

## GOES-R Risk Reduction Bi-Annual Report

**Reporting Period:** July 2019 – Dec 2019 (1<sup>st</sup> half of FY19 / Year 3 funding cycle)

**Team Lead:** Steven Miller (CSU/CIRA)

**Team Members:** CIRA: Curtis Seaman, Jeremy Solbrig, Yoo-Jeong Noh, Jason Apke, Kyle Hilburn  
RAMMB: Don Hillger, Deb Molenaar

**Federal Partners:** Bill Ward (ESSD Chief, NWS Pacific Region Headquarters)

**Additional Collaborators:** Chad Gravelle (Operations Proving Ground);  
Amanda Terborg (AWC);  
Mark DeMaria (NHC)

**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) has 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. 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 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).

With GOES-16 and GOES-17 now both operational, this DEAR ABII project focuses on transitioning, refining, and demonstrating through established Satellite Proving Ground channels all imagery products developed over the past years. The products will be made available to operational centers and National Weather Service (NWS) forecasters in the AWIPS-II display environment.

## **Special Achievements:**

- **AWIPS RGB telecon**, 5 December 2019: (Lindsey, Foster, Gravelle, Molenar, Line, Miller): **Chad Gravelle** comment: *“reviewed GeoColor, noted its widespread usage...this is the future of RGB...very powerful visualization. Could transcend satellite and change the game.”*
- In August 2019, Steve Miller submitted a **manuscript on GeoColor Algorithm Description** to the Journal of Atmospheric and Oceanic Technology (JTECH). Manuscript title: GeoColor: A Blending Technique for Satellite Imagery. It was published in March 2020. <https://doi.org/10.1175/JTECH-D-19-0134.1>.
- **Steve Miller visits Korea Meteorological Administration, South Korea:** The week of 11-15 November 2019, Steve Miller traveled to South Korea to visit the National Meteorological Satellite Center (NMSC), Korea Meteorological Administration (KMA; meeting their new Director, Hyun-Kyun Kim), and the Seoul National University. He gave several seminars on GOES-R ABI and Himawari AHI satellite algorithm development and collaborated with South Korean scientists at these institutions.
- **While visiting the KMA satellite facility, Steve Miller met with the POC for the GEOKOMPSAT-2A AMI data feed, Jinho Shin**, and then worked with Don Hillger to provide the right folks on the NESDIS side in touch with KMA and supplied the application form, so that we can receive AMI data in the same manner as AHI.
- **Six NOAA Managers highlight GeoColor as part of their presentations at the 2019 Joint Satellite Meeting** in Boston, 30 September – 4 October 2019:
- **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.
- Based on discussions with **Brad Pierce**, at the **2019 Joint AMS/EUMETSAT Conference in Boston**, CIRA’s Fire Temperature RGB was used extensively by flight operations during the **FIREX-AQ** campaign, conducted during summer 2019 over the US.
- **GeoColor used for the 2019 CAMP2Ex and 2019 PISTON ship cruise operations—high profile NASA/DoD field campaigns**
- **Special RAMMB/CIRA GeoColor Sector for NHC Media Desk** (July 2019):  
As requested by Mark DeMaria, Chief of the Technology and Science Branch (TSB) at NOAA’s National Hurricane Center, **RAMMB/CIRA implemented real-time processing and dissemination of a special AWIPS2 GOES-16 GeoColor product sector.**
- **ABI and VIIRS imagery of Alaska fires provided to Congress:** A congressional committee asked NASA for satellite imagery of wildfires in Alaska during the spring of 2019. CIRA provided two videos to fulfill this request: a nearly month-long loop of VIIRS

Fire Temperature RGB images (25 June-17 July 2019) from both S-NPP and NOAA-20, and a 5-day loop of GOES-17 GeoColor images (6-10 July 2019)

## Progress toward FY19 Milestones

### **PROJECT ACCOMPLISHMENTS**

(covering July 2019 – Dec2019)

**Milestone 1: Continued near-real-time demonstration of core products in AWIPS/NAWIPS and on the web. Conduct validations of products against independent observations.**

#### **❖ Core Product: GeoColor**

- GOES-16/17 GeoColor imagery is examined daily and monitored for performance. When there is a downtime, we hear about it from external users.
- Instructions to ingest and display the products in **AWIPS2 D2D** have been sent to requesting WFOs (distributed via the Regional Headquarters).
- The **GOES-R Program Office continues to use CIRA's GeoColor imagery products daily:**
  - 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
- GeoColor is available on the **NESDIS GOES-East** and **NESDIS GOES-West Viewer** websites: <https://www.star.nesdis.noaa.gov/GOES/conus.php?sat=G16> and <https://www.star.nesdis.noaa.gov/GOES/conus.php?sat=G17>
- **Special RAMMB/CIRA GeoColor Sector for NHC Media Desk** (July 2019):  
As requested by Mark DeMaria, Chief of the Technology and Science Branch (TSB) at NOAA's National Hurricane Center, **RAMMB/CIRA implemented real-time processing and dissemination of a special AWIPS2 GOES-16 GeoColor product sector.** The data covers the NHC Atlantic Basin domain and is being used in briefings from the NHC Media Desk (see **Figure M1-1, lifted from one of the NHC Media sessions**).
- **NOAA Managers highlight GeoColor as part of their presentations at the 2019 Joint Satellite Meeting** in Boston, 30 September – 4 October 2019:

- **Stephen Volz**, Assistant Administrator for Satellite and Information Services (NESDIS). Volz’s talk was **filled with many of CIRA’s Loops-of-the-Day, most of those were GeoColor loops. (Figure M1-2)**
  - **Louis Uccellini**, Head of NWS. He showed a **Fire Temperature RGB loop** from 6-7 March 2017 (Oklahoma, Kansas), a **Hurricane Harvey loop** (from Dan L.) and he showed a **GeoColor image of Hurricane Dorian**.
  - **Pam Sullivan**, GOES-R System Program Director. **Pam’s talk was filled with CIRA’s GeoColor loops.**
  - **Neil Jacobs**, Assistant Secretary of Commerce for Environmental Observation and Prediction, performing the duties of Under Secretary of Commerce for Oceans and Atmosphere. His presentation **title slide depicted a GeoColor image.**
  - **Tim Walsh**, JPSS Deputy Program Director. Walsh **presented a Polar SLIDER GeoColor loop** which he downloaded the evening before his talk to make sure it is recent). He gave CIRA full credit for the Polar SLIDER tool, and added: **“I love this tool – I look at it every day”!**
  - **Lori Brown**, NOAA/NESDIS, Developer of the NESDIS GOES-East and GOES-West Viewer websites. Her poster focused on satellite data stream statistics. She mentioned that the **GeoColor data stream accounts for 95% of the web and image download traffic.**
- **GeoColor was used for the 2019 CAMP2Ex and 2019 PISTON ship cruise operations—high profile NASA/DoD field campaigns:** The CIRA team, with help from Dan Lindsey (NOAA/NESDIS), supplied a special sector for CAMP2Ex and PISTON. GeoColor imagery was used extensively by many of the forecasters for the field campaign as part of their regular forecast duties. **Figure M1-3** an example of a typical slide used for the daily briefing. [http://rammb.cira.colostate.edu/ramsd/online/himawari-8.asp#PISTON\\_Experiment](http://rammb.cira.colostate.edu/ramsd/online/himawari-8.asp#PISTON_Experiment)
  - **ABI and VIIRS imagery of Alaska fires provided to Congress:** A congressional committee asked NASA for satellite imagery of wildfires in Alaska during the spring of 2019. CIRA provided two videos to fulfill this request: a nearly month-long loop of VIIRS Fire Temperature RGB images (25 June-17 July 2019) from both S-NPP and NOAA-20, **and a 5-day loop of GOES-17 GeoColor images (6-10 July 2019).** The VIIRS Fire Temperature RGB images provide high-resolution views of the numerous hot spots and **the GOES-17 GeoColor loop shows the thick smoke that blanketed most of Alaska in early July. (Figure M1-4).**
  - **Steve Miller is currently serving as part of the NASA LANCE Users Working Group,** which fields near real-time data (primarily NASA assets, but also Suomi-NPP and most recently, GOES-R ABI) for various purposes, including support of the NASA Disasters Program and the NASA Worldview website. **Miller suggested that instead of re-developing its own ABI true color product for Worldview, NASA should consider adopting**

**GeoColor for this purpose.** Discussions are ongoing to determine the logistics and feasibility of this concept, which would provide a positive example of how the two agencies can work together to benefit end-users.

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

- **The Snow/Cloud Layer products are running in SLIDER as well as in AWIPS2.**
- **Snow/Cloud Layer products are being evaluated regularly by CIRA Scientists and Operational Forecasters.** NWS forecasters at WFO **Buffalo** (BUF) use this product regularly.

BUF requested Snow/Cloud-Layers product in AWIPS. 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/](http://rammb.cira.colostate.edu/training/visit/quick_guides/)

- **Improvements:** Steve Miller and Jeremy Solbrig are working on a “**Snow/Cloud Layer false alarm**” problems:

Low clouds over ocean may appear as false-snow, due to a combination of large particle size and spatial resolution issues. A tentative fix has been evaluated but not yet implemented.

In case of dry air, high-altitude snow and low cloud can sometimes show up as false-cirrus. The correction requires an indexing of the cirrus threshold. Miller has a pseudo-code algorithm that bases this index on the ABI vapor bands (8-10) but this needs to be coded and tested.

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

- **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.**
- **Very Popular within the operational NWS/WFO forecasters** (especially California!).
- **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.
- **Use of Fire Temperature RGB by forecasters:** At the 2019 Joint AMS-EUMETSAT Satellite Conference in Boston, Curtis came away with that “forecasters are using the Fire Temperature RGB and not the official GOES-R fire products, a fact that even Chris Schmidt (CIMSS) acknowledged during his talk.”

- Based on discussions with **Brad Pierce, at the 2019 Joint AMS/EUMETSAT Conference in Boston, CIRA's Fire Temperature RGB was used extensively by flight operations during the FIREX-AQ campaign, conducted during summer 2019 over the US.** The product was particularly useful in identifying nascent small fires in the southeast US. **Brad plans to write up a summary of this campaign and acknowledge CIRA, the Fire Temperature RGB, and the SLIDER interface for critical support of this important joint NOAA/NASA research program**
- **Review provided for Fire Temperature RGB “Job Aid”:** C. Seaman reviewed a “job aid” developed by K. White and K. Fuell (NASA SPoRT) discussing the basic science behind the Fire Temperature RGB as it applies to GOES-R ABI. **Job aids are intended for operational users to learn the basics of the RGB via real-time data at their workstation. C. Seaman was selected as the subject matter expert (SME) as he was the original developer of this RGB product.**

### ❖ Core Product: DEBRA Dust Product

#### ➤ **GeoColor with Dust Signature “Signal Imprinting”:**

During the reporting period, work continued on a **new overlay product that combines GeoColor with dust-detection** (either via the traditional split-window “12-11 micron BTD” or the DEBRA product) through a special technique described in the brand-new Miller et al. JTECH publication as “**Signal Imprinting**”. On 10 March 2020, the peer-reviewed science article “*GeoColor: A Blending Technique for Satellite Imagery,*” was published in the Journal of Atmospheric and Oceanic Technology (JTECH) as an open-access paper:

**Miller, S. D.,** D. T. Lindsey, C. J. Seaman, and J. E. Solbrig, 2020: GeoColor: A Blending Technique for Satellite Imagery. *J. Atmos. Ocean. Tech.*, **37**(3), 429-448, <https://doi.org/10.1175/JTECH-D-19-0134.1>.

The basic concept of signal imprinting is to modulate the base image (in this case, GeoColor) RGB components in a way that is governed by an algorithmically-identified feature (e.g., dust, snow, etc.). In the case of the split-window, used for dust detection, a scaled and normalized version of the split-window difference is used to augment the R/G and suppress the B components of the GeoColor image, imparting a yellow tonality to only those pixel locations where the split-window difference is deemed significant as an indicator for lofted dust. **(Figure M1-5).**

- Further progress was made in the development and analysis of **cloud-cleared background to be used for DEBRA.**
- **Transitioning the existing DEBRA code from Terascan over to IDL is now completed.** This transition will expedite future revisions, debugging, and innovations on DEBRA by coupling it to the powerful IDL toolkit.

- Next step: **Evaluation of the DEBRA Dust product over water.** The goal is to **improve the algorithm by also using ABI visible bands.**

### ❖ **Core Product: Optical Flow**

The CIRA DEAR-ABII Team continued its work on **Optical Flow in GOESR ABI. Different types of Optical Flow algorithms are currently being tested** (LK, Affine LK, 8-Parameter LK, and Fanreback). During the past reporting period, optical flow on GeoColor imagery was done by using a pre-packaged code called *Butterflow*. For the initial validation we are using the red band and Channel 07. Efforts continue to validate and tune optical flow produced with 1-min ABI data to render a dense field atmospheric winds.

### **Milestone 2: Begin near real-time demonstration of augmented core products and custom tailored products in AWIPS/NAWIPS and on the web.**

- **Real-time demonstration of most DEAR-ABII products** happens via **RAMSDIS online** and on **SLIDER** (available to the public):  
[http://rammb.cira.colostate.edu/ramsdis/online/loop\\_of\\_the\\_day/](http://rammb.cira.colostate.edu/ramsdis/online/loop_of_the_day/)  
<https://rammb-slider.cira.colostate.edu/>
- **GeoColor with Multi-Radar/Multi-Sensor (MRMS) overlay on SLIDER:**  
GOES-16 CONUS sector with MRMS product overlay:
  - Merged Base Reflectivity (Quality Controlled)
  - Reflectivity at Lowest Altitude
  - 1-hour Precipitation Accumulation
  - Surface Precipitation Type
  - Precipitation Rate  
GOES-17 CONUS sector with MRMS product overlay:
  - Merged Base Reflectivity (Quality Controlled)
- **@NOAA Satellite tweets a GeoColor nighttime image with GLM lightning** overlay (25 July 2019) (**Figure M2-1**).

### **Milestone 3: Continue supplying materials to satellite training partners.**

- **CIRA Participation in the 10<sup>th</sup> Asia-Oceania Meteorological Satellite Users' Conference (AOMSUC)**, held from 2-7 December 2019, in Melbourne, Australia. Curtis Seaman gave two presentations on the latest developments of CIRA's Satellite Loop Interactive Data Explorer in Real-time (SLIDER) titled: "*SLIDER: A website for viewing global, full-*

resolution satellite imagery in realtime”, one for the “AOMSUC Training Event on Satellite Data and Product Application” and one for the “AOMSUC Conference”. **Several forecasters who attended the Training Event told Curtis “that learning about SLIDER was the highlight of the event”!**

➤ **18-29 November 2019: Paraguay and Uruguay Workshop**

Workshop report received from **José Manuel Gálvez, SRG at NOAA/NWS/NCEP/WPC**.  
*Good morning,*

*I wanted to share with the group the two reports from the Workshops conducted in Paraguay and Uruguay, which have been cleared by NOAA. I'm sending the reports to the list of the participants invited to the last call. But I'm also including a few people that were key to the success of the workshops. Special thanks to these folks:*

***Bernie Connell (CIRA)**, Marcial Garbanzo and Anthony Segura (University of Costa Rica), Diego Souza (INPE), Dan Lindsey (NOAA), **Curtis Seaman (CSU)**, Scott Lindstrom (CIMMS/U. Wisconsin) and Natalia Donoho (NOAA). Your contributions on the development of the case studies, and shared slides in some cases, were essential to improve the service provided to our NWS partners in South America.*

*Thank you for the team work and happy holidays! Jose*

➤ **Extensive use of GeoColor imagery by NESDIS Public Relations:**

- GOES-R Program Office Newsletter:  
<https://www.goesr.gov/downloads/multimedia/newsletters/GOESRQ32019NewsFINAL.pdf>
- GOES-R Program Office “Fact Sheets”  
<https://www.goes-r.gov/resources/education.html>
- @ NOAA Satellites Twitter  
<https://twitter.com/NOAASatellites>

*Example: On November 18<sup>th</sup>, the @ NOAA Satellite page depicted 31 GeoColor imagery (mostly loops), 4 Snow/Cloud Layer RGB, and 5 Fire Temperature RGB imagery.*

#### **Milestone 4: Work with Satellite Liaisons to coordinate NWS recommendations to NOAA/OSPO for operation transitions.**

**GeoColor and other DEAR-ABII products are making their way into operations! National Centers, Regional HQs, and WFOs are using our core products.**

- 1) **AWIPS RGB telecon, 5 December 2019:** (Lindsey, Foster, Gravelle, Molenaar, Line, Miller): **Chad Gravelle comment: reviewed GeoColor, noted its widespread usage...this is the future of RGB...very powerful visualization. Could transcend satellite and change the game.**
- 2) From: **Andy Just - NOAA Federal** <[andy.just@noaa.gov](mailto:andy.just@noaa.gov)>  
*Andrew Just, ForecastBuilder Manager, Techniques Development Meteorologist, NWS Central Region Headquarters SSD*

Date: Thu, Sep 26, 2019 at 9:50 AM

Subject: Re: GeoColor data outage

"Even though it's (*i.e.* *GeoColor*) not operational, in my opinion, it's far superior to any of the operational RGB products, at least for what I want to see. It would be great to see this become an operational product at some point. "

- 3) February 2019: **Western Region Headquarters implemented LDM data access** which disseminates GeoColor to individual WR NWS forecast offices. Instructions to ingest and display the product in AWIPS2 D2D were sent out as well.
- 4) **DoD Dugway Proving Ground Meteorology Division** in Dugway, UT requested access to GeoColor. LDM data access for that site was implemented in February. Instructions to ingest and display the product in AWIPS2 D2D were sent out as well.
- 5) NWS forecaster at **NWS Buffalo, NY** used SLIDER Snow/Cloud RGB for information about the ice cover on Lake Erie and Lake Ontario (called it 'breathtaking'). Also used for case studies and workshops. (**Figure M4-1**).
- 6) **Fire Temperature RGB was used during FIREX-AQ** (see under Milestone 1, under Core Product Fire Temperature RGB). **FIREX-AQ**, a large field program (summer 2019) joint between NOAA and NASA, involved many flights to various fire events to study smoke and air quality impacts in situ. It turns out that **the Fire Temperature RGB was one of the "go-to" products used by the forecasters.**
- 7) **GeoColor imagery was used extensively by forecasters for the CAMP2Ex Field Campaign** in summer 2019 (see under Milestone 1, under Core Product GeoColor).

**Milestone 5: Prepare/submit 1-2 publication(s) on selected DEAR-ABII products and illustrative use-cases based on Satellite Liaison and forecaster interactions.**

Miller, S. D., D. T. Lindsey, C. J. Seaman, and J. E. Solbrig, 2020: GeoColor: A Blending Technique for Satellite Imagery. *J. Atmos. Ocean. Tech.*, **37**(3), 429-448, <https://doi.org/10.1175/JTECH-D-19-0134.1>.

**Note:** This GeoColor publication is an important contribution of DEAR-ABII to the community, and will serve as a launching point for the NASA-ROSES A.33 proposal, where we will propose to explore higher-order versions of GeoColor with new information layers!

Grasso, L. D., D. E. Bikos, and S. D. Miller, 2018: Observations of lower tropospheric water vapor structures in GOES-16 ABI Imagery. *JGR-Atmospheres*, **123**(24), 13,625-13,642, doi: 10.1029/2018JD029220.

**Note:** This publication highlights the unexpected capability of the 1.38 micron cirrus band on ABI to detect low-level water vapor features in cases when upper atmosphere is dry coupled with high-altitude terrain, demonstrated in this case over parts of Mexico.

### **Other Items: Presentations**

- **10<sup>th</sup> AOMSUC, held from 2-7 December 2019, in Melbourne, Australia:**
  - Curtis Seaman: *SLIDER*: A website for viewing global, full-resolution satellite imagery in real-time.”
- Steve Miller: GOES-R ABI Research and Applications Development: Lessons Learned from Himawari-8 AHI and Practical Benefits to the Weather Forecasting Community. **Seminar at the Korean Meteorological Administration**, Seoul, South Korea, 15 November 2019.
- **2019 Joint AMS EUMETSAT Satellite Conference, 28 September - 04 October, Boston:**
  - Steve Miller: *Geocolor*—Taking Value-Added Satellite Imagery to the Next Level in the GOES-R Era.
  - Curtis Seaman: Polar Slider: A Website for the Display of Global Polar-Orbiting Satellite Data in Near Realtime
  - Ed Szoke: Some Lessons Learned from the CIRA GOES-R Proving Ground Effort.
  - Natalie Tourville: CIRA Specialized Satellite Data Products and Visualization Tools for GOES, JPSS and Himawari.
- **Stephen Volz visit to CIRA on 20 August 2019:**  
Steve Miller and Met Sat Team presentation: CIRA-RAMMB Satellite Research

### **Other Items: GeoColor in the Media**

**GOES-16 and GOES-17 GeoColor Imagery continues to be used extensively by the media and science community like, and is the undisputed “flagship product” of the GOES-R Program.**

Media sources (which we know about) which used GeoColor for their postings (during July 2019 – December 2019):

CNN, NPR, Washington Post, Miami Herald, Boston Globe, The Guardian, TIME Magazine, German ARD TV, news.com Australia, The Watchers, Florida Times-Union  
ACCU Weather, Weather Nation.

#### **IV. Relevant Journal Publications**

**Just published:**

**Miller, S. D.**, D. T. Lindsey, C. J. Seaman, and J. E. Solbrig, 2020: GeoColor: A Blending Technique for Satellite Imagery. *J. Atmos. Ocean. Tech.*, **37**(3), 429-448, <https://doi.org/10.1175/JTECH-D-19-0134.1>.

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.*, **36**(3), 427-442, <https://doi.org/10.1175/JTECH-D-18-0060.1>.

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.

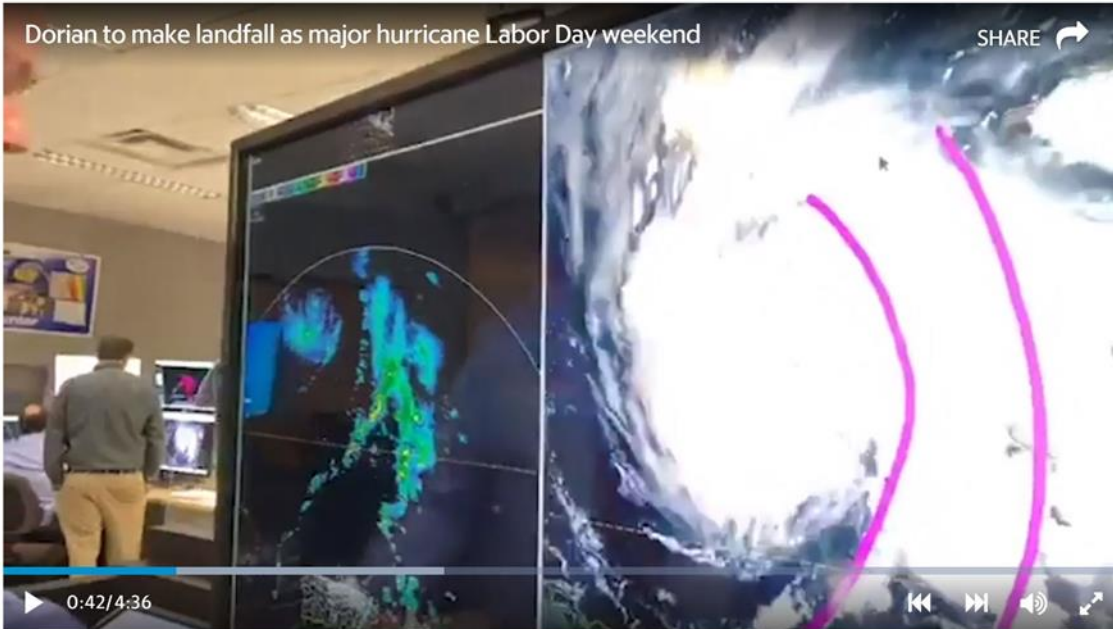
**NOTE:** *BAMS* Cover Article

***Key Graphics***

# Hurricane Dorian is now predicted to hit Florida as a Category 4. But where?

BY ALEX HARRIS AND MICHELLE MARCHANTE

AUGUST 29, 2019 07:05 AM, UPDATED 6 MINUTES AGO

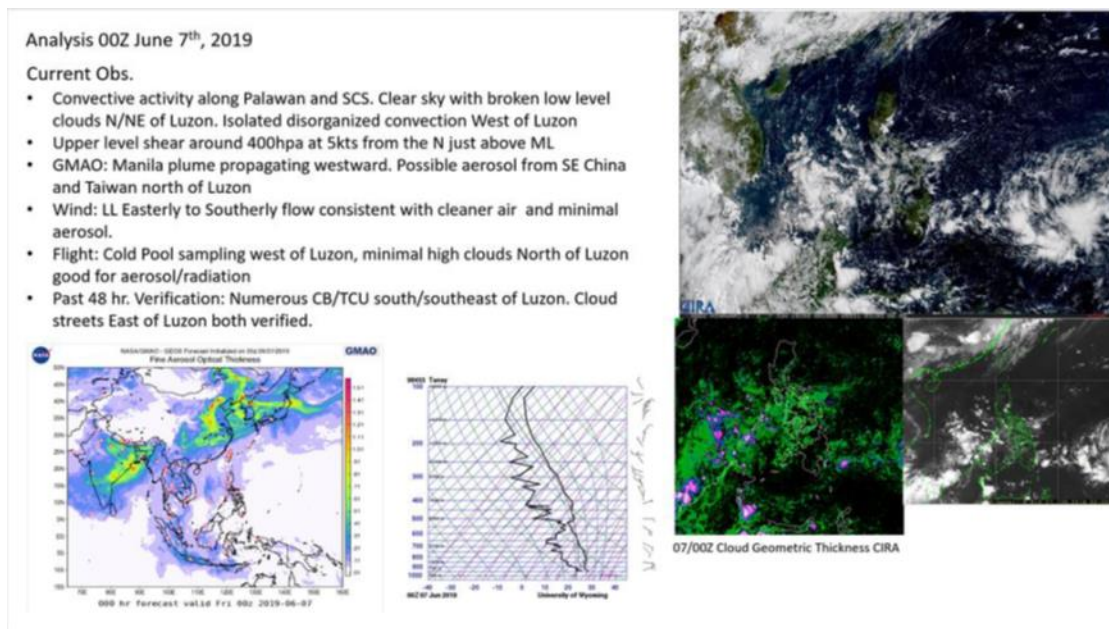


Hurricane Dorian could make landfall between Florida and Georgia Labor Day weekend. Heavy rain is expected in the Bahamas, Florida, and other parts of the United States this week. BY META VIERS

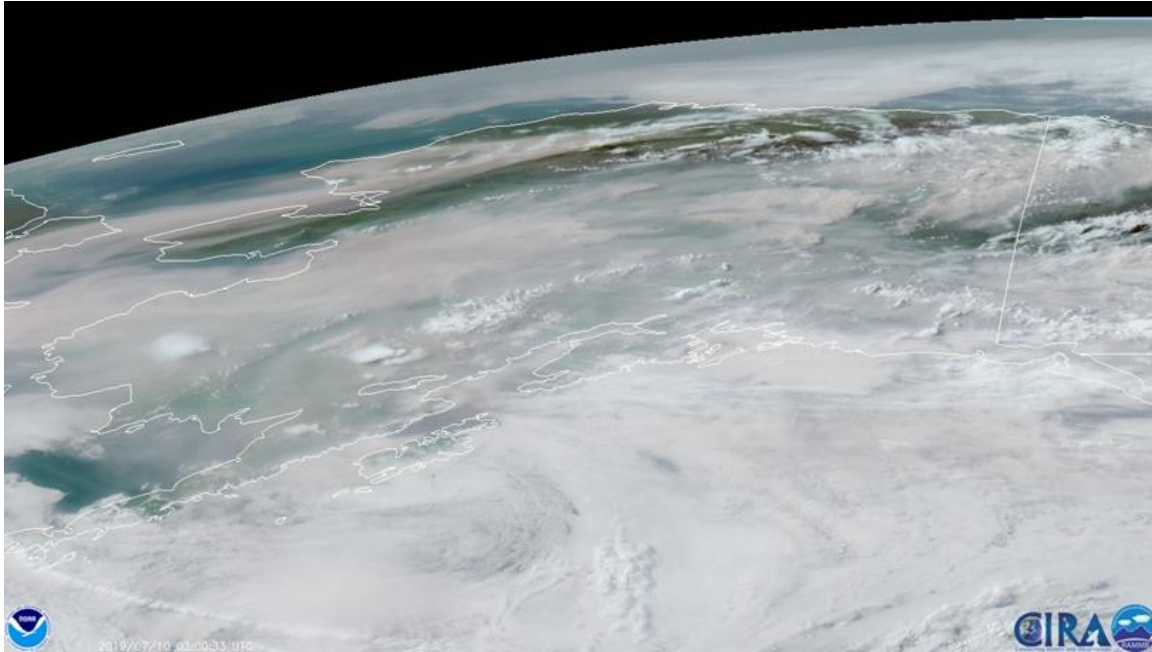
**Figure M1-1:** *Figure: NHC Director Ken Graham using GeoColor imagery (nose and eyebrows, at upper left....) explains to the Media how far out Hurricane Dorian's rain bands are currently reaching (on 29 August 2019).*



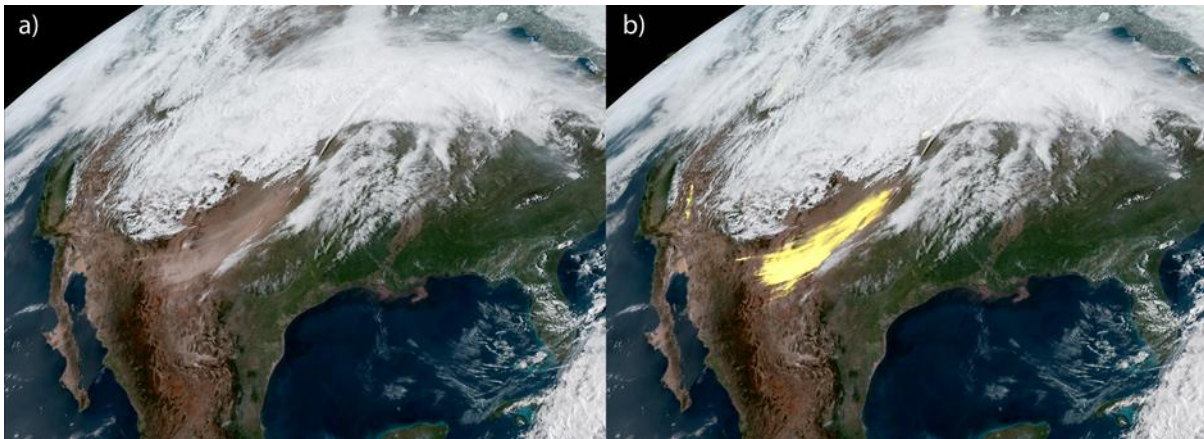
**Figure MI-2:** Stephen Volz, presenting TC Dorian GOES-16 GeoColor imagery loop (Session I, Talk 1.4).



**Figure MI-3:** Typical slide with GeoColor imagery used for the 2019 CAMP2Ex and 2019 PISTON ship cruise operations during summer 2019.



**Figure MI-4:** CIRA GOES-17 GeoColor product shows the thick smoke that covered much of Alaska due to recent fire activity (0300 UTC, 10 July 2019).



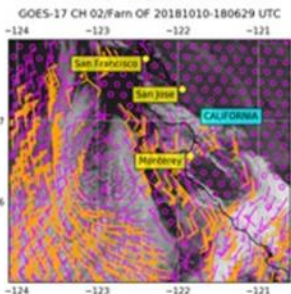
**Figure MI-5:** GeoColor with Dust Signature “**Signal Imprinting**” taken from:  
Miller, S. D., D. T. Lindsey, C. J. Seaman, and J. E. Solbrig, 2020: GeoColor: A Blending  
Technique for Satellite Imagery. *J. Atmos. Ocean. Tech.*, **37**(3), 429-448,  
<https://doi.org/10.1175/JTECH-D-19-0134.1>.

# Optical Flow for Improved Atmospheric Motion Vectors



The HAALE-MURI team is refining, developing, and evaluating new optical flow techniques to capture dense vector fields for a variety of meteorological flows and features:

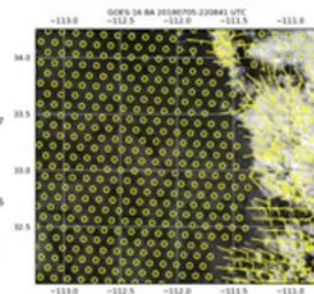
## Boundary Layer Clouds



Provides dense motion field vs. traditional differential motion vector techniques.

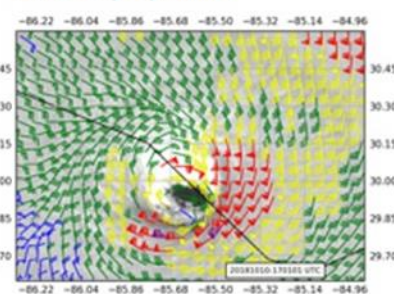
POCs: Jason Apke and Steven Miller (CSU/CIRA)

## Outflow Boundaries



Enables tracking of convective outflow boundaries when arcus clouds or dust front is present.

## Storm-Top Dynamics



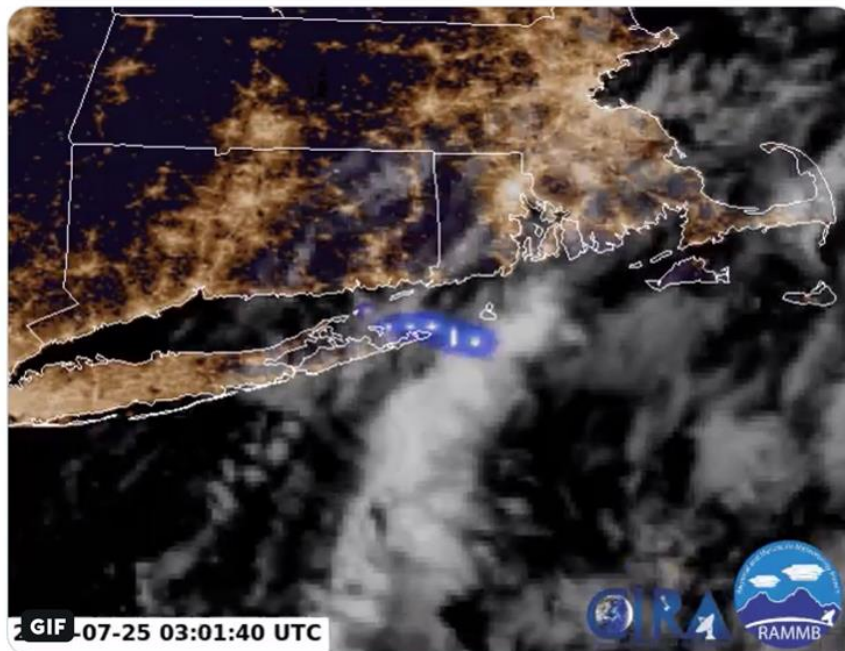
Exploring information content of storm top dense motion vectors in terms of divergence and vorticity fields.

Figure M1-6: Optical Flow for improved Atmospheric Motion Vectors.



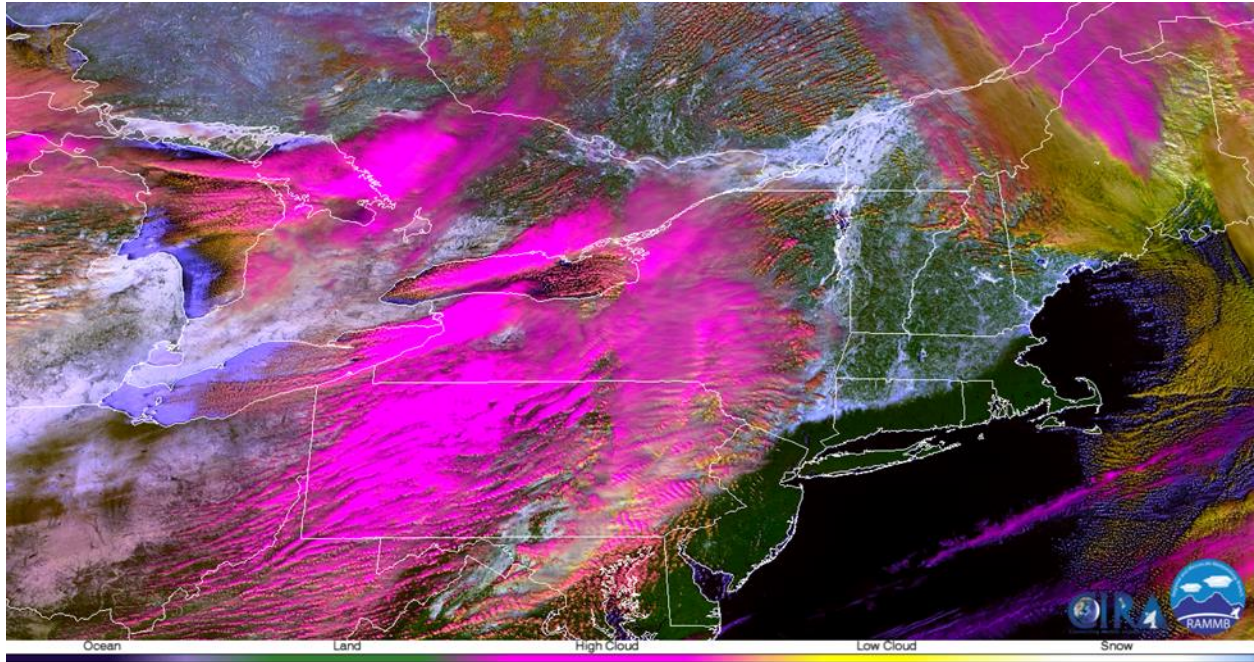
NOAA Satellites @NOAASatellites · Jul 25

From 22,300 miles in space, #GOESEast's Geostationary Lightning Mapper saw the #meteor that lit up the sky just east of Long Island Wednesday night. @amsmeteors received more than 200 reports about the #fireball. More imagery: [go.usa.gov/xyAgb](http://go.usa.gov/xyAgb)



1 52 100

Figure M2-1: @NOAA Satellite tweets a GeoColor nighttime image with GLM lightning overlay (25 July 2019).



*Figure M4-1: GOES-16 imagery from CIRA's Snow/Cloud-Layers in SLIDER showing a severe winter storm over western New York from 30 January, 2019.*