improve weather and climate prediction. 🌐📡
go.usa.gov/xmfQE



9:31 AM - 22 May 2019

35 Retweets 85 Likes



Figure M6-3: On 22 May 2019, @NOAAResearch congratulated CSU for being selected to host CIRA. The tweet came with a GeoColor image loop of the solar eclipse event from 21 August 2017. <https://twitter.com/NOAAResearch/status/1131236028965052421>