VIIRS Imagery: Transitioning Novel Ideas into Operations

Curtis Seaman[1], Steven Miller[1] and Jorel Torres[1]

Carl Dierking[2], Jay Cable[2] and Eric Stevens[2]

Kathy Strabala[3] and the CSPP Development Team[3]

Don Hillger[4]

Anita Leroy[5], Emily Berndt[5] and Kevin Fuell[5]

4th Annual STAR JPSS Science Team Meeting, College Park, MD

14-18 August 2017

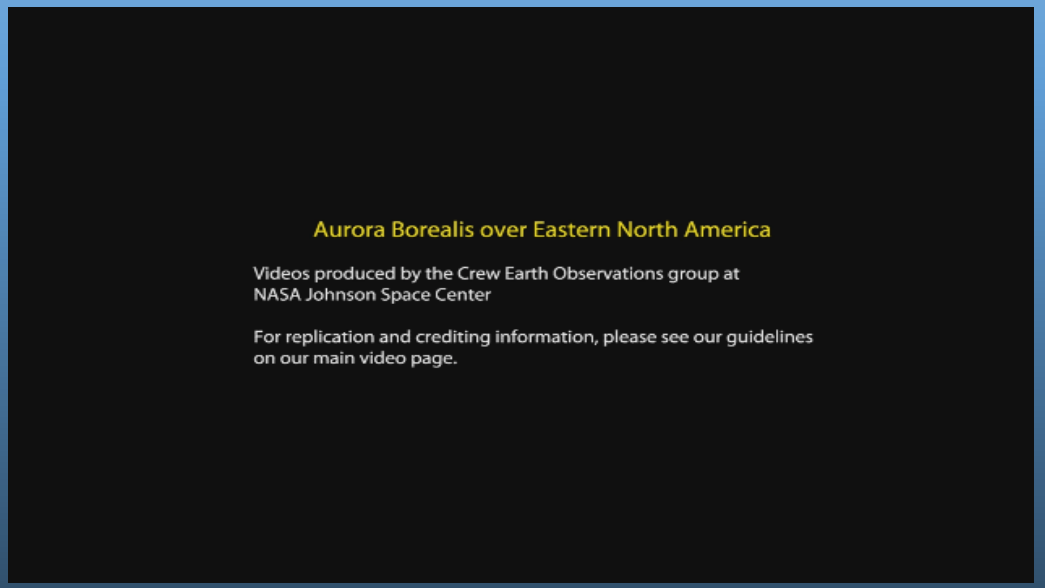
Outline

- Making the most out of the Day/Night Band
- VIIRS imagery for fire weather monitoring
- The Snow/Cloud Discriminator
- Summary

Making the Most of the Day/Night Band

Wielding the Power

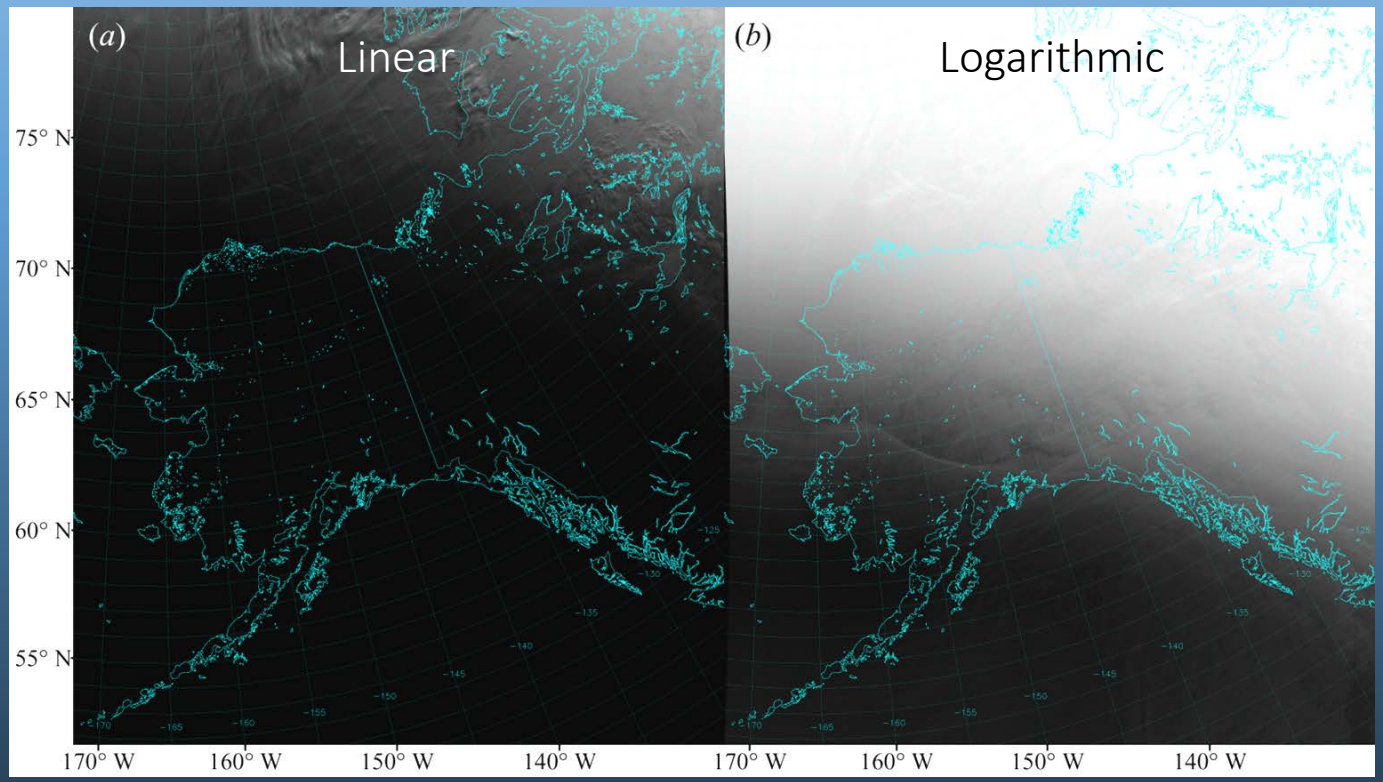
Credit: Robert Simmon (NASA)



- The Day/Night Band is sensitive to radiation over a range of intensity spanning 8-orders of magnitude from sunlight to new moon (airglow)
- This presents a particular challenge for Imagery

Global Nighttime Lights of the World (Chris Elvidge; NOAA/NGDC), Baugh et al. (2013)

Displaying 8 orders of magnitude in 256 colors

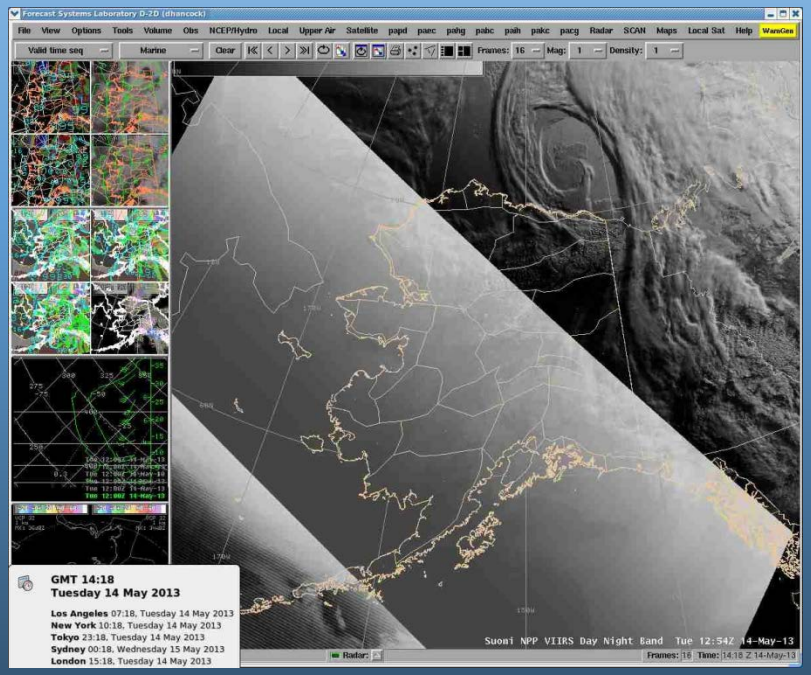


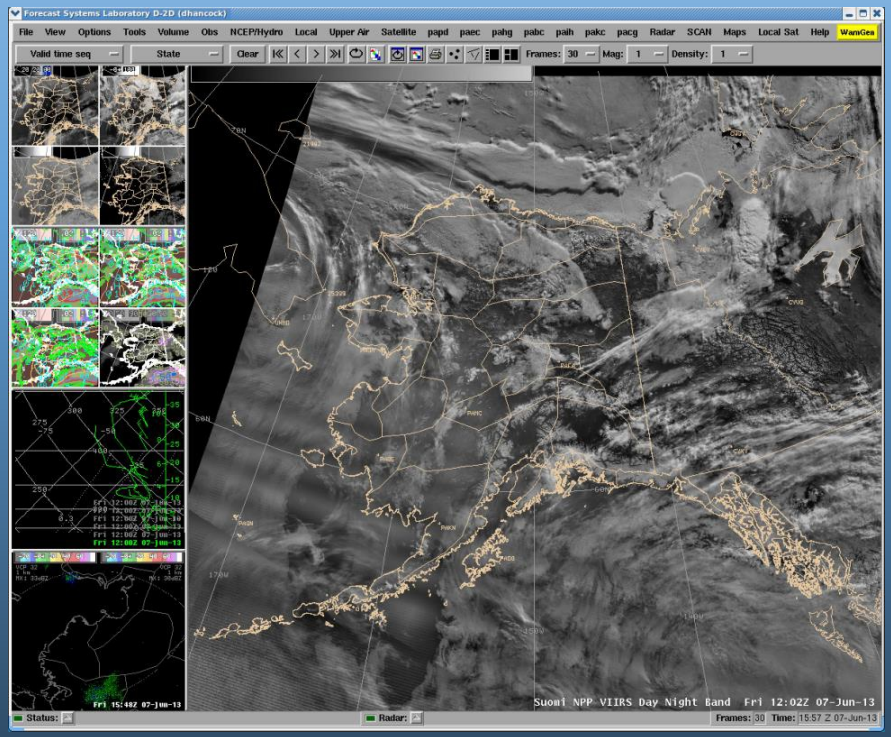
1 May 2013

- DNB radiance values vary between ~10^{-2} and ~10^{-10} W cm^{-2} sr^{-1}
- Simple scaling methods fail to capture the full range of the data
- What is the best way to capture the full range in 256 colors?

Old Scaling for Alaska Region WFOs

Image Credits: Eric Stevens, Alaska Region Satellite Liaison



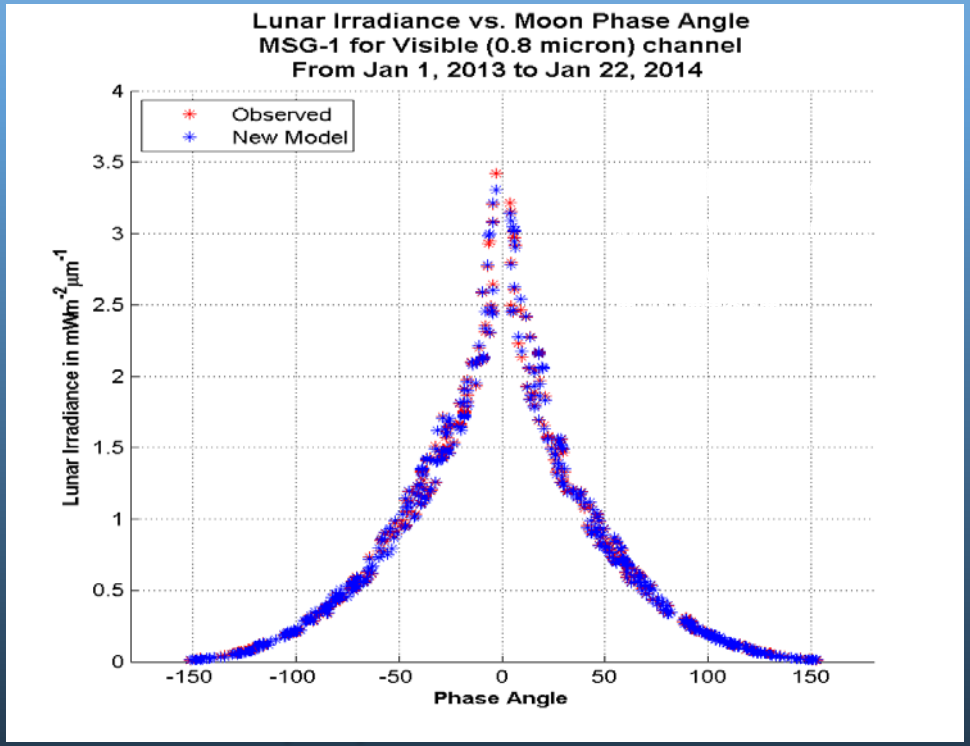


Forecasters in the Alaska Region have been using imagery in AWIPS that have been provided to them with a variety of scaling algorithms

These algorithms have artifacts near the terminator

Remember: the terminator is always present in Alaska for “daytime” overpasses in Winter, “nighttime” overpasses in Summer

Lunar Irradiance Modeling



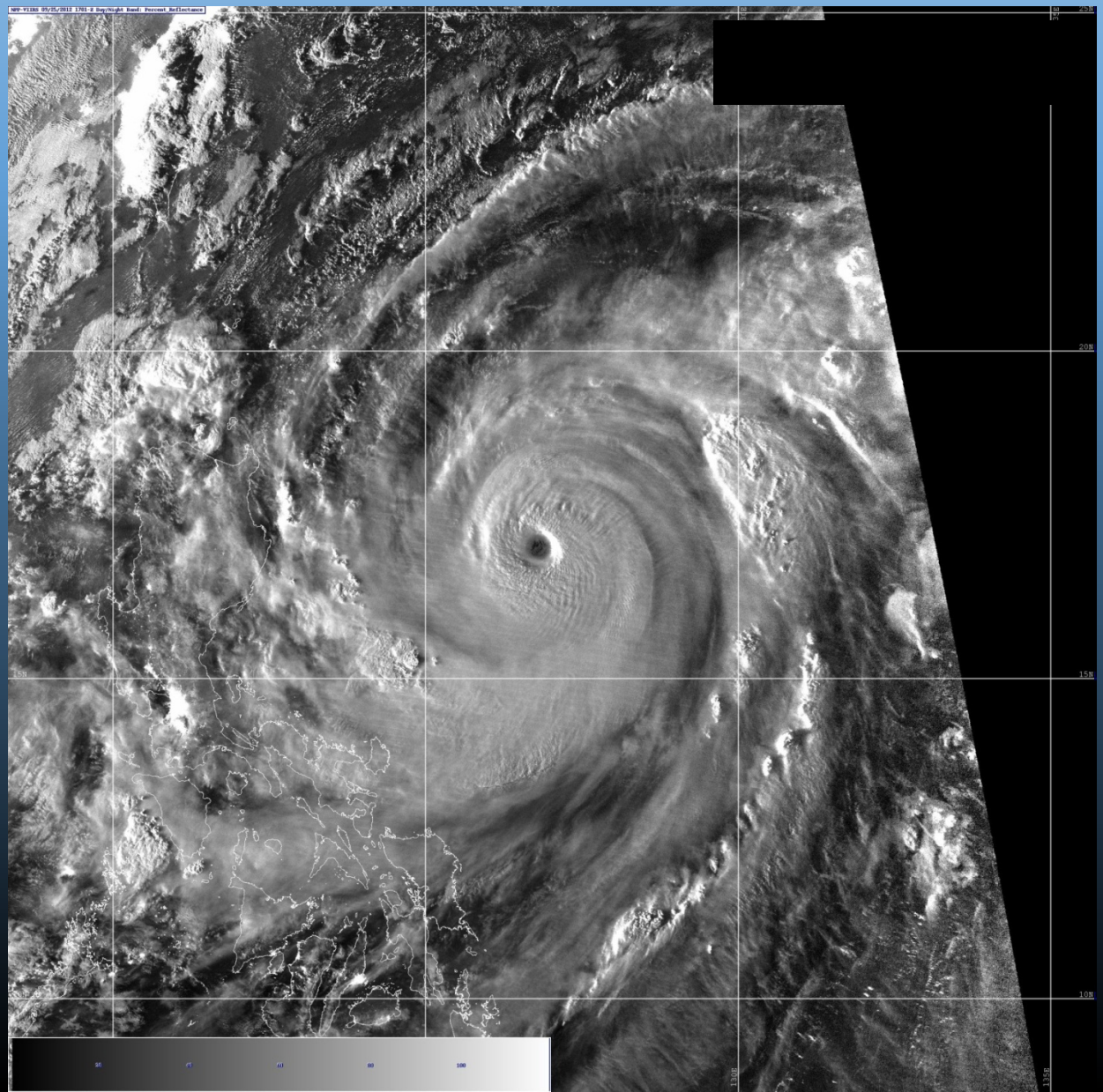
Enables Calculation of Lunar Reflectance:

$$R_m = \pi I_m / (\mu_m F_m)$$

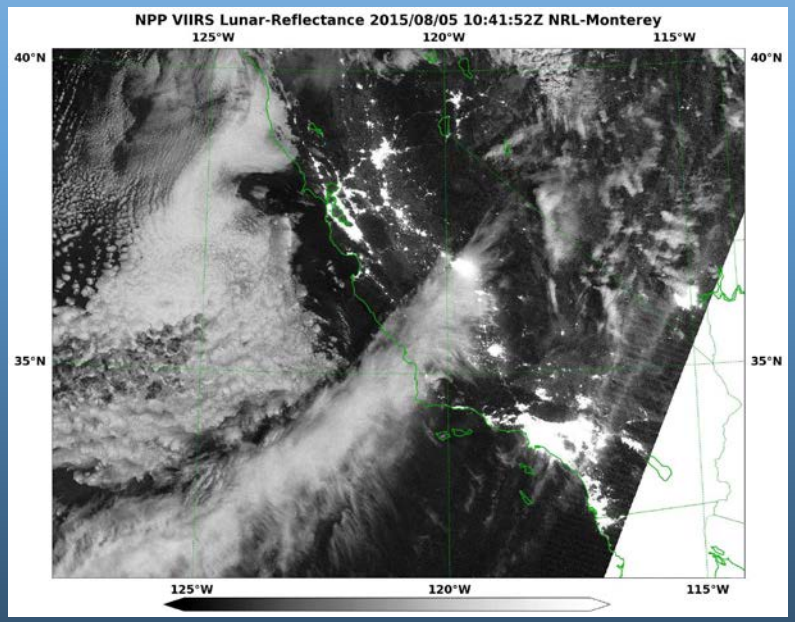
- → *Reduces 8 orders of magnitude range in radiance to <1 order of magnitude range in reflectance*
- → *Opens the door to possible quantitative applications involving the calibrated DNB observations of moonlight*

From Irradiance to Reflectance

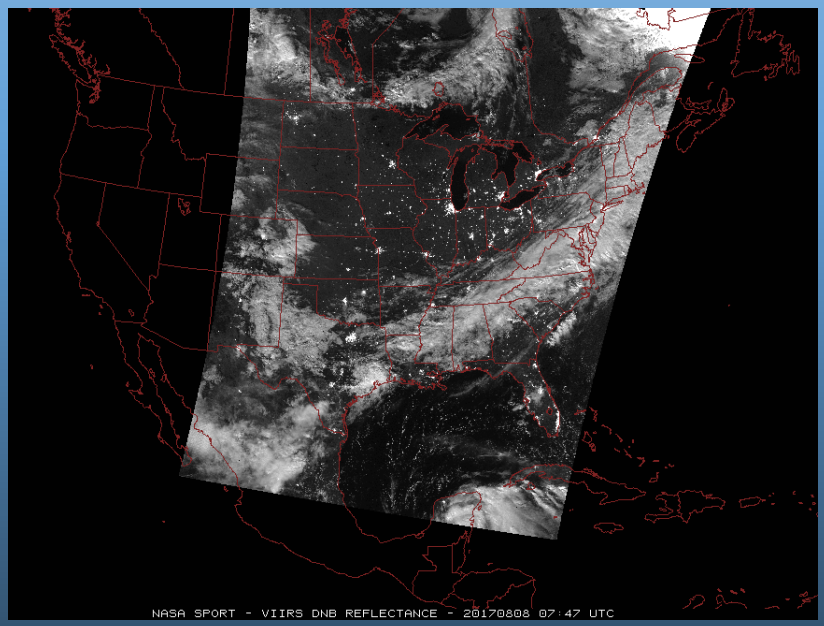
Typhoon Jelawat: 9/25/2012 ~1700Z



Lunar Reflectance in Operations



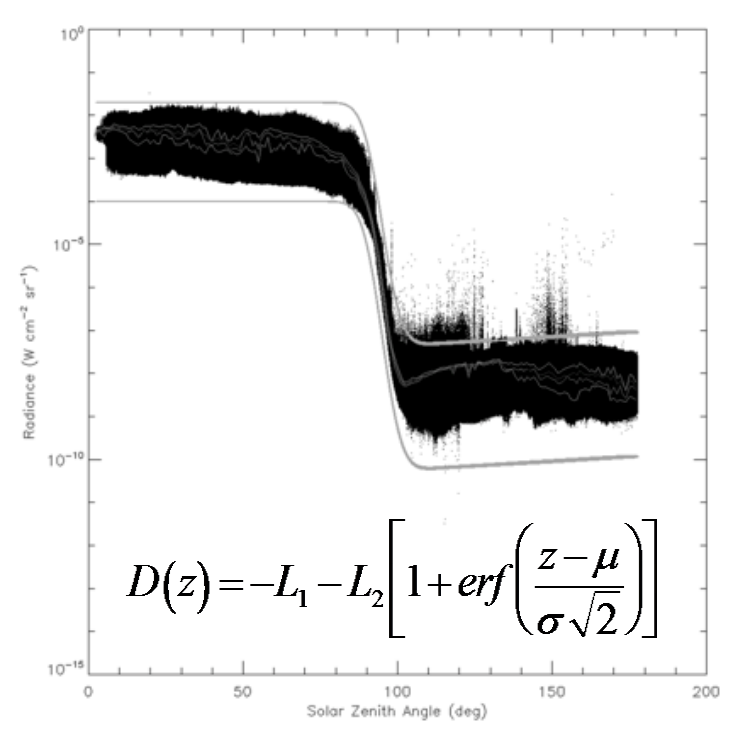
http://www.nrlmry.navy.mil/NEXSAT.html



https://weather.msfc.nasa.gov/sport/

- *Used by NRL and distributed to users via FNMOC*
- *NASA SPoRT provides Lunar Reflectance to NWS WFOs that request it through AWIPS LDM*

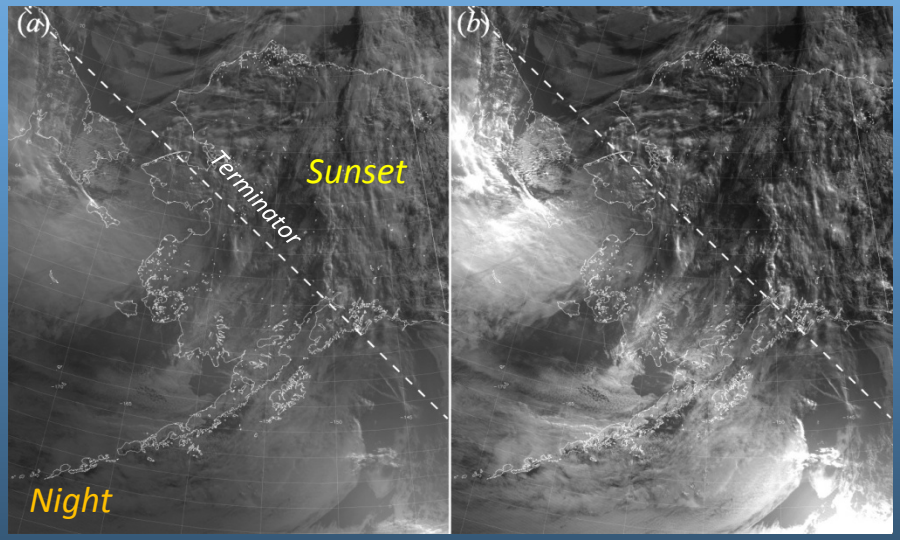
ERF-Dynamic Scaling



Seaman and Miller (2015) describe a non-linear log scaling based on the structure of the 'error function' (*erf*).

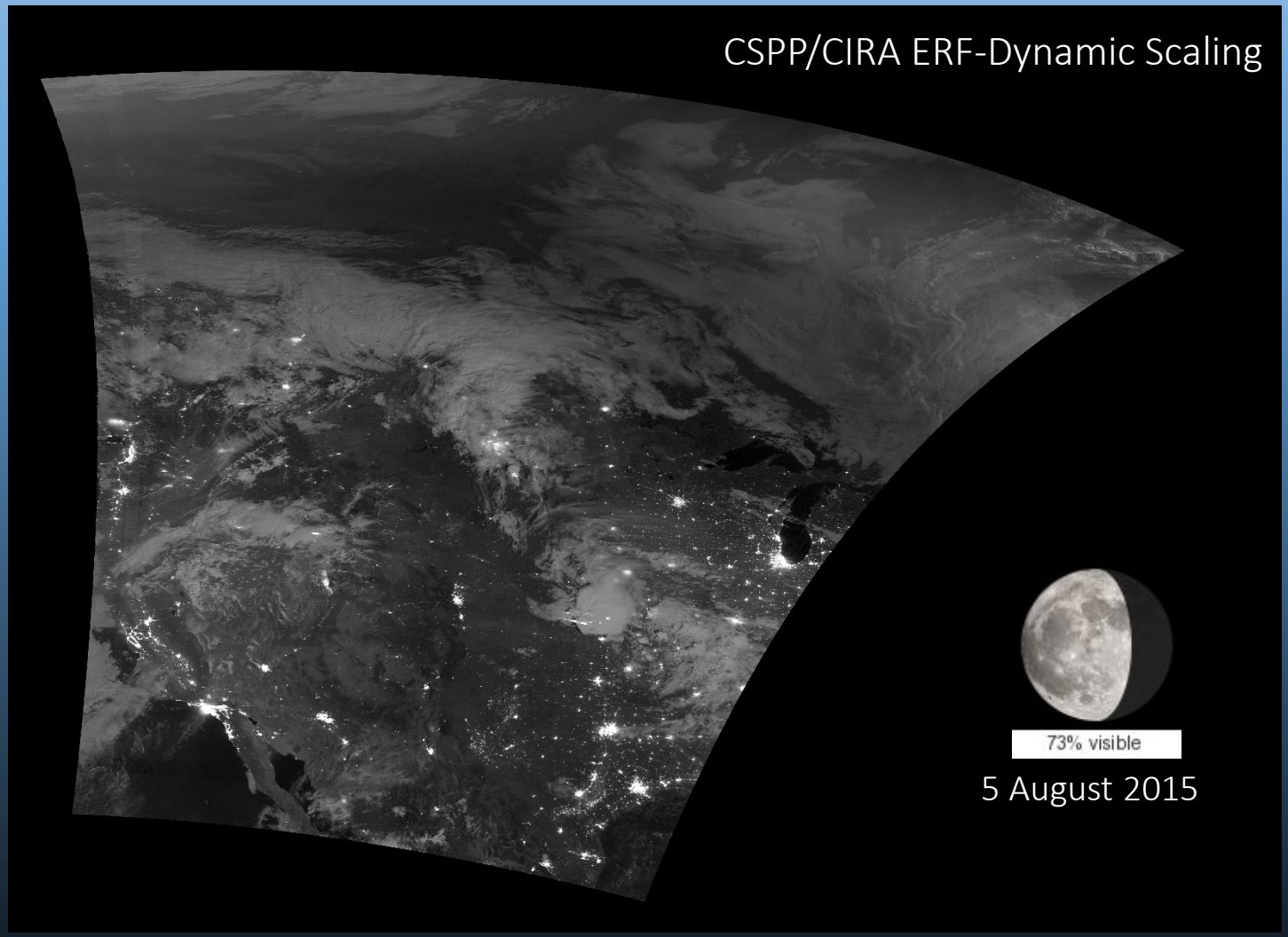
ERF Scaling

NCC Product



Strength: produces imagery with nearly constant contrast across the day/night terminator. (ERF-Dynamic Scaling is as good as, or better, than NCC in these cases.)

CSPP Polar2Grid



CSPP: Community Satellite Processing Package

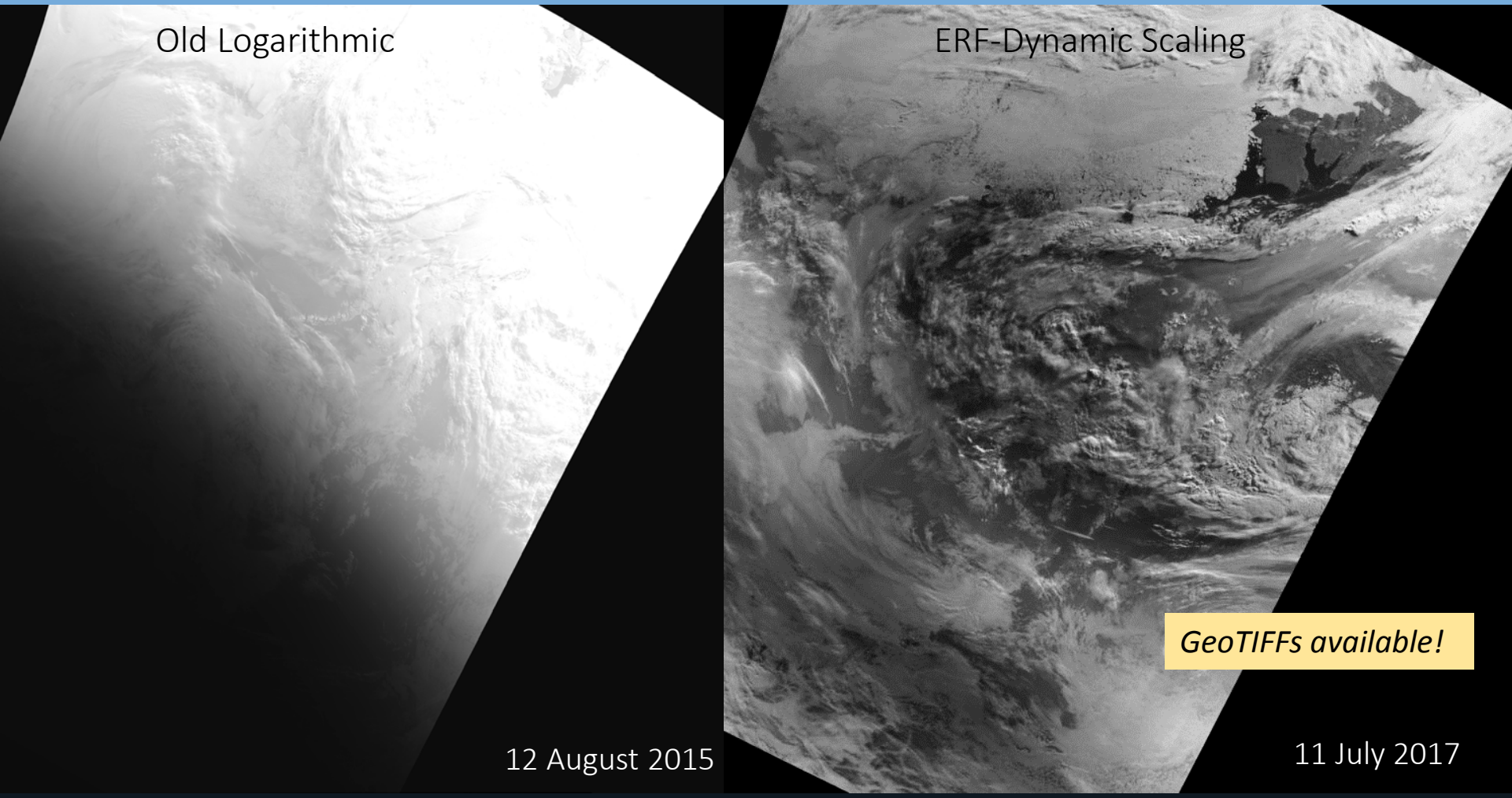
http://cimss.ssec.wisc.edu/cspp/

ERF Scaling for Alaska Region WFOs

Just talking informally with a couple of the forecasters there earlier this week, I get the impression they are very happy with this scaling approach.

Eric Stevens (GINA)

ERF-Dynamic Scaling now on Puffin Feeder



http://feeder.gina.alaska.edu/

Near Constant Contrast in AWIPS

The Near Constant Contrast (NCC) EDR has been delivered to AWIPS through the SBN since December 2015.

We have developed training on NCC (Thanks, Jorel!) and look forward to implementing our Auto Contrast algorithm to optimize the display of the NCC.

VIIRS Near Constant Contrast
Quick Guide For Imagery Enhancement in AWIPS 2

The NPP polar-orbiting satellite passes twice per day, once around 1:30 pm and again around 1:30 am local time. Its VIIRS instrument has a Day/Night Band (DNB) that is very sensitive to low levels of light and provides unique visible imagery at night. The DNB can detect a broad range of light intensities, ranging from full sunlight in the day down to faint atmospheric glow on moonless nights (the focus here will be on the nighttime imagery). This 8-order of magnitude range in radiance space is difficult to display as an image without losing detail at either end of the radiance scale, so a product called **Near Constant Contrast (NCC)** was developed in order to mitigate enhancement issues by using a model of the sun and moon to convert the DNB radiance values into a reflectance-like value. Doing so reduces the dynamic range from 8 orders of magnitude down to 3, which is much easier to display in AWIPS and other software. **But, beware! The NCC *does not* provide a true reflectance value like other visible imagery or the DNB Lunar Reflectance product!**

NCC "pseudo-albedo" values vary throughout the lunar cycle. The DNB instrument is sensitive to reflected light from the sun and moon as well as many other sources of emitted light – cities, the aurora, gas flares and fires, lightning, nightglow and even boats! These sources may be 2-3 orders of magnitude brighter than the moon, particularly when the moon is below the horizon when VIIRS is passing overhead. As a result, NCC pseudo-albedo values can vary from -10 to 1000. Most meteorological features of interest have pseudo-albedo values between 0 and 1.5. Side illumination of clouds near the terminator may result in NCC values of 2 or more, like the bright areas in the example at right.

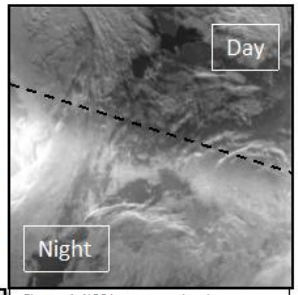
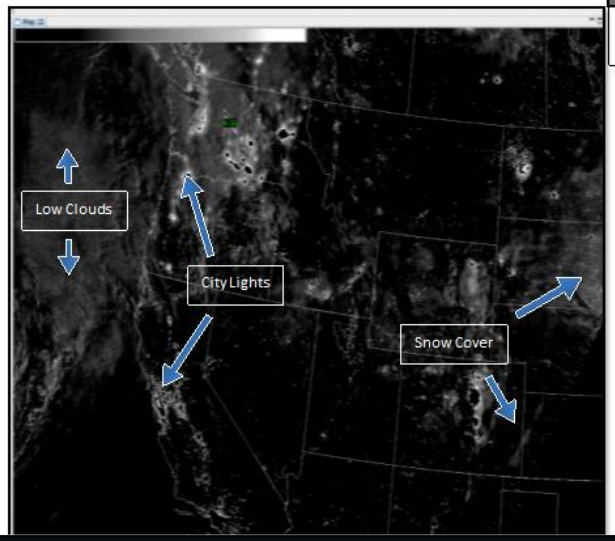
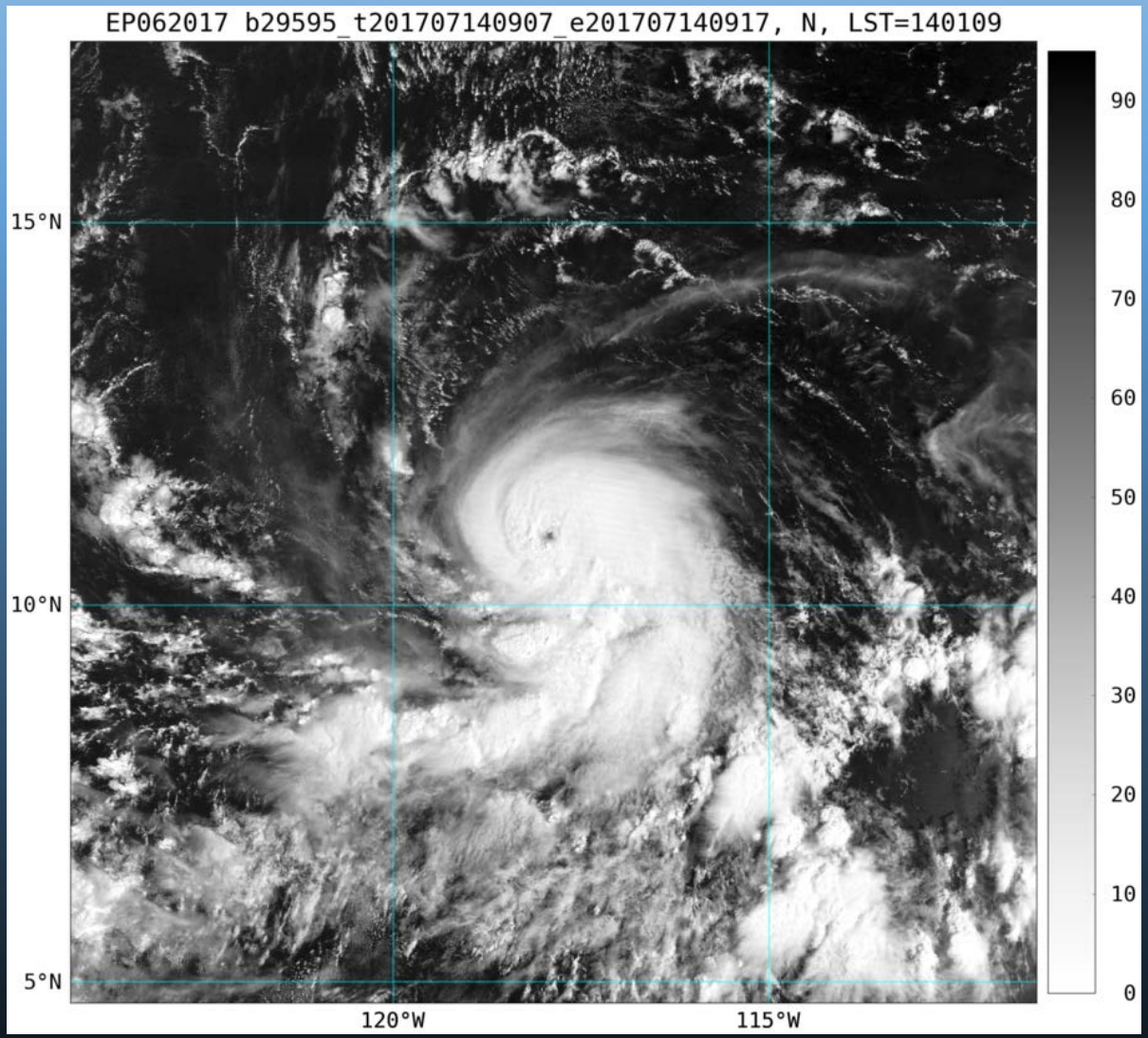


Figure. 1. NCC image spanning the terminator. Clouds are clearly seen on both day and night sides.



AWIPS 2 scales NCC values from 0 to 1.6 by default. Many clouds are moderately bright while areas where there should be bright city lights are black. These "black" lights have values > 1.6 and are a result of the default color table, as seen in Figure 2. Using the color table editor, change the Colormap size to the maximum 2048 colors. Stretch the values between 0 and 1 by making the top arrow point to the minimum value (0.0), then set the red, green, and blue bars to 0 (black). Set the bottom arrow to a value of 1, and the red, green, and blue values to 255 (white). Click 'Interpolate.' Finally

Optimizing DNB for NHC/CPHC/JTWC



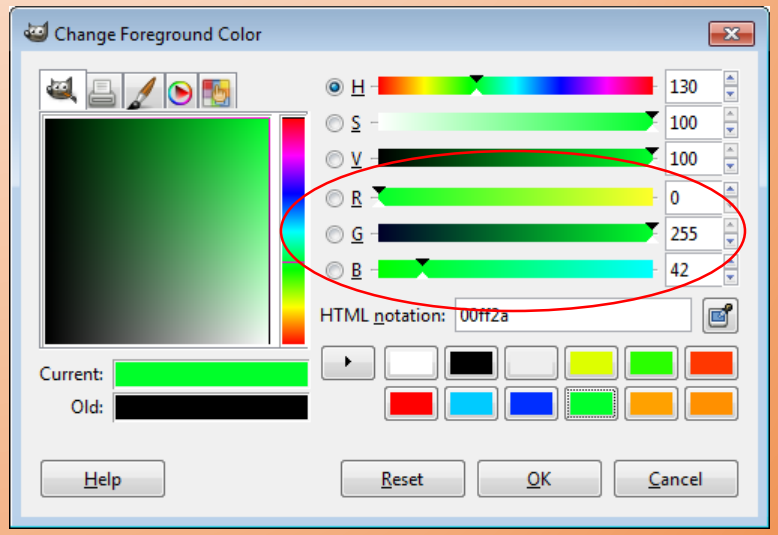
Stay tuned for Galina Chirokova's talk…

VIIRS Imagery for Fire Weather Monitoring

Introduction to RGB Composites

- Every color on a computer monitor may be expressed as 1-byte (8-bit) values of red, green and blue (0-255)

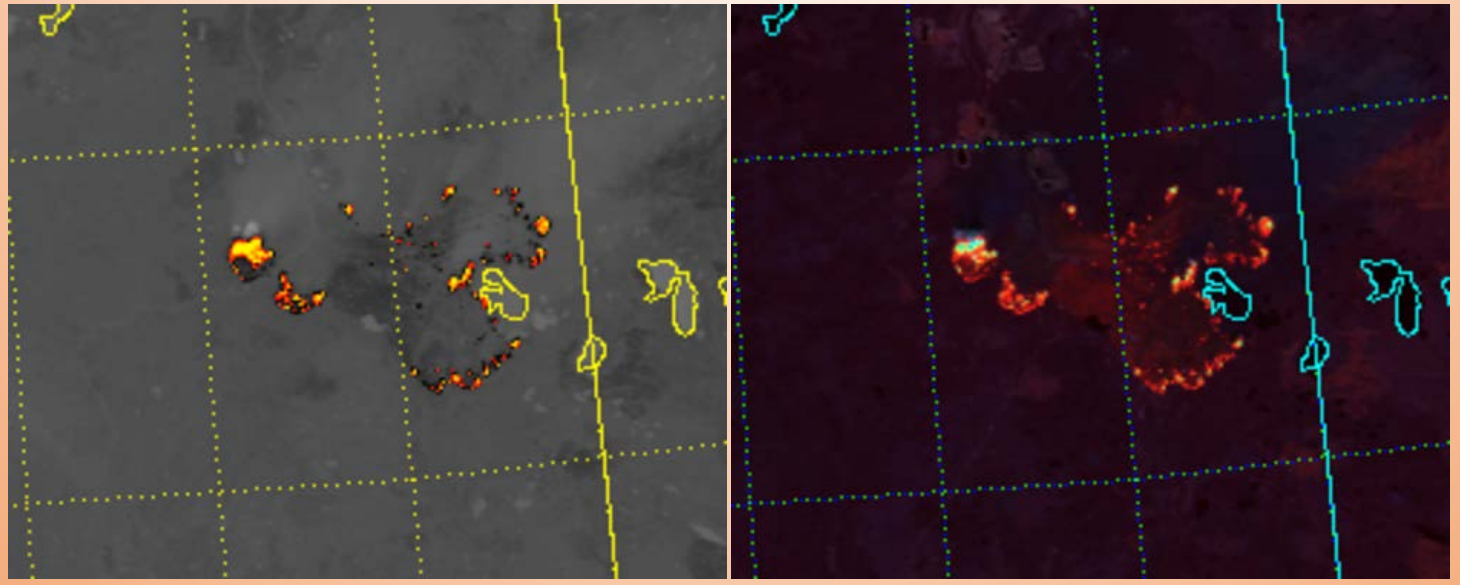
- RGB composites take three different values (raw channels, channel differences, Rayleigh corrected values, etc.), scale them from 0-255 and assign them to red, green or blue



- In this way, three different images are combined to produce one color image

Fire Temperature RGB

M-13 (3.9 μm) "Fire Temperature" RGB

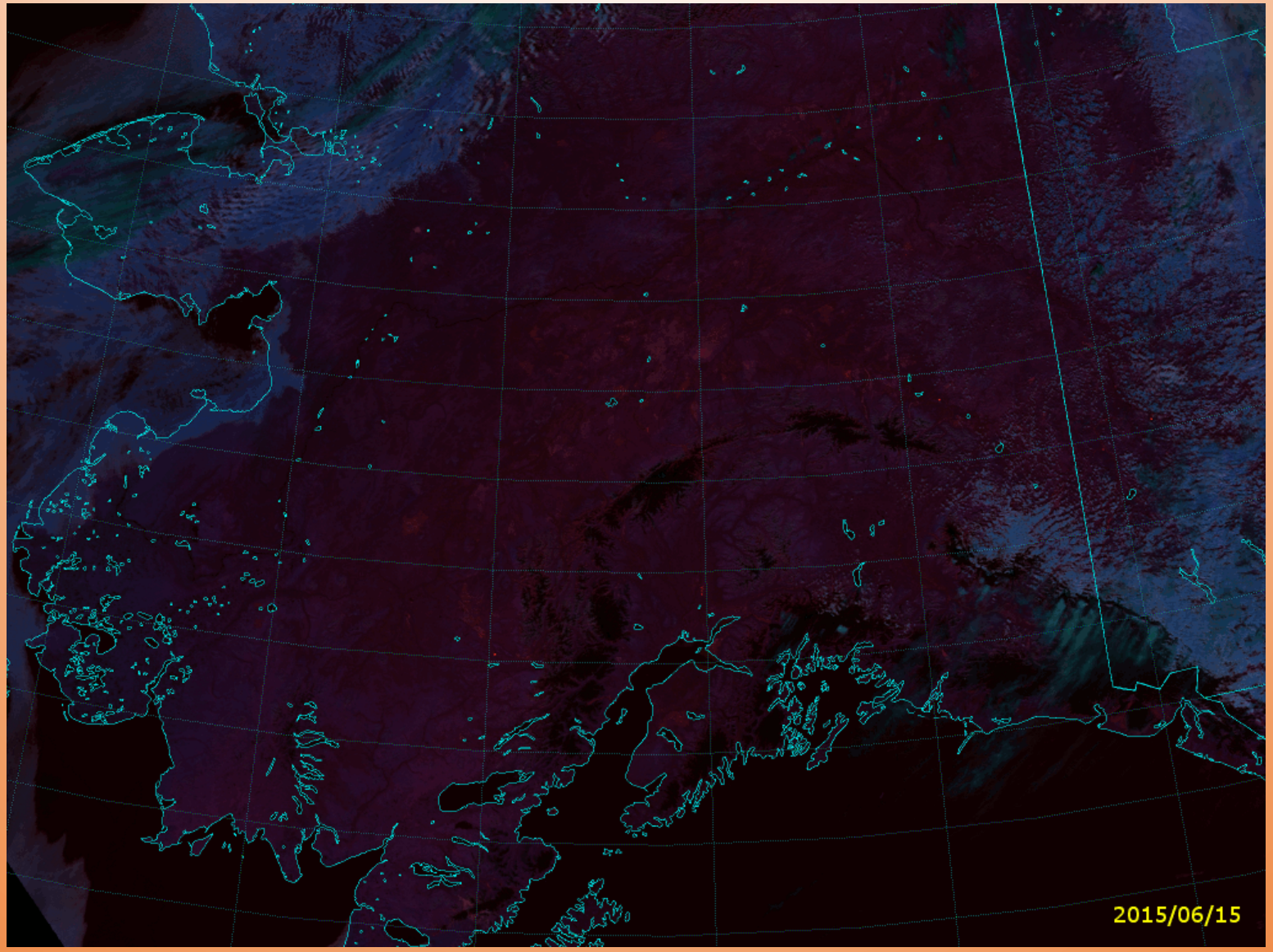


Fort McMurray Fire 19:42 UTC 16 May 2016

- CIRA's "Fire Temperature" RGB uses M-10/1.61 μm, M-11/2.25 μm and M-12/3.7 μm
- Smaller/cooler fires only show up at 3.7 μm and appear red
- Moderate fires show up at 3.7 μm and 2.25 μm and appear orange/yellow
- Intense fires show up in all three bands and appear white (or cyan if saturation/fold-over occur in M-12)
- Sees through smoke and makes fires look like fires!

CIRA Connecting Models and Observations

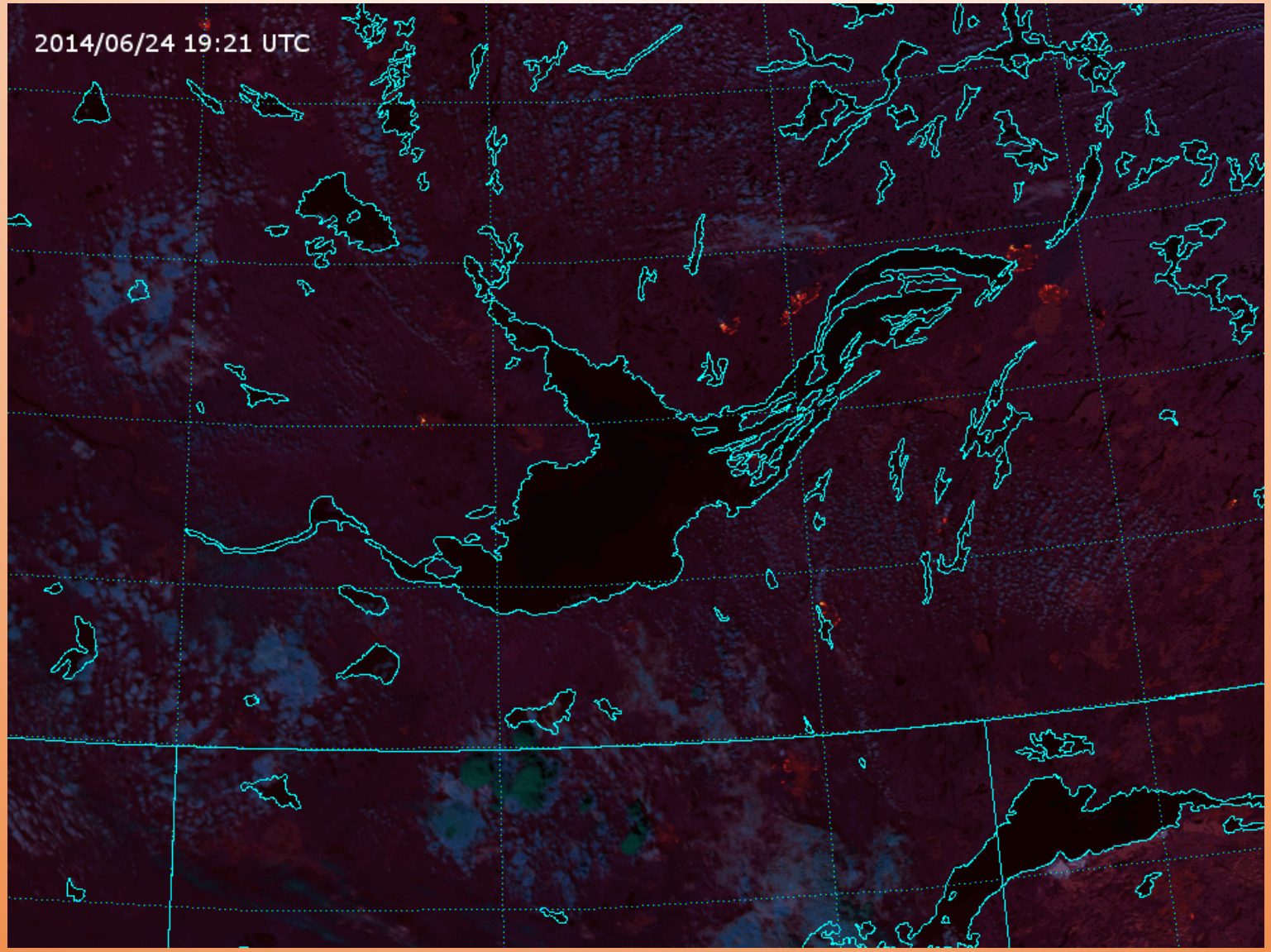
An “active” fire season



Animation (15-25 June 2015)

CIRA
Connecting Models and Observations

Northwest Territories (2014)



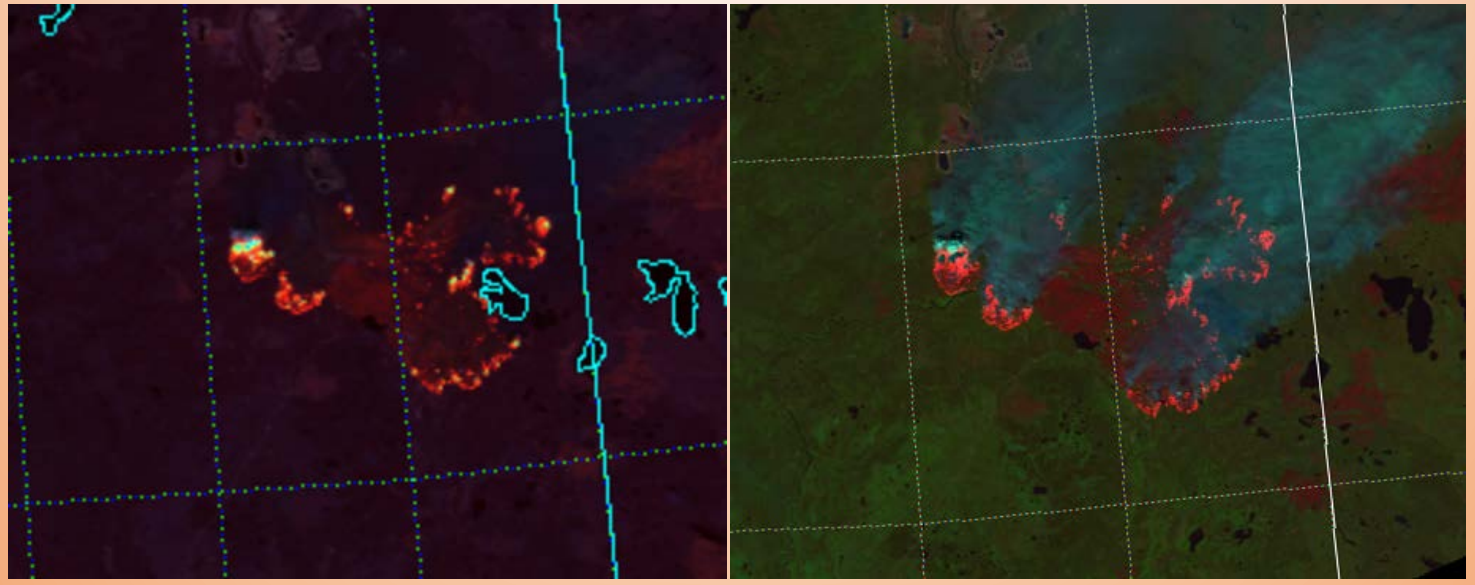
Animation (June/July 2014)

CIRA
Connecting Models and Observations

Natural Fire Color RGB

"Fire Temperature" RGB

"Natural Fire Color" RGB

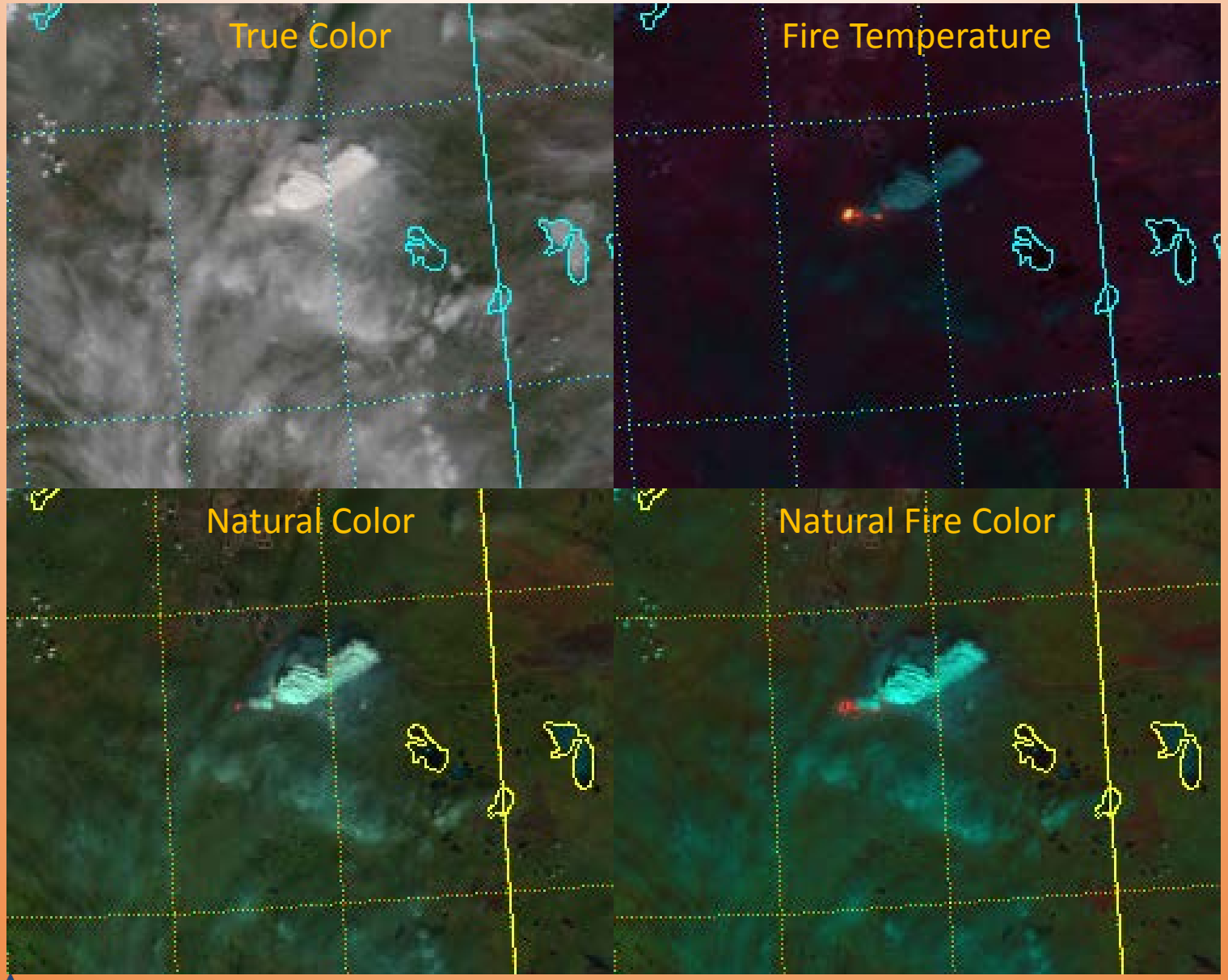


Fort McMurray Fire 19:42 UTC 16 May 2016

- CIRA's "Natural Fire Color" RGB uses I-1/0.64 µm, I-2/0.86 µm and I-4/3.7 µm (375 m resolution!)
- Looks similar to the "Natural Color" RGB, except fires show up as bright red pixels (unless saturation/fold-over occurs in I-4)
- More sensitive to smoke than Fire Temperature RGB; smoke appears blue/cyan
  - Not good for people who are red-green colorblind!

CIRA
Connecting Models and Observations

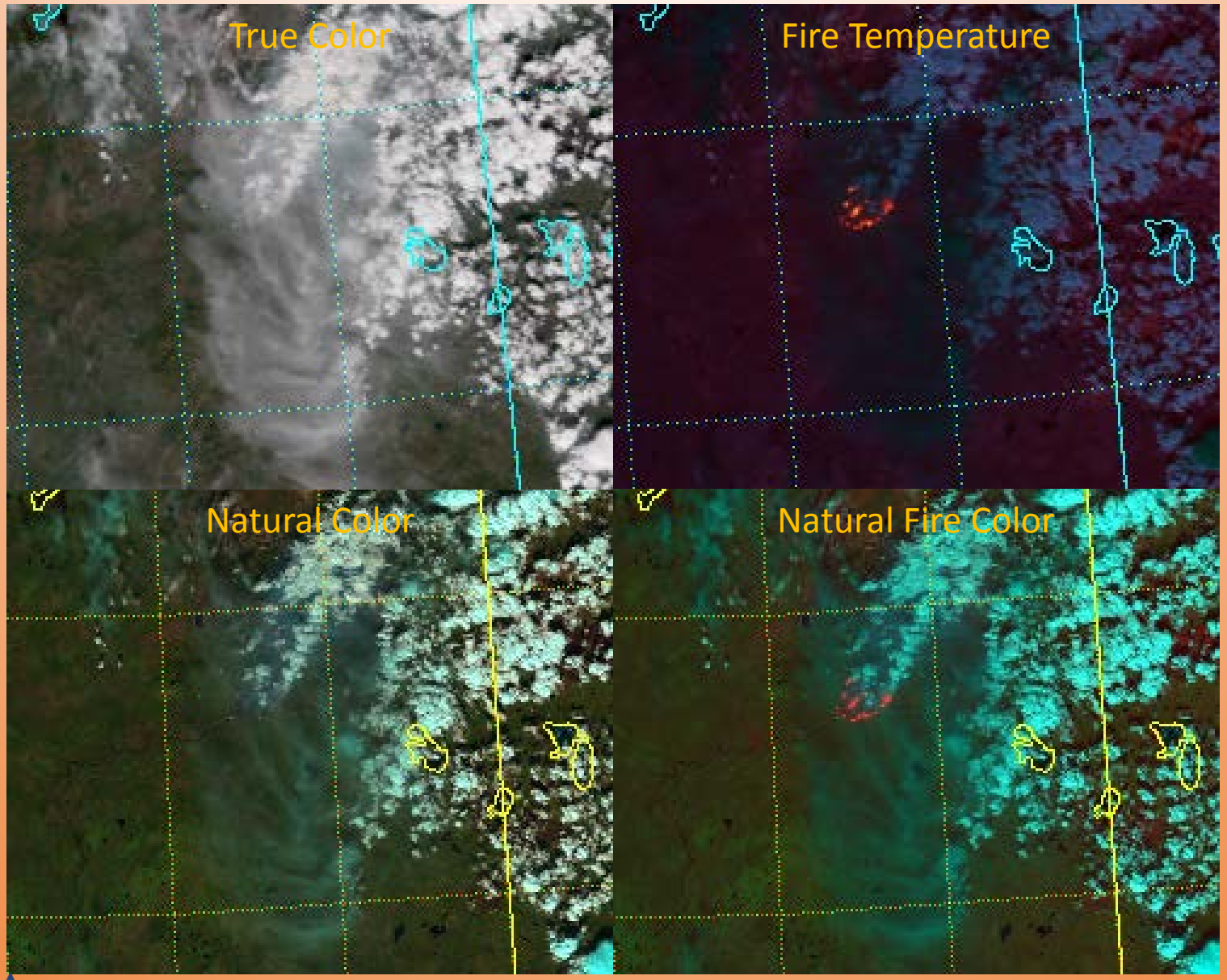
Fort McMurray Fire (2016)



20:25 UTC 3 May 2016

CIRA
Connecting Models and Observations

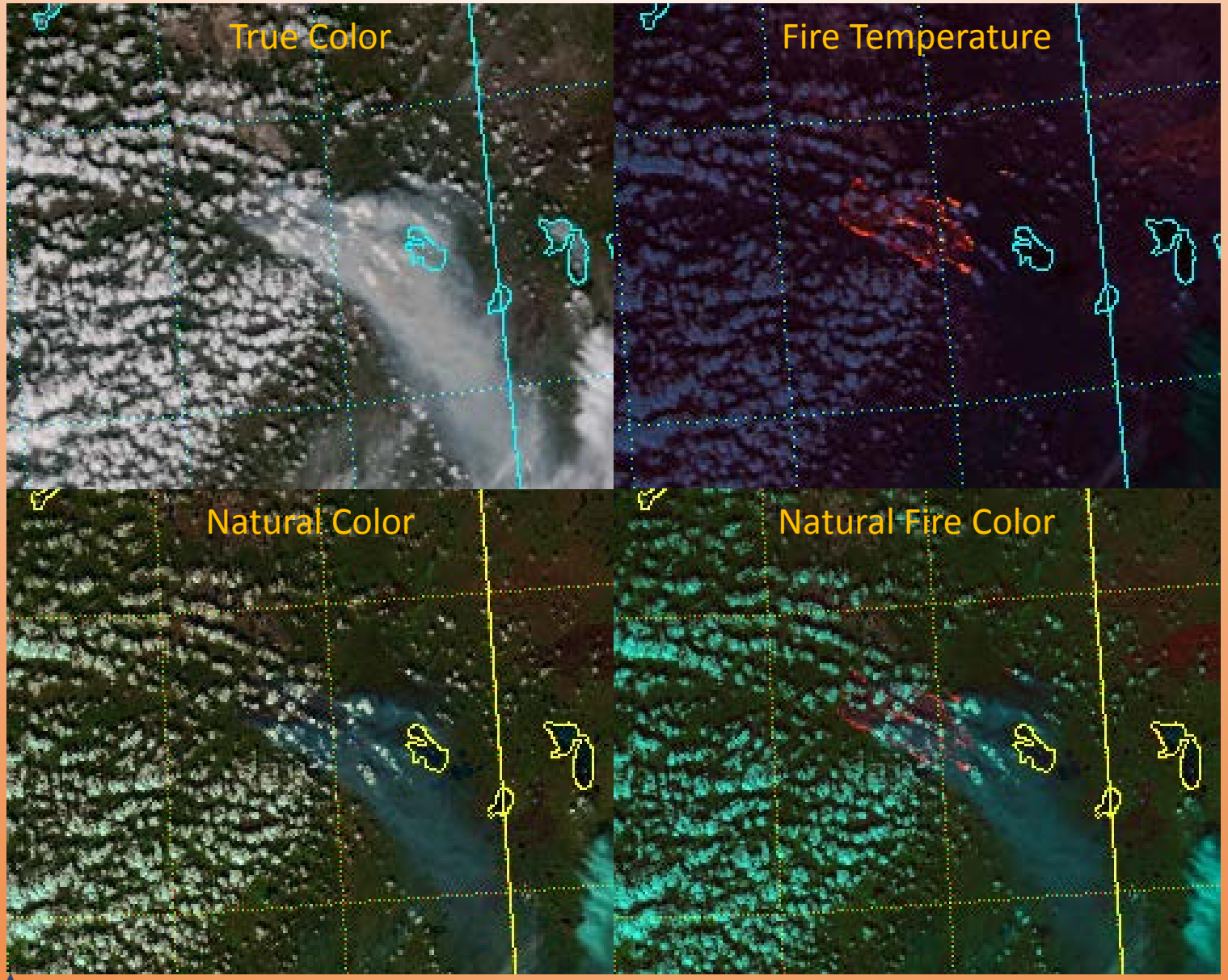
Fort McMurray Fire (2016)



20:05 UTC 4 May 2016

CIRA
Connecting Models and Observations

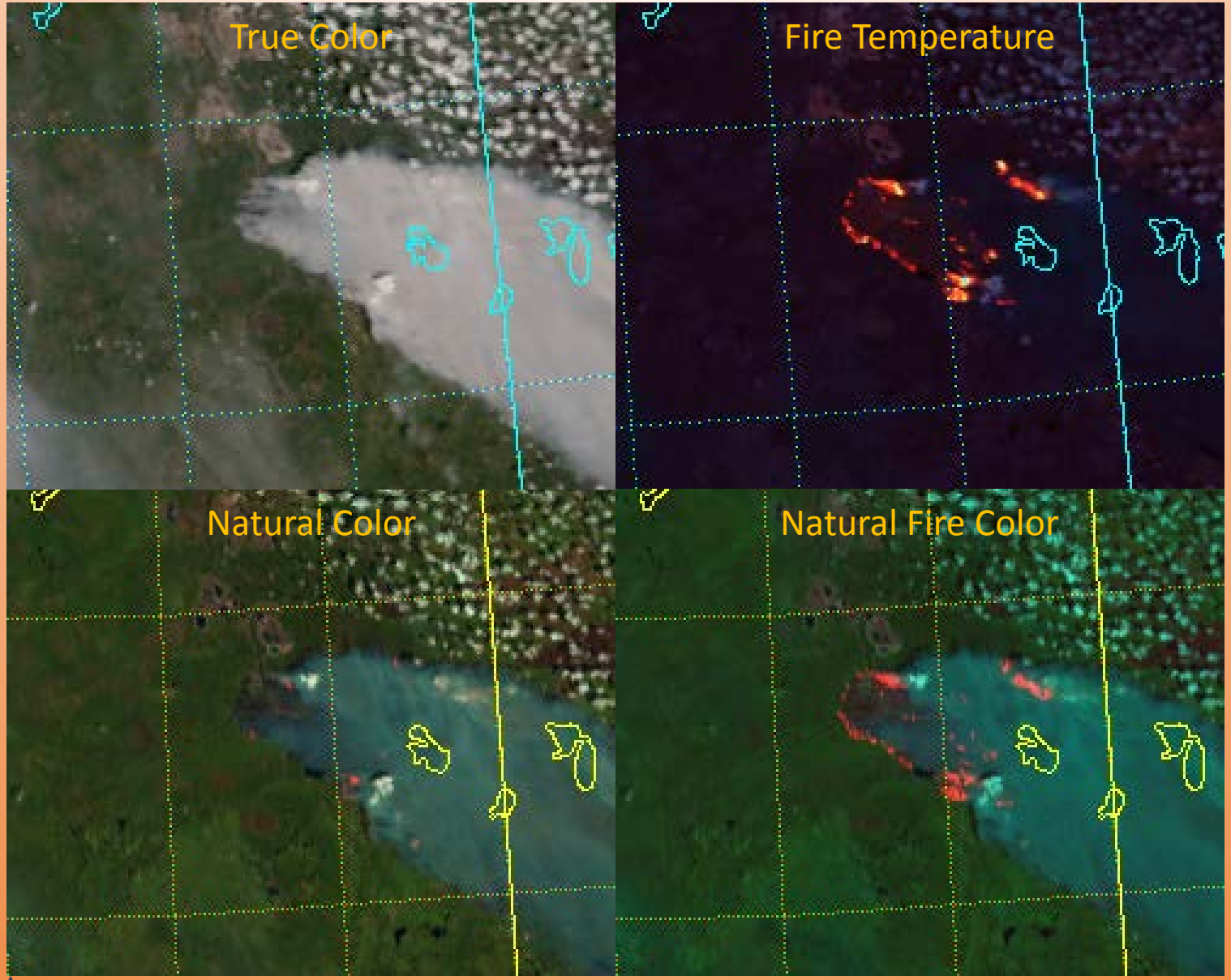
Fort McMurray Fire (2016)



19:47 UTC 5 May 2016

CIRA
Connecting Models and Observations

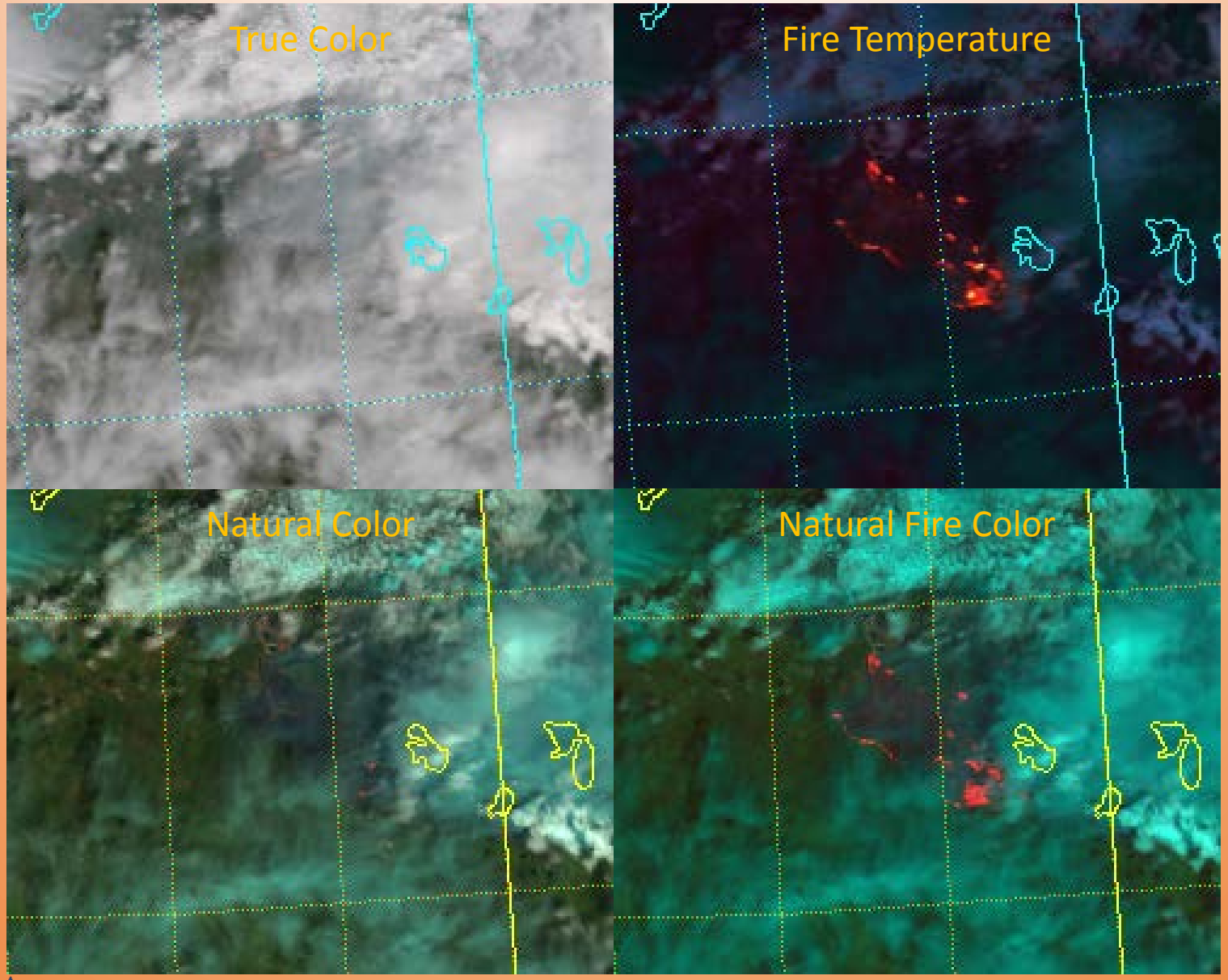
Fort McMurray Fire (2016)



21:06 UTC 6 May 2016

CIRA
Connecting Models and Observations

Fort McMurray Fire (2016)



20:48 UTC 7 May 2016

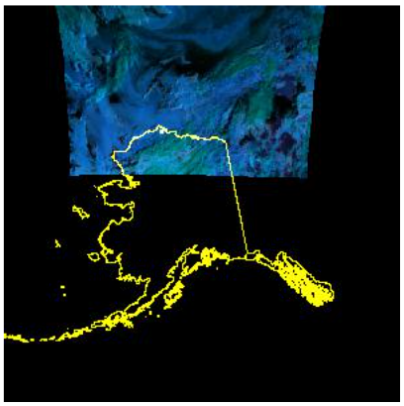
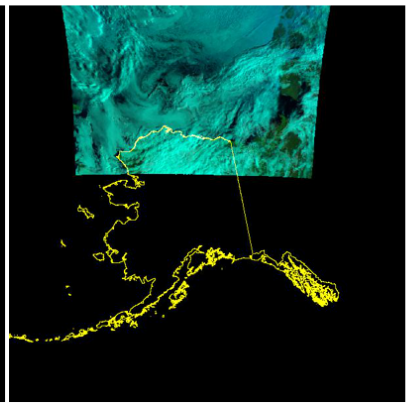
CIRA
Connecting Models and Observations

Fire RGBs for Alaska Fire Service (AFS)

hippy.gina.alaska.edu/firecolor

This page presents VIIRS fire color products .

A KML feed of this data is available here.

Date	Age	M band combo	I band combo
08/03/17 17:39:00 UTC	1h, 40m		
		TIFF (25 Mb)	TIFF (92 Mb)
		JPEG compressed TIFF (3 Mb)	JPEG compressed TIFF (13 Mb)
		KML	KML

We have been using it and we are HUGE fans!!! Seriously, it is just about the closest thing we have to real-time information on fire growth and behavior. Over the past few days we (AFS GIS) have been checking the page multiple times a day and grabbing new images. I am partial to the I-Band combo due to the better resolution..

Jenn Jenkins (BLM/AFS)

M-band combo = Fire Temperature RGB

I-band combo = Natural Fire Color RGB

CIRA Connecting Models and Observations

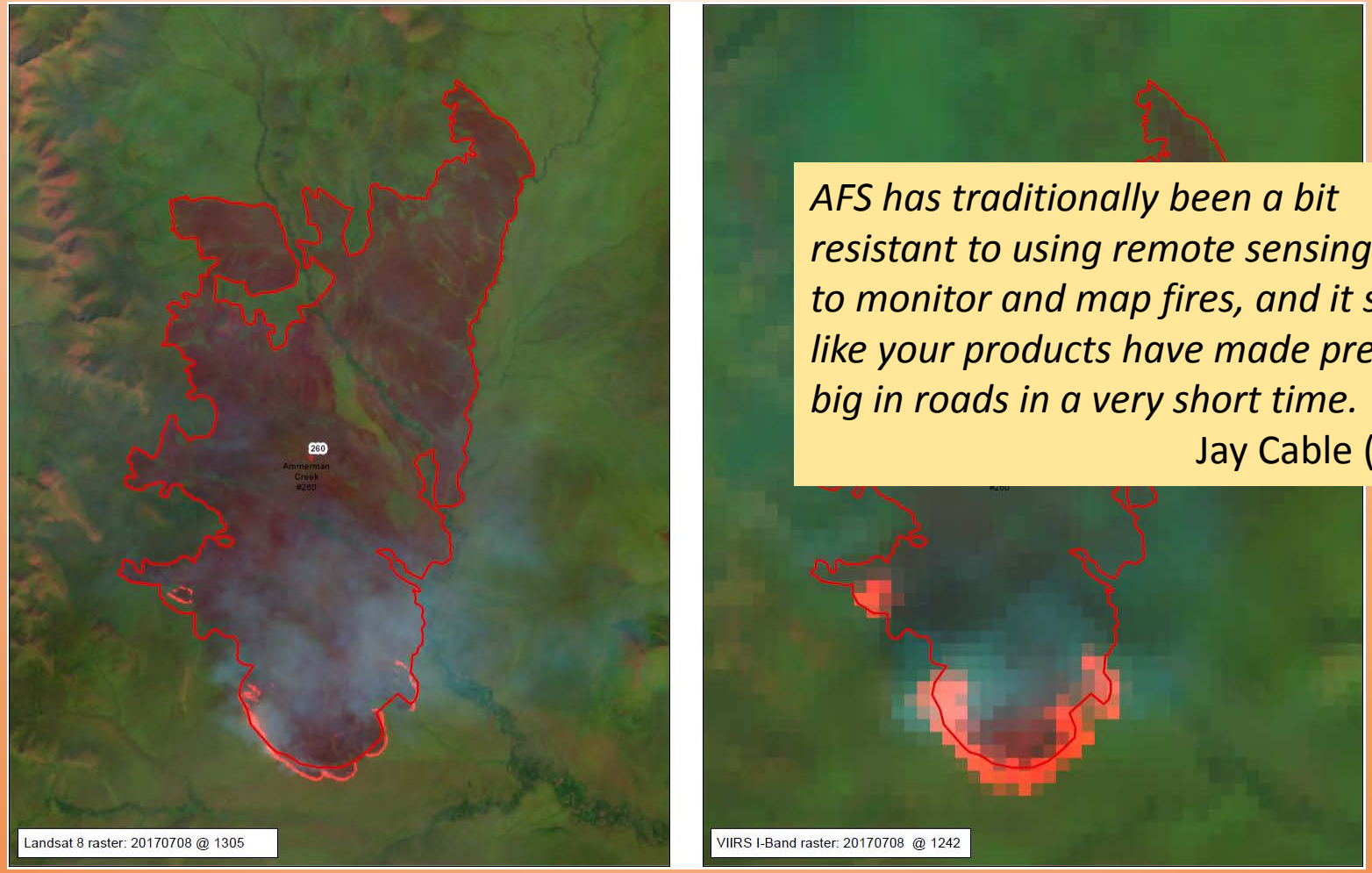
GINA www.gina.alaska.edu

URL above is temporary. Check for updates at:

http://feeder.gina.alaska.edu/

Natural Fire Color: CIRA to GINA to AFS

Images courtesy AFS

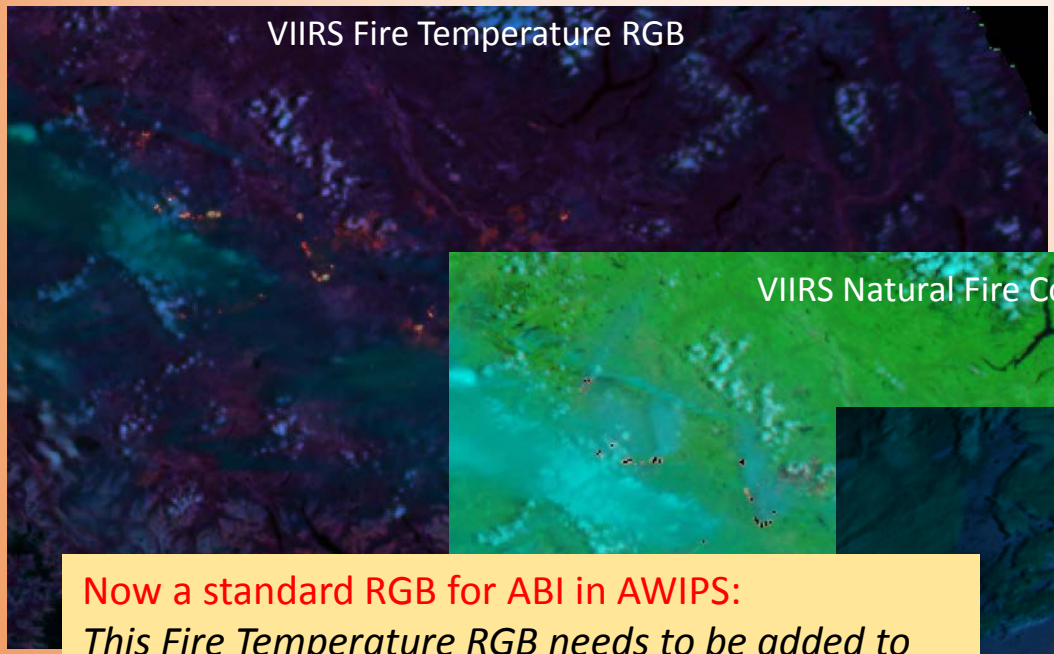


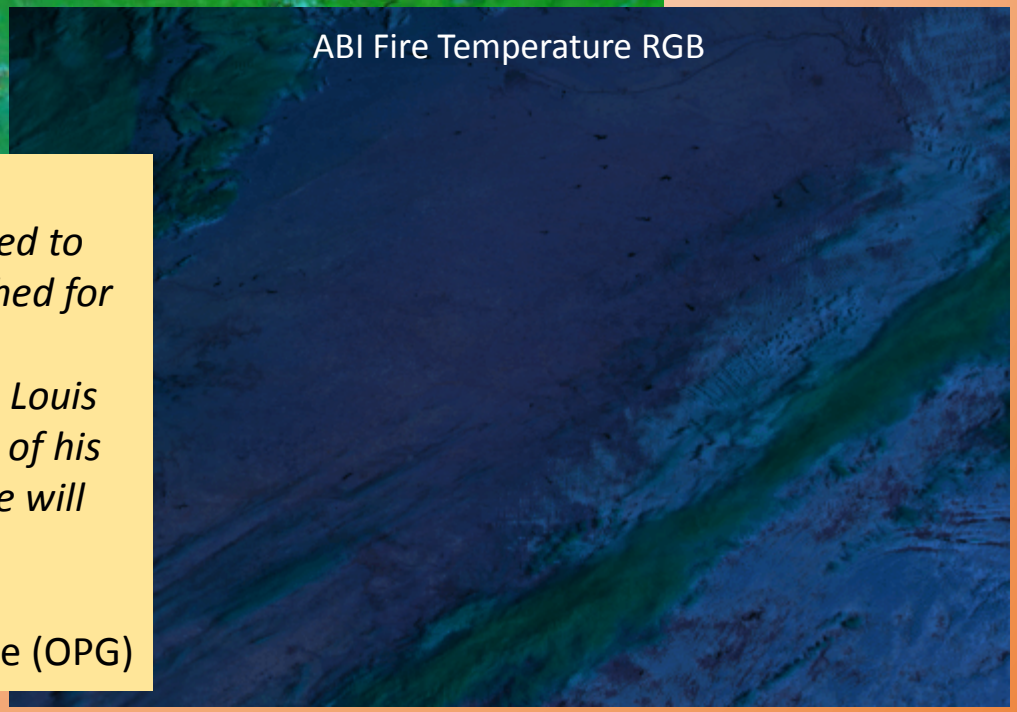
AFS has traditionally been a bit resistant to using remote sensing data to monitor and map fires, and it seems like your products have made pretty big in roads in a very short time.

Jay Cable (GINA)

Comparing Landsat with VIIRS for the Ammerman Creek Fire (2017/07/08)

Fire RGBs in AWIPS





VIIRS Fire RGBs now sent from GINA to Alaska Region WFOs through the AWIPS LDM

Now a standard RGB for ABI in AWIPS:

This Fire Temperature RGB needs to be added to the list. It's a simple RGB, has been researched for a while, and is far superior to the other fire detection/monitoring RGBs. On top of that, Louis (Uccellini) is going to be showing it in a few of his upcoming high-profile presentations that he will be giving. Including one to the Senate Appropriations Committee.

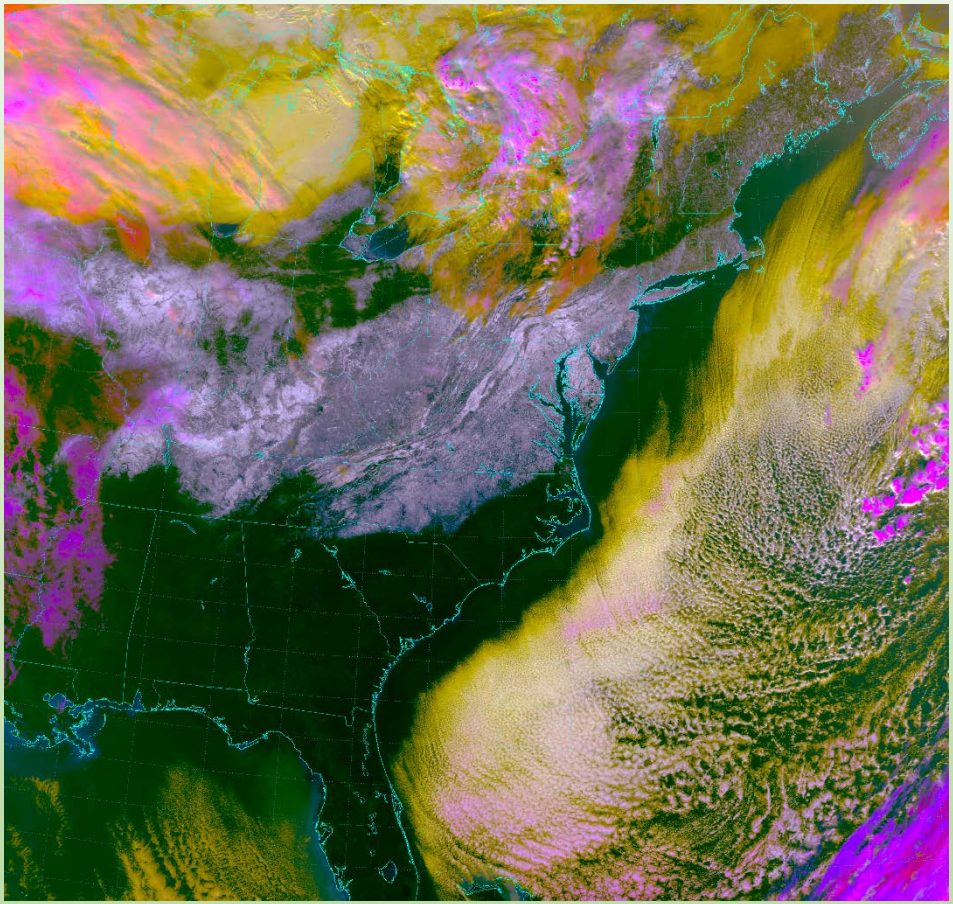
Chad Gravelle (OPG)

NASA SPoRT has agreed to send the Fire Temperature RGB to non-AWIPS users!

The Snow/Cloud Discriminator

The Great Blizzard of ‘16

- Can you tell what is cloud and what is snow in the True Color RGB (M-3, M-4, M-5)?
- EUMETSAT Natural Color RGB (M-5, M-7, M-10) discriminates low clouds from snow and ice
- Variation of EUMETSAT Snow RGB (M-11, M-10, M-7) highlights snow in pink/red
- Snow RGB from Météo France produced upon request from UK Met Office (M-7 through M-11)
- CIRA’s Snow/Cloud Discriminator (uses up to 11 bands) keeps snow white and highlights low, mid and high clouds

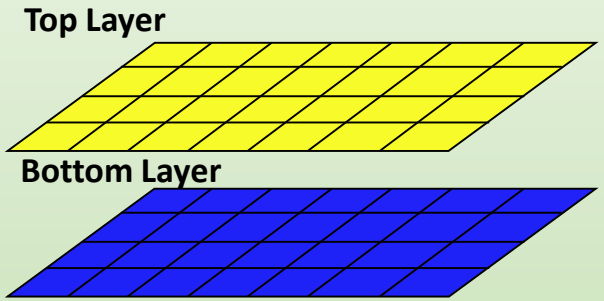


18:12 UTC 24 January 2016

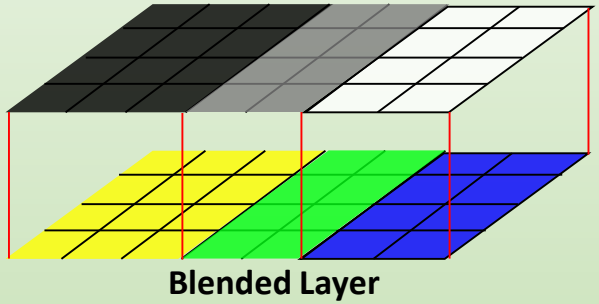
CIRA
Connecting Models and Observations

Multilayer Blending: A Novel RGB Concept

Layers of Information (2 layer example)



Spatial Opacity Rules for Top Layer (Black= Opaque, White=Transparent)

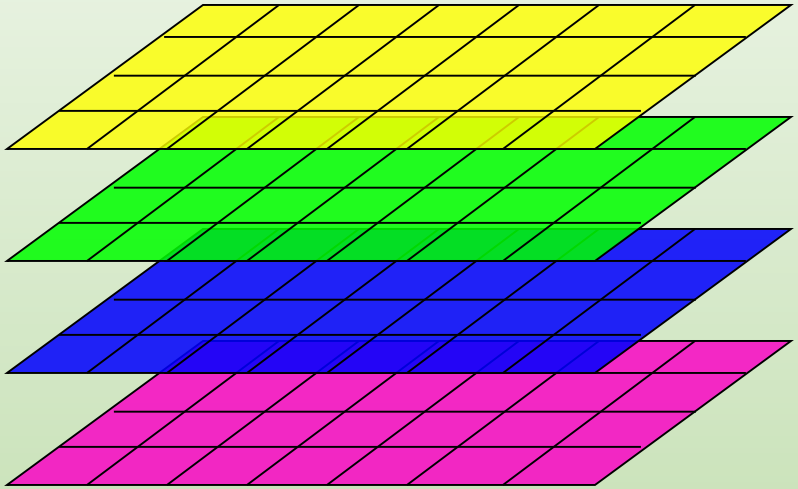


- Each layer of information is assigned a 2D transparency field (defined at every pixel location).
- A separate blend can be done for each color gun (R/G/B), achieving realistic ‘color bleed-through’ effects.
- Allows for the simultaneous display of multiple semi-transparent layers and blending in both the horizontal and vertical dimensions.

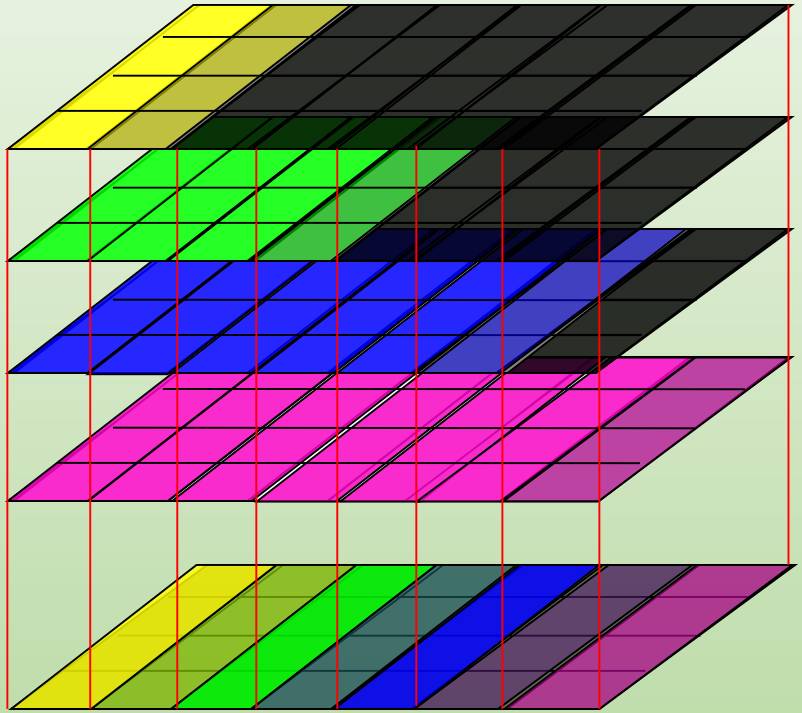
CIRA
Connecting Models and Observations

As many layers as you wish…

Layers of Information



Spatial Opacity Rules



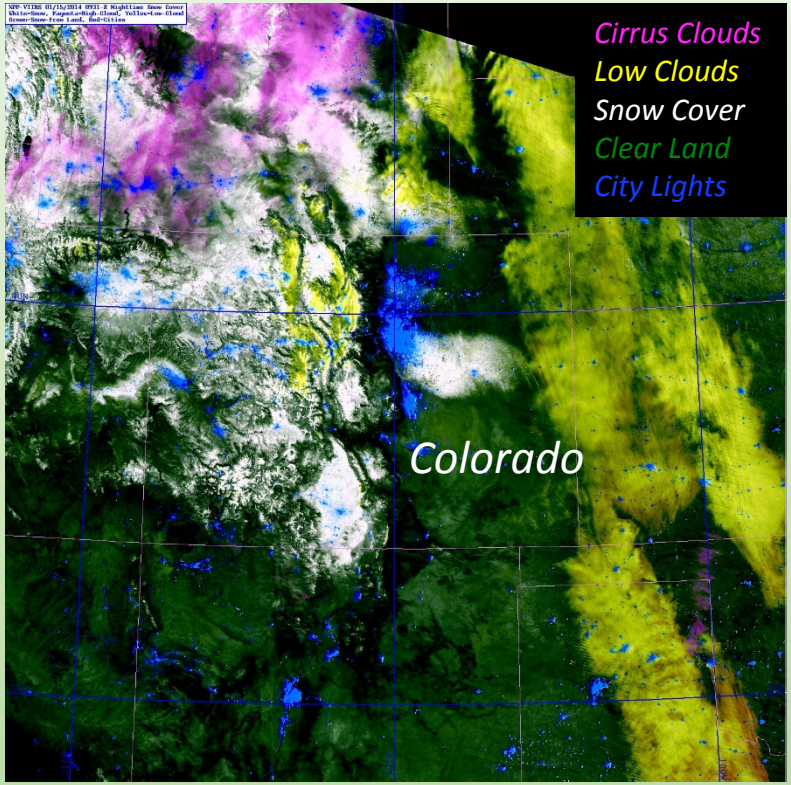
Blending is done in both the vertical and horizontal dimensions of the image

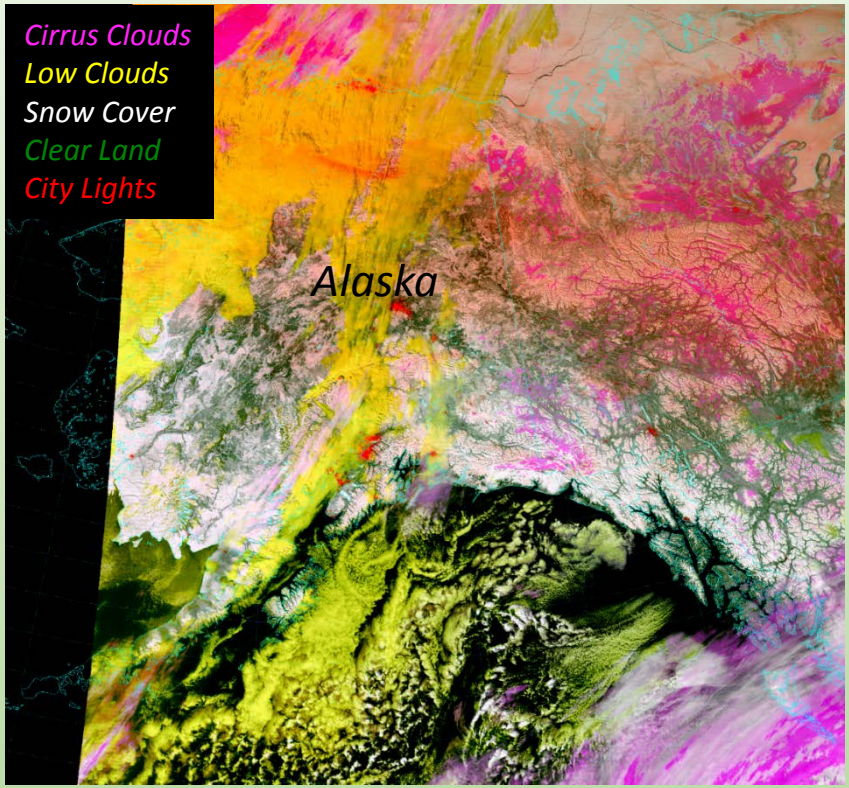
$$C = (N_1 + (1.0 - N_1)(N_2 + (1.0 - N_2)[...(N_{M-1} + (1.0 - N_{M-1})N_M))))]$$

"N-Dimensional Blending" allows for the *dynamic blending of multiple information layers*

CIRA
Connecting Models and Observations

The Snow/Cloud Discriminator



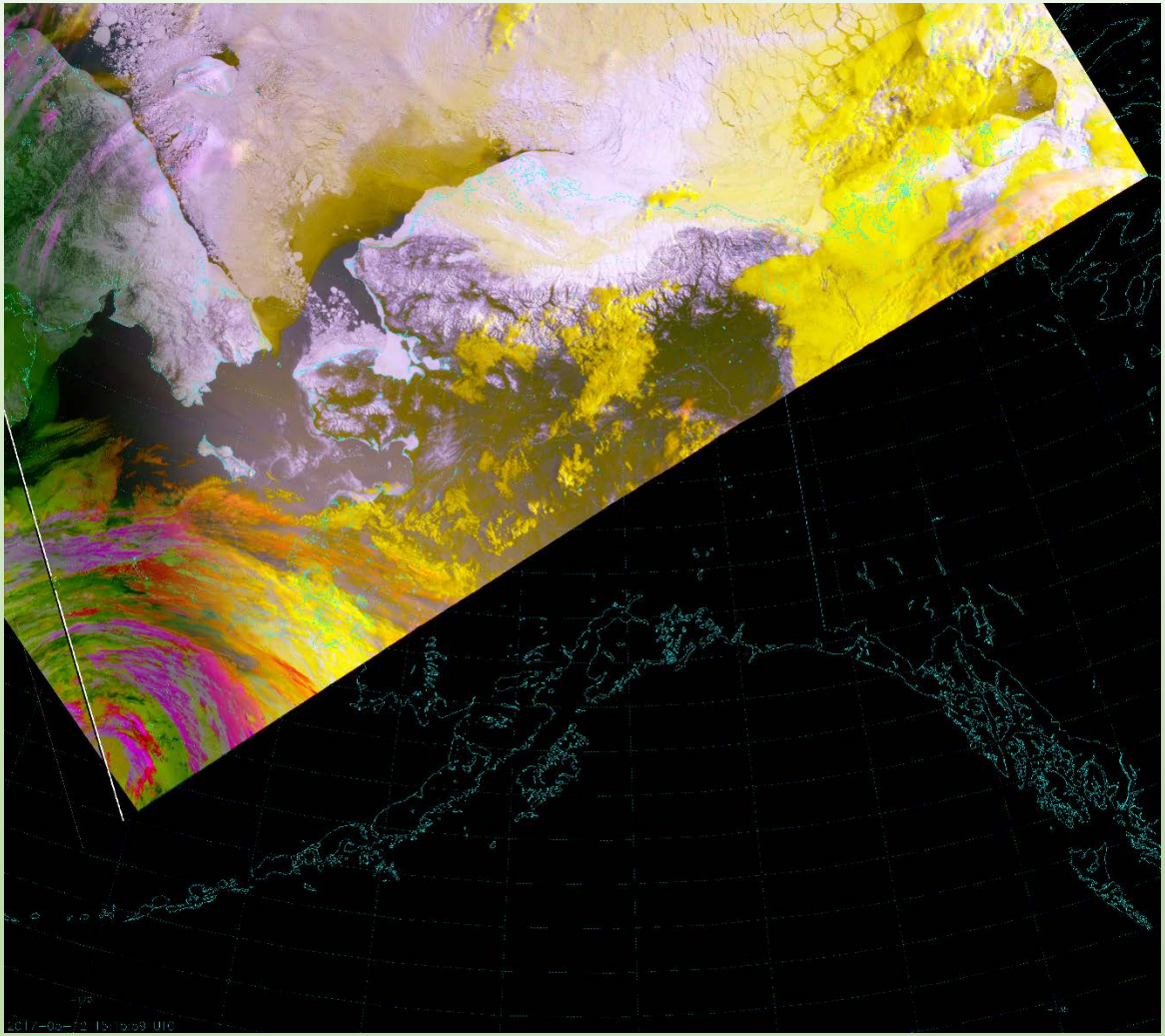


→ Blends information from 11 different VIIRS bands, plus NCEI Nighttime Lights dataset (C. Elvidge) to discriminate snow from clouds

→ First snow detection RGB that works at night!

CIRA
Connecting Models and Observations

On the Path to Operations



- → Now produced in real time at GINA using CIRA code
- → GeoTIFFs available
- → Soon to be added to GINA's Puffin Feeder
- → AWIPS to follow through GINA LDM feed
- → To be completed before Arctic Initiative extensive evaluation period (Spring 2018)

CIRA Connecting Models and Observations

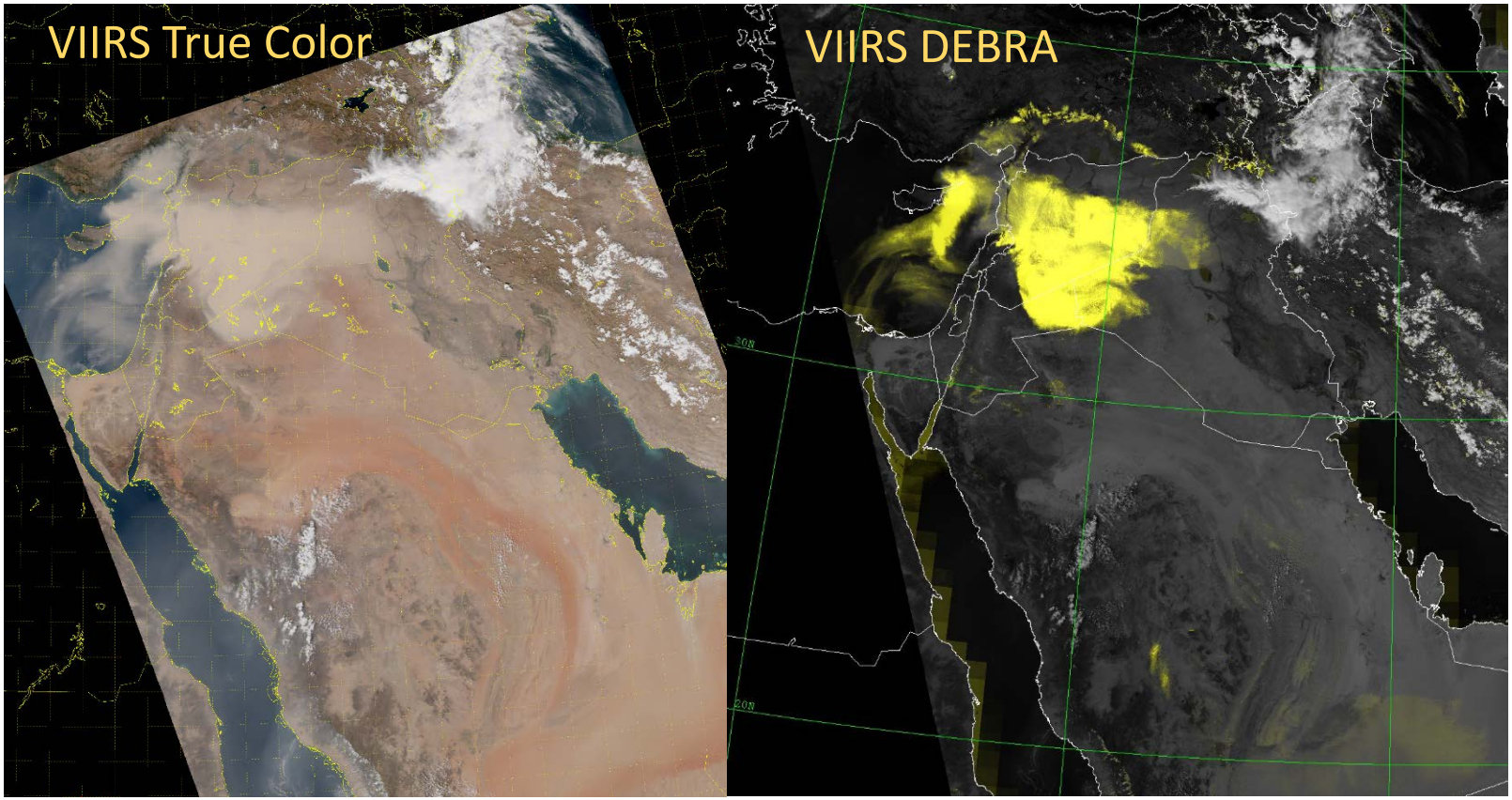
GINA www.gina.alaska.edu

Summary

- → Partnerships between CIRA, GINA, CIMSS, NRL and NASA SPoRT have brought improved VIIRS imagery products to forecasters
- → AWIPS/NAWIPS, GeoTIFF, Puffin Feeder, Nexsat
- → Improved Day/Night Band imagery
- → Fire RGBs
- → Snow/Cloud Discriminator (almost in ops!)
- → We continue to collaborate on training materials with the Satellite Liaisons and SPoRT

Other Products

DEBRA Dust



Syrian Dust Storm (7 September 2015)

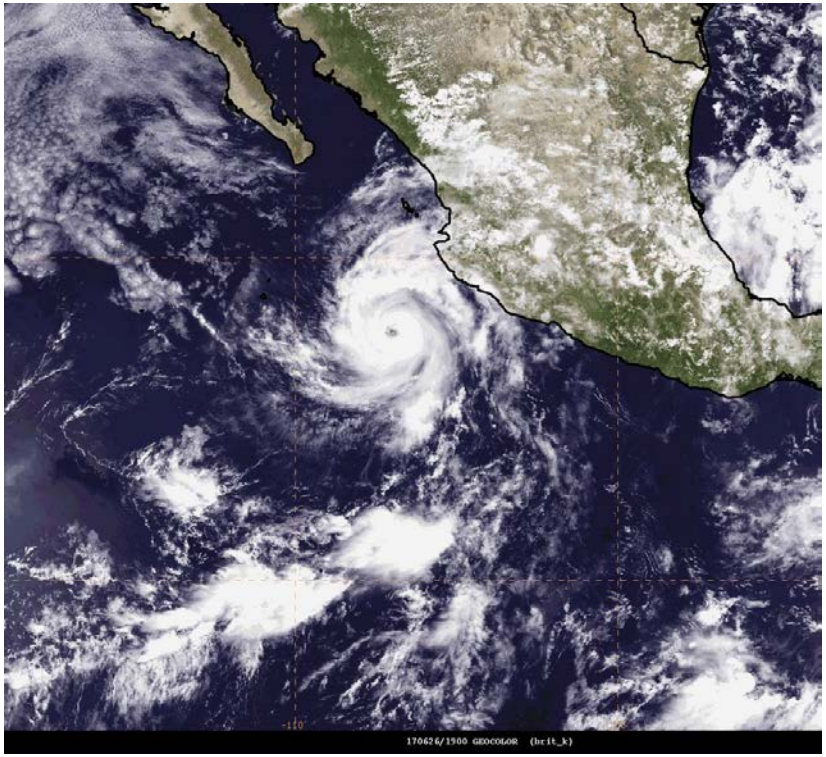
→ Dynamic Enhanced Background Reduction Algorithm (DEBRA) uses the multi-layer blended RGB concept to highlight dust in yellow according to confidence

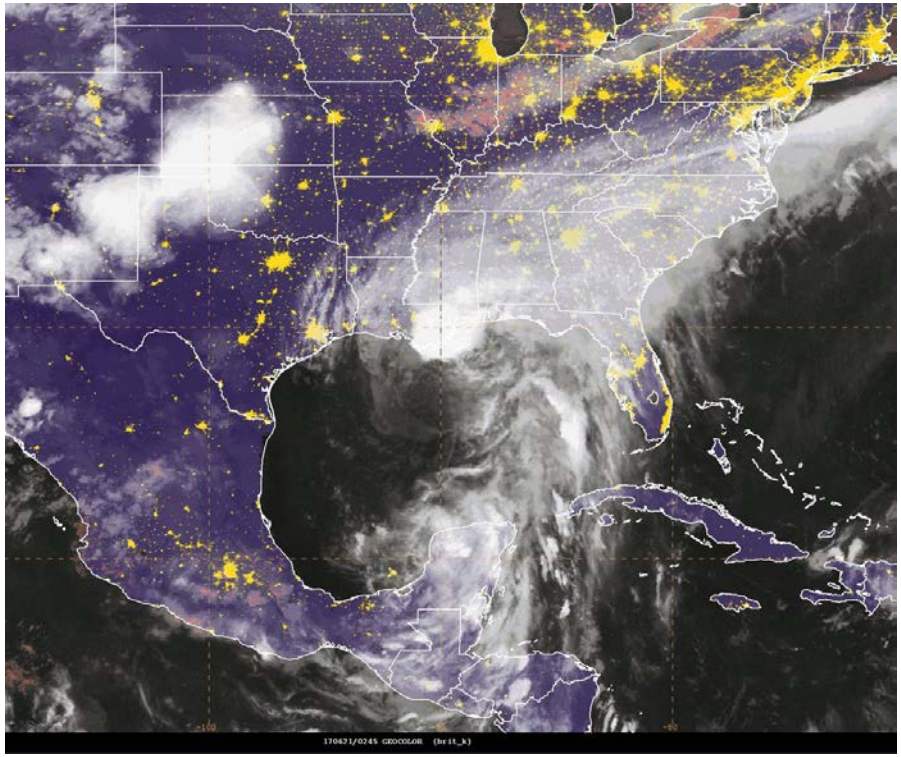
→ Used operationally by the US Navy

CIRA Connecting Models and Observations

U.S. NAVAL RESEARCH LABORATORY

Geocolor





- → Blends True Color imagery during the day with a low cloud detection algorithm at night
- → Applied to GOES, GOES-R, Himawari
- → Used heavily by NWS Aviation Weather Center (AWC), Weather Prediction Center (WPC), Ocean Prediction Center (OPC)

- → VIIRS version in the works (request from GINA for Alaska WFOs)

CIRA Connecting Models and Observations