Polar Satellite Imagery for Fire Monitoring and Analysis

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Outline

- VIIRS Fire Imagery products for fire monitoring & analysis:
  1. VIIRS i04 Shortwave IR (3.74 µm)
  2. DayFire RGB (FireColor RGB)
  3. VIIRS i05 Longwave IR (11.5 µm)
  4. DayLandCloud RGB
  5. TrueColor RGB
  6. FireTemperature RGB
- Other satellites and sensors

VIIRS Fire Point Detections in Use

The Alaska Interagency Coordination Center (AAIC) manages logistical support for state and federal agencies involved in Wildfire suppression in Alaska. It is one of 10 centers in the US.

AICC Situation Report - 14 Jun 2021

Daily Report From: 06/13 — **28.0 Acreage On 06/13**

N2TH Lat: **64 54.0900** Status: **S/U** Acres: **28.0** Option: **Full**
111186 Lon: **149 26.8300** Personnel: **33** Start Date: **06/13** Area: **FAS**
Owner: **State** Unit: **AKDNS-AK Dept. Natural Resources**
186 Name: **Minto Lakes** Cause: **Undetermined**

11N called in a smoke in the area of Minto Lakes. H-120SH, A/A, 2 fire bosses, 1 tanker and jumpers responded to a 28 acre fire burning in black spruce with group torching. North Star and Tanana Chief crews en route.

Daily Report From: 06/13 — **10.0 Acreage On 06/13**

N2S2 Lat: **66 28.8444** Status: **U/U** Acres: **10.0** Option: **Limited**
Lon: **150 24.1080** Start Date: **06/13** Area: **UYD**
Owner: **BLM** Unit: **AKCYD-Central Yukon Field Office**
185 Name: **Kanuti River** Cause: **Lightning**

N9011N flew reconnaissance of the fire today and reported it to be 10 miles east of the Dalton Highway. The fire is 10 acres 50% active, smoldering and creeping in tundra and brush.

Daily Report From: 06/13 — **0.2 Acreage On 06/13**

N2SW Lat: **65 33.9800** Status: **U/U** Acres: **0.2** Option: **Full**
131184 Lon: **144 54.7083** Start Date: **06/13** Area: **UYD**
Owner: **State** Unit: **AKDNS-AK Dept. Natural Resources**
184 Name: **Boulder** Cause: **Human**

Upper Yukon Tanana Dispatch noticed VIIRS dots in the area, they plotted in Full protection. J-17 responded to the fire and reported a burning debris pile. Fire was reported to be .2 acres, smoldering, on flat terrain in a gravel parking area. No values at risk and no chance for the fire to spread into the wildlands. No further action was taken at this time.

AICC Situation Report – 21 Jun 2021

New Count: 3 Acres: 175.0

Daily Report From: 06/20 — **5.0 Acreage On 06/20**

N3E8 Lat: **68 11.0267** Status: **Out 06/20** Acres: **5.0** Option: **Limited**
Lon: **159 07.6017** Start Date: **06/20** Area: **GAD**
PDN3E8 Owner: **NPS** Unit: **AKNOP-Noatak Preserve**
245 Name: **Anisak River** Cause: **Lightning**

At 1931 agency aircraft N864SF reported a new fire 83 miles NW of Ambler. Fire was approximated at 5 acres and plotted in Limited suppression. Fire is a natural out.

Daily Report From: 06/20 — **20.0 Acreage On 06/20**

N3EN Lat: **64 44.1100** Status: **S/U** Acres: **20.0** Option: **Full**
111244 Lon: **148 39.0750** Personnel: **30** Start Date: **06/20** Area: **FAS**
PNN3EN Owner: **ANCSA** Unit: **AKVLN-Toghotthele Corporation**
244 Name: **Straight Creek** Cause: **Lightning**

H-120SH reported a smoke in the Ester Dome area when they were returning from Haystack Helibase. Helicopter responded to a 5 acre (that grew to 20 acres) rank 4 fire in black spruce. A/A, 2 tankers, FBs, jumpers and additional helicopter also responded. Yukon crew on scene.

Daily Report From: 06/20 — **150.0 Acreage On 06/20**

N3D9 Lat: **67 49.7150** Status: **U/U** Acres: **150.0** Option: **Limited**
Lon: **163 32.5617** Start Date: **06/20** Area: **GAD**
PDN3D9 Owner: **State** Unit: **AKDNS-AK Dept. Natural Resources**
243 Name: **Tutak Creek** Cause: **Lightning**

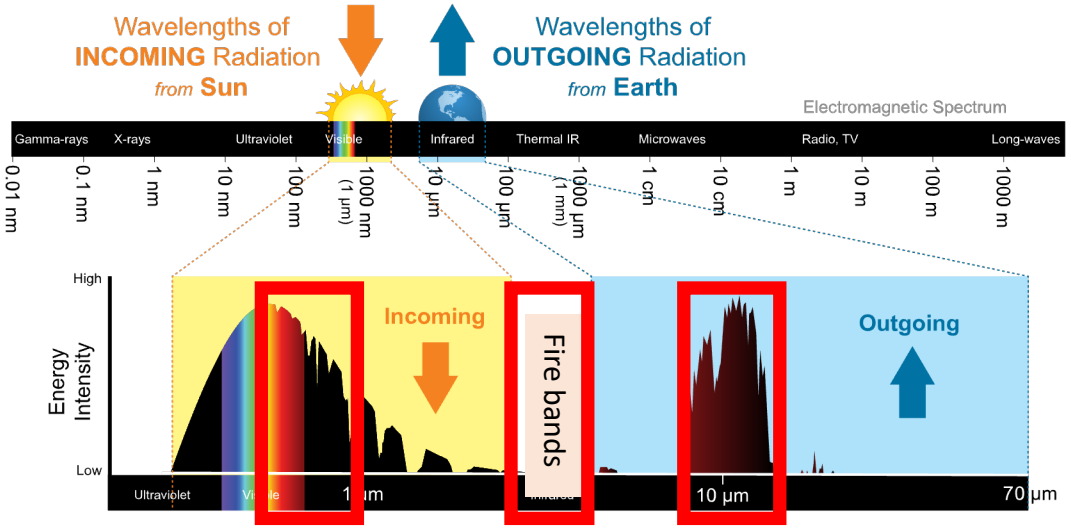
At 1403, a VIIRS signature approximately 24 miles NW of Noatak appeared on the map. AA 131 responded to the area and advised the fire was approximately 150 acres in size, smoldering, running, creeping, backing in tundra in Limited suppression. No action was taken at this time.

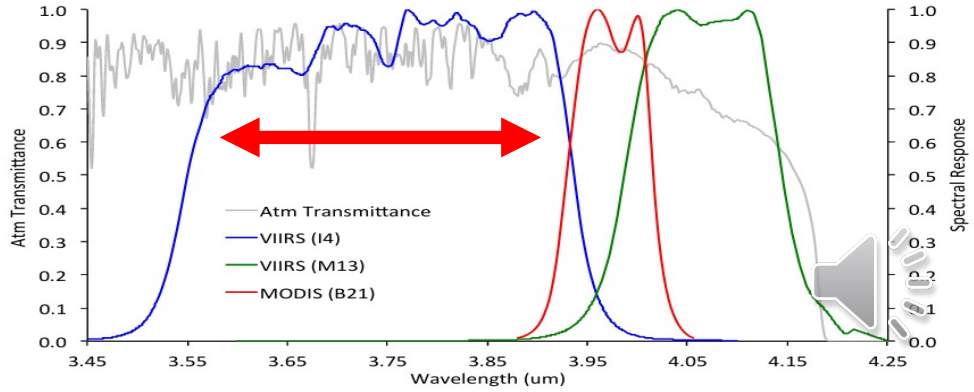
[Alaska Interagency Coordination Center: https://fire.ak.blm.gov/content/aicc/sitreport/AICC%20Situation%20Report.pdf](https://fire.ak.blm.gov/content/aicc/sitreport/AICC%20Situation%20Report.pdf)

Primary VIIRS Satellite Bands (i-bands)

Resolution: 375 meters

- i04 Shortwave IR (3.74 µm) - highly sensitive to fire emissions:
  - Primary band used in fire applications
  - Wide spectrum range (3.55 – 3.93 µm)
  - Sensor saturates at ~367K (94 °C) *
  - Sensitive to reflected solar energy
- i05 Longwave IR (11.5 µm) – IR emissions only, no reflected solar energy
- i01 Red Visible (0.64 µm) – red visible, strong solar reflectance from clouds, smoke, snow
- i02 Veggie band (0.86 µm) – solar reflectance from vegetation (used in RGBs)
- i03 Snow/Ice band (1.61 µm) – solar absorption by snow/ice (used in RGBs)



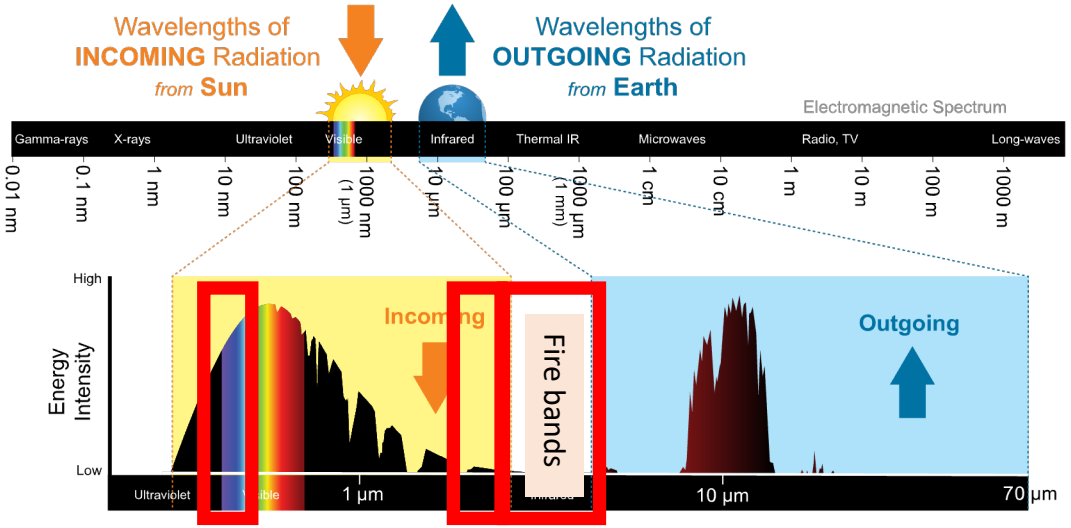


More on sensor saturation at:
https://rammb.cira.colostate.edu/projects/npp/blog/index.php/uncategorized/a-wild-week-of-wildfires/

Secondary VIIRS Satellite Bands (m-bands)

Resolution: 750 meters

- m13 Fire Band (4.0 µm) – highly sensitive to fire emissions
  - Sensitive to reflected solar energy
  - Narrow spectral range
  - Sensor saturation 600K (326 °C)
  - Used for the calculation of FRP
- m03 Blue Visible (0.49 µm)– sensitive to smoke and aerosols. Hazy due to Rayleigh scattering
- m11 Cloud Particle Size (2.25 µm) – moderately sensitive to fire. Moderate solar absorption by snow/ice



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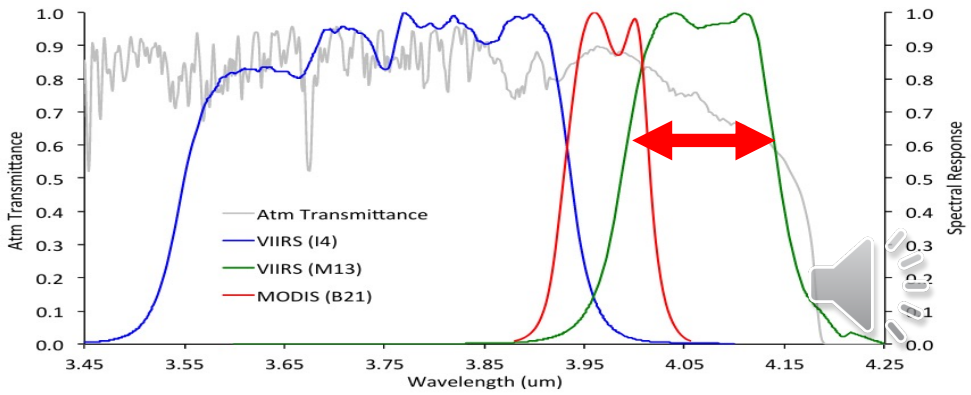

More on sensor saturation at:
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1. VIIRS i04 “Shortwave IR” Band (3.74 µm)

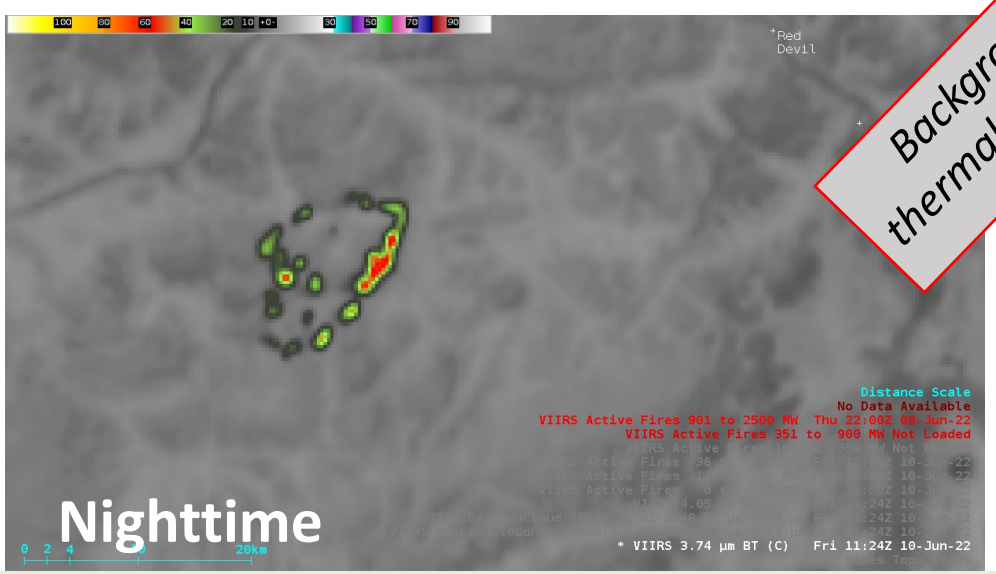
Colormap legend: colors assigned to Brightness Temperatures

Max +95 °C

Min -109 °C

Hotter (+C°)

Colder (-C°)



Background thermal emissions

2022 Aghaluk Mt Fire

Benefits:

- **Highly sensitive shortwave emissions of fires**
- **Map of SW thermal energy emissions day or night**
- **Resolution 375 m.**
- **Basis for most fire-related products.**

6

1. VIIRS i04 “Shortwave IR” Band (3.74 µm)

Colormap legend: colors assigned to Brightness Temperatures

2022 Aghaluk Mt Fire

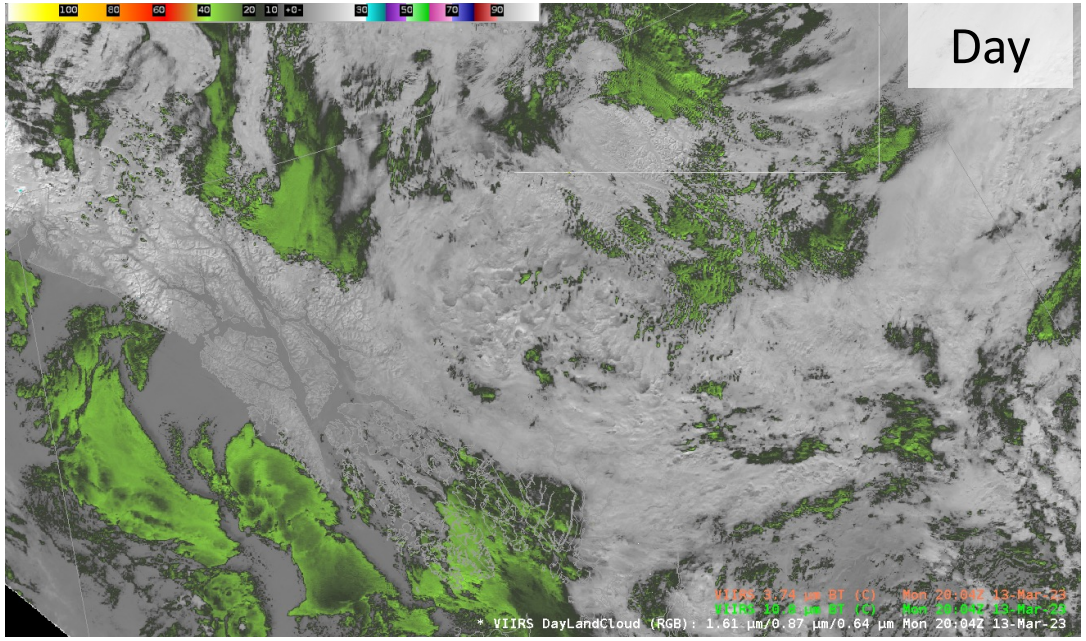
Benefits:

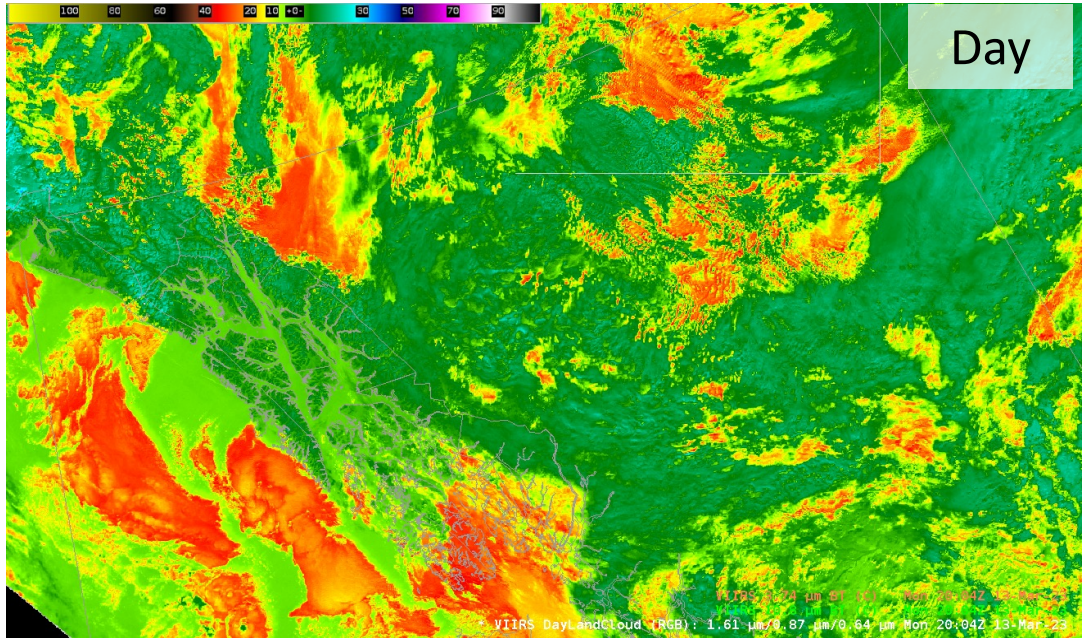
- **Highly sensitive shortwave emissions of fires**
- **Map of SW thermal energy emissions day or night**
- **Resolution 375 m.**
- **Basis for most fire-related products.**
- **Fire emissions not impacted by solar reflectance**

Limitations

- **Reflected solar radiation adds to background energy**
- **Sensor saturates at 368K or 95 °C**
- **Surface features are relative to the background**
- **Fires can be obscured by clouds, smoke, or terrain**

Shortwave IR (3.74 µm) Colormaps

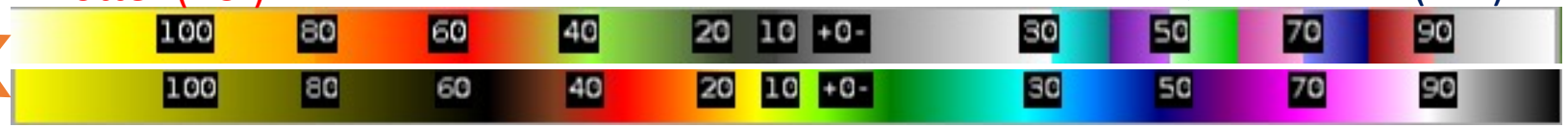




Hotter (+C°)

Colder (-C°)

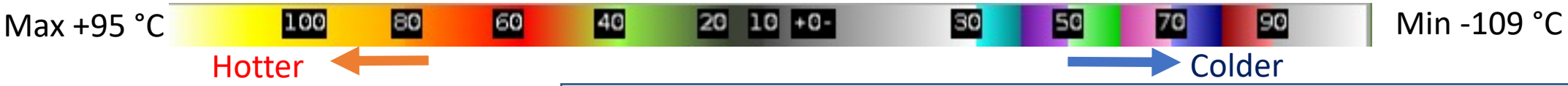
Brightness Temperatures

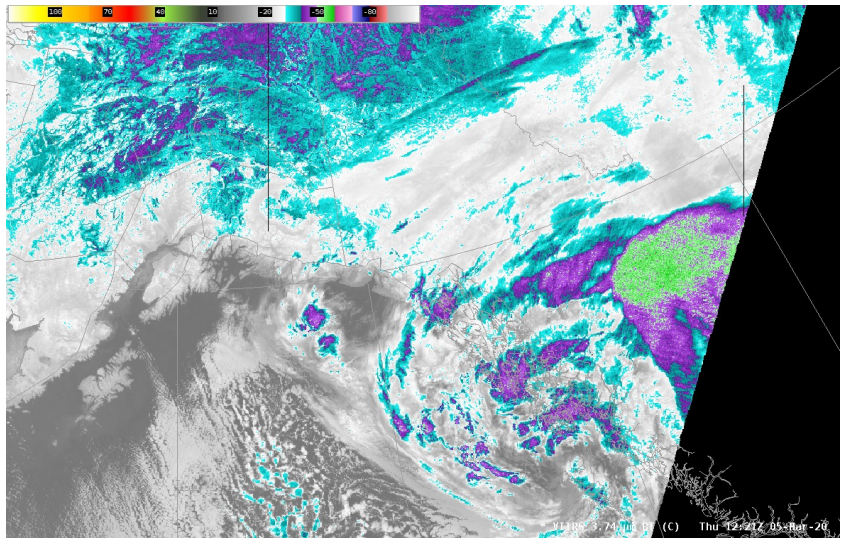


- Single band infrared images are a map of shortwave thermal emissions received by the satellite
- Thermal radiation units are “Brightness Temperatures”
- Colors are assigned to highlight specific temperature ranges shown in a color legend
- **Reflected solar energy (daytime) adds to the thermal pattern and changes colors**

Shortwave IR (3.74 um) Cloud Tops

Colormap legend: Brightness Temperatures (BT)



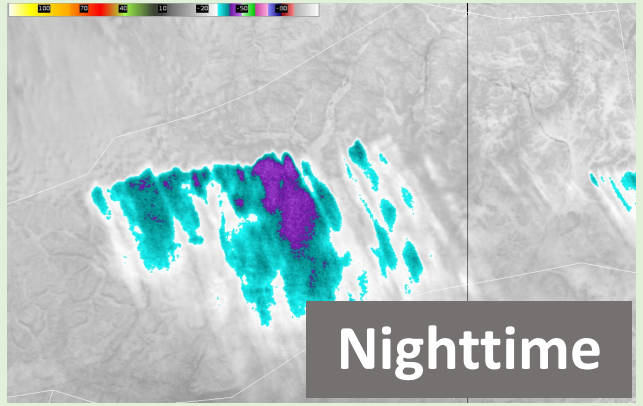


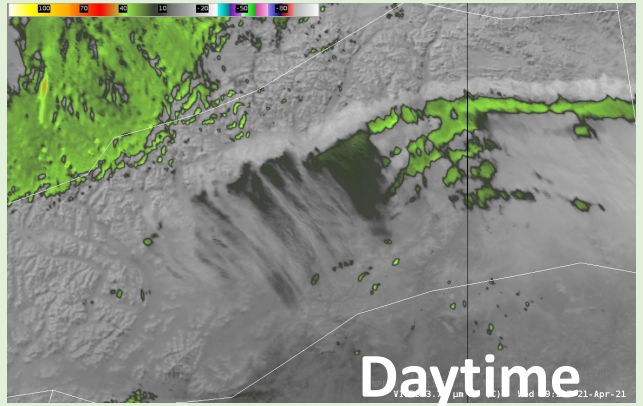
- Cold emissions indicate high clouds.
- High cloud tops can indicate:
  - strong convection: possible lightning
  - heavy rain.

Shortwave IR Temperature pattern with clouds changes night/day.

Night: Only emitted energy so high clouds are cold

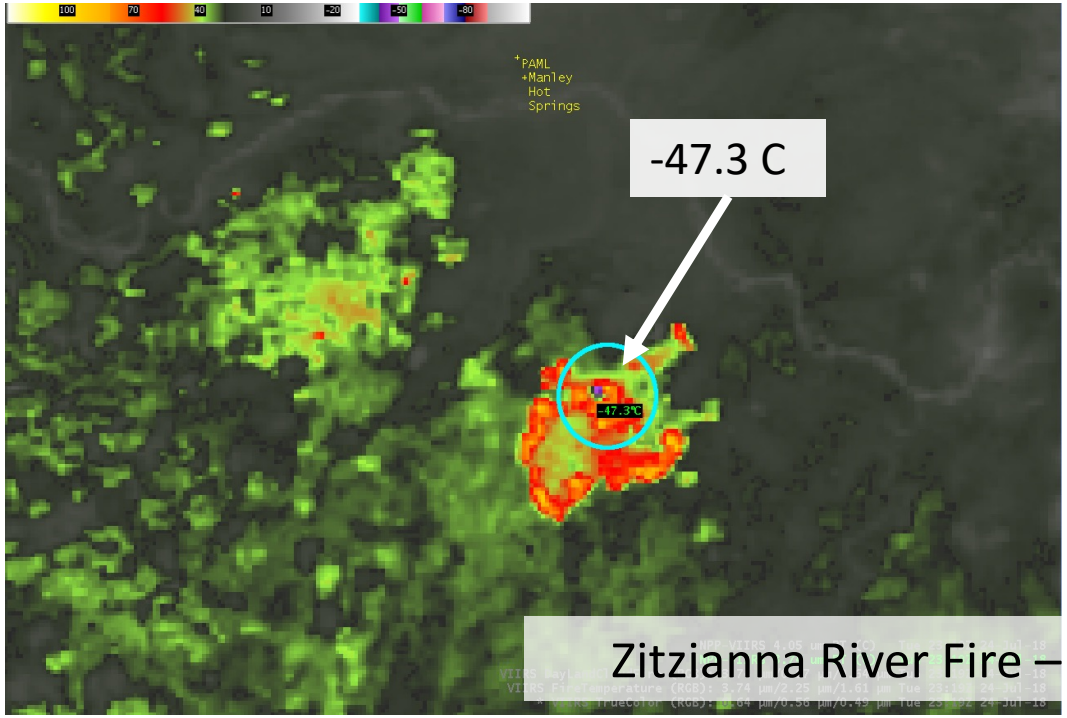
Day: Clouds reflect solar radiation that increases total energy received at the sensor



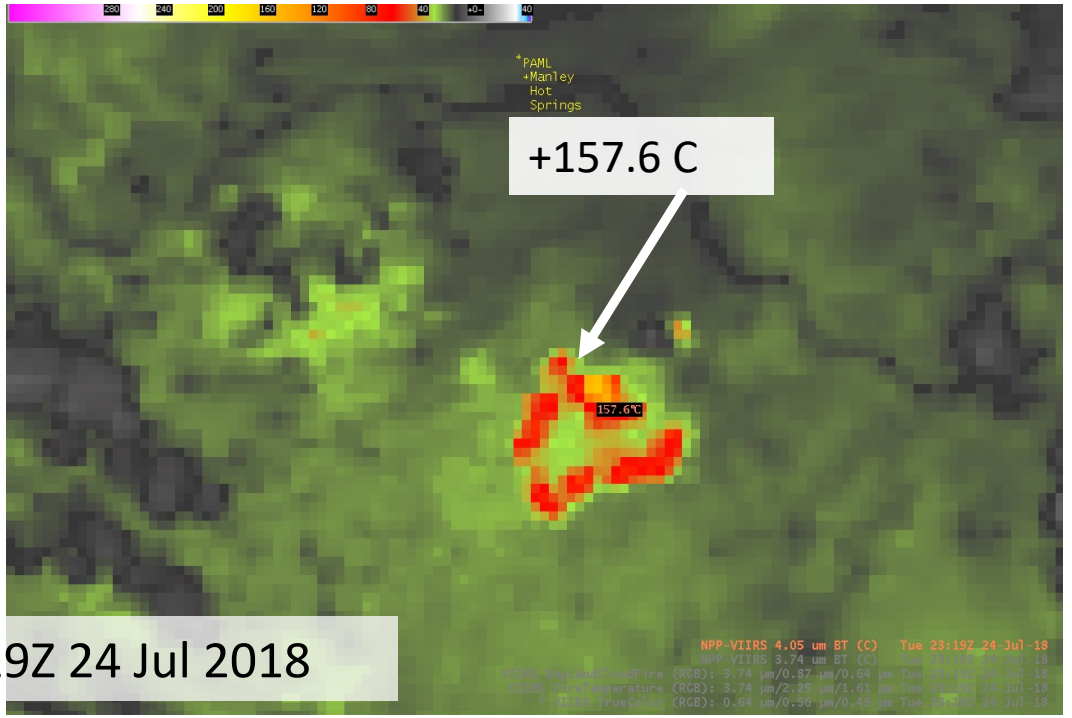


Shortwave IR Sensor Saturation

VIIRS i04 (3.74 µm)



VIIRS m13 (4.0 µm)



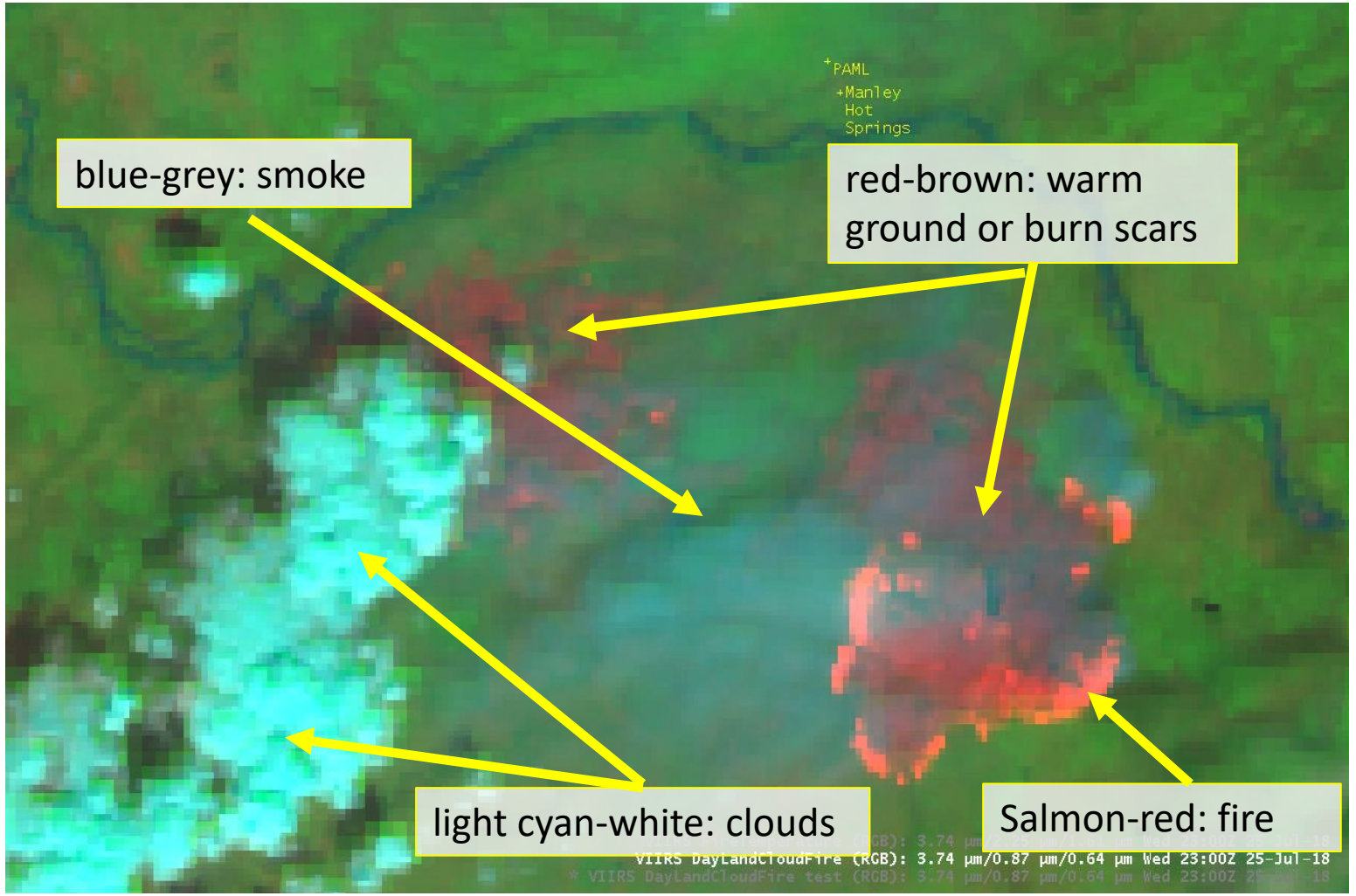
Zitzianna River Fire – 2319Z 24 Jul 2018

- Intense fires saturate the sensor (BT = 95 °C)
- Saturation causes “fold-over” where high BT pixels appear to be cold.
- VIIRS m13 (4.0 µm) should be checked for saturation

- Similar characteristics as the VIIRS i04
- Lower resolution (750 m)
- Much higher sensor saturation: 600K (326 °C) .
- Used in calculation of Fire Radiation Power (FRP)

2. VIIRS DayFire RGB

Aka: FireColor, DayLandCloudFire, NaturalFireColor



Zitziana River Fire
18 Jul 2018

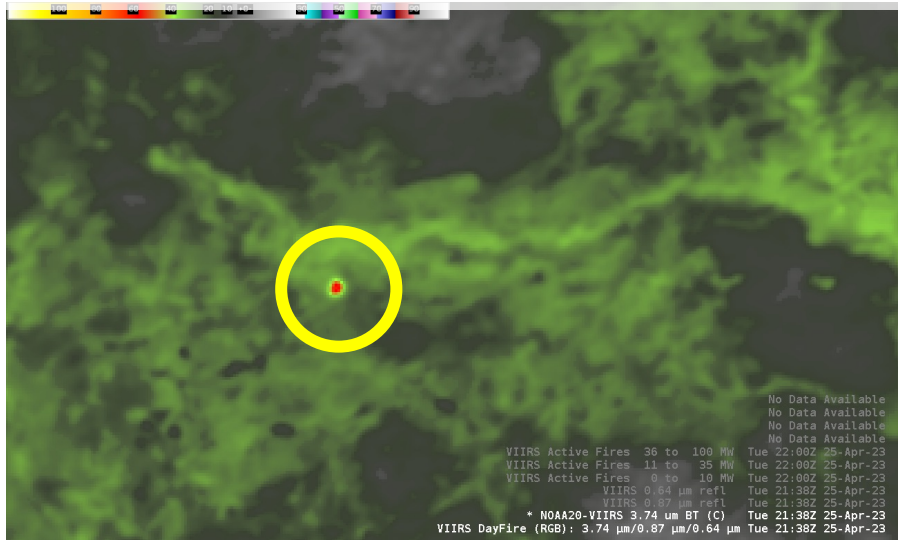
Daytime only

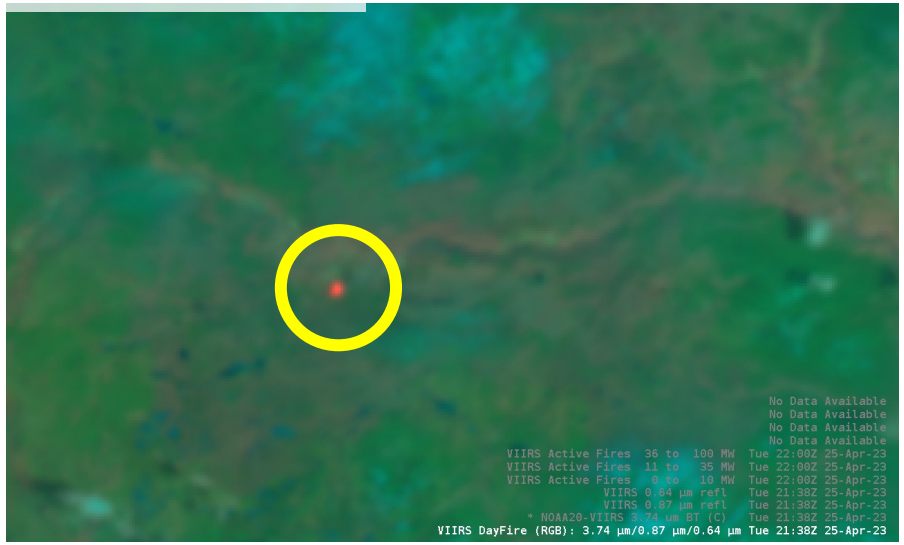
- Two reflectance bands
- SW IR: additional reflected solar energy taken into account

28 Feb 2023

2. VIIRS DayFire RGB

Aka: FireColor, DayLandCloudFire, NaturalFireColor





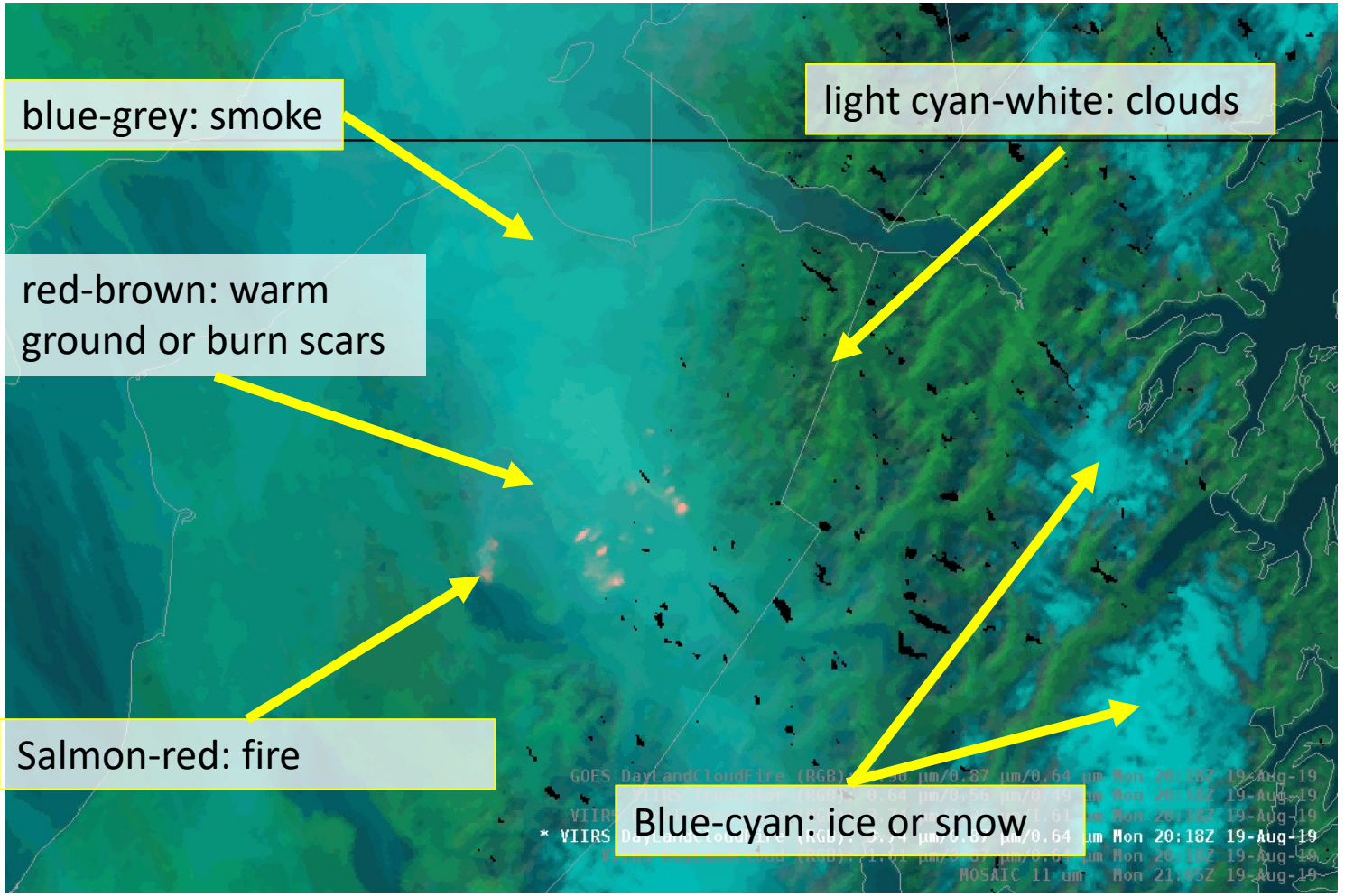
Color	Band (chnl)	Type	Res (m)	Large Contribution	Small Contribution
Red	3.74µm (i04)	Shortwave IR	375	wildfires, volcanos, industrial burns, solar reflections (sun glint, solar farms)	water, ice, snow
Green	0.87µm (i02)	Veggie band (reflectance)	375	thick clouds, vegetation, snow	water, bare ground, burn scars
Blue	0.64µm (i01)	Red visible (reflectance)	374	thick clouds, snow	water, bare ground, burn scars

2. VIIRS DayFire RGB

Aka: FireColor, DayLandCloudFire, NaturalFireColor

Frequent afternoon passes:
- Monitor fire evolution
- Determine smoke source and distribution
- Identify clouds/pyrocumulus

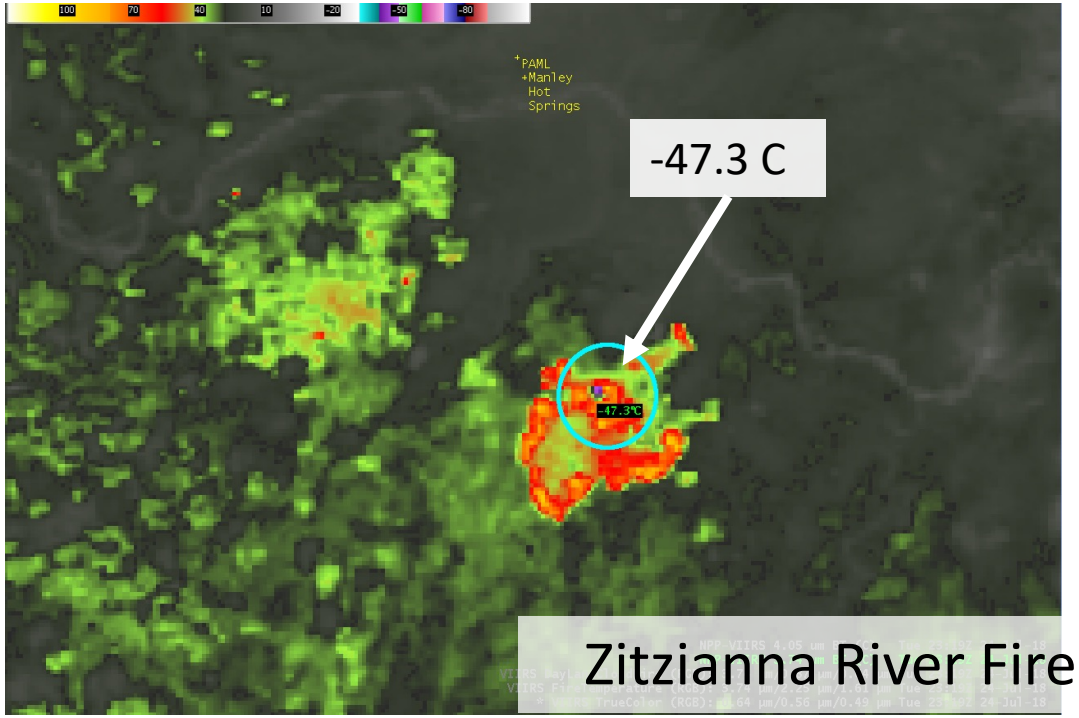
Considerations:
- Clouds, snow, ice similar color
- No intensity information
- Small fires hard to distinguish



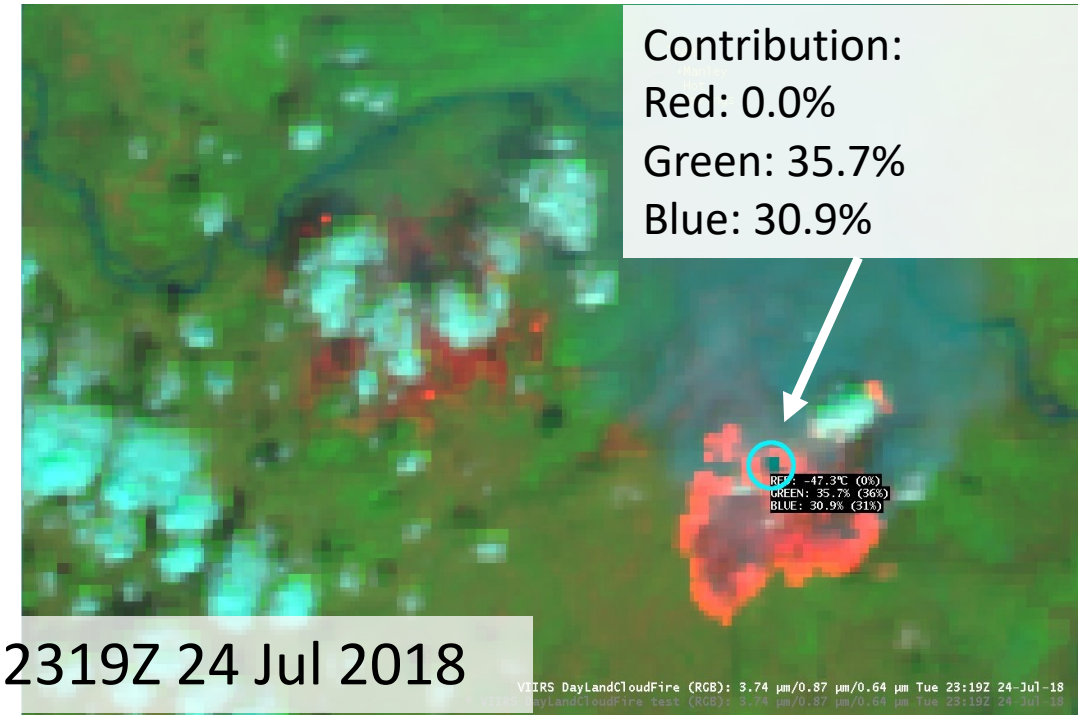
Swan Lake Fire - 19 Aug 2019

VIIRS i04 Sensor Saturation & DayFire RGB

VIIRS i04 (3.74 µm)



VIIRS DayFire RGB

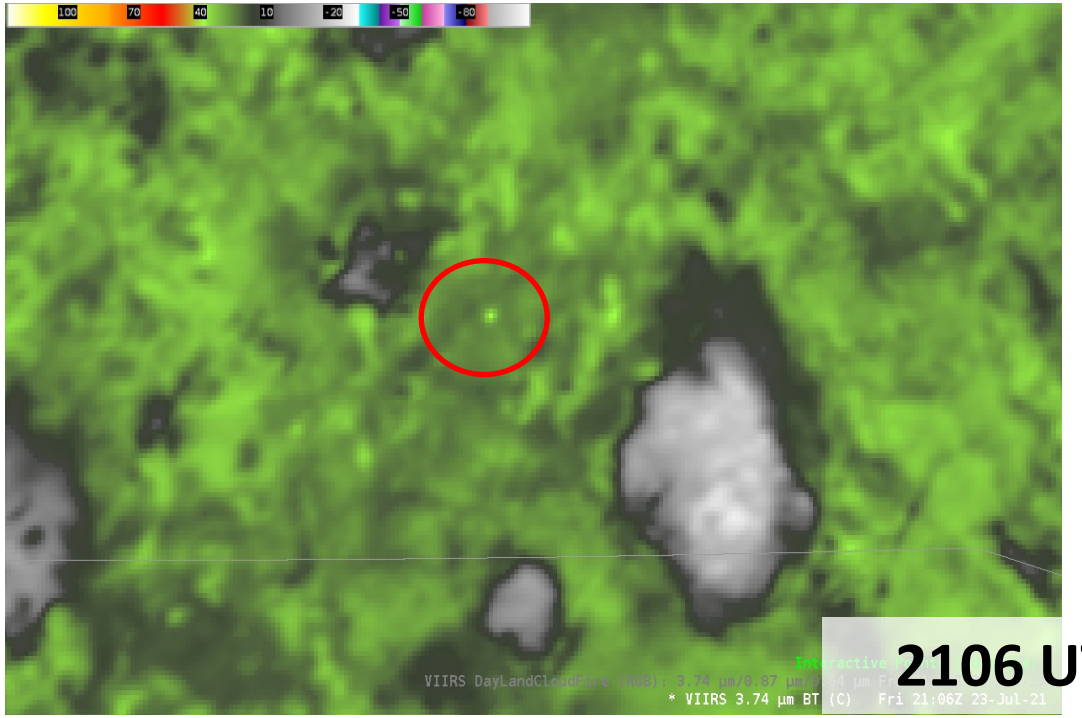


Zitzianna River Fire – 2319Z 24 Jul 2018

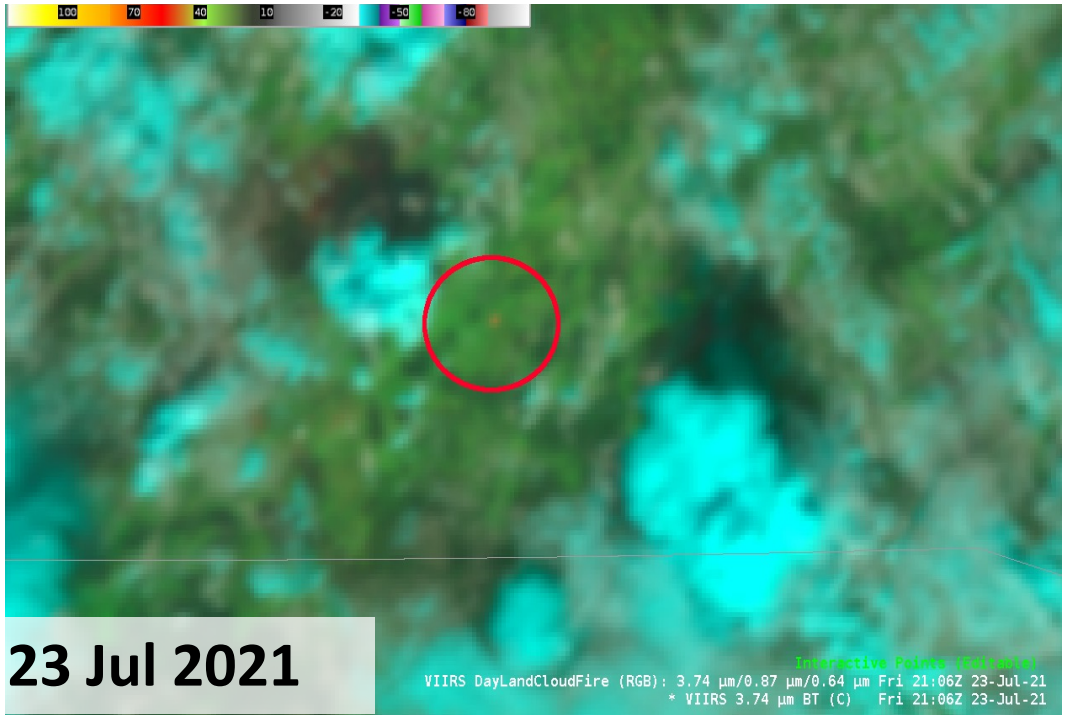
- Intense fires cause saturation of the sensor (BT = 95 C) and pixels appear cold due to “fold-over”
- DayFire RGB: cold pixels cause the red contribution to be negligible.
- Because of saturation, The hottest pixels in the fire are not apparent in the RGB.
- VIIRS i04 should be checked for saturation

DayFire RGB: Fire Detection and Context

VIIRS i04 (3.74 µm)



VIIRS DayFire RGB

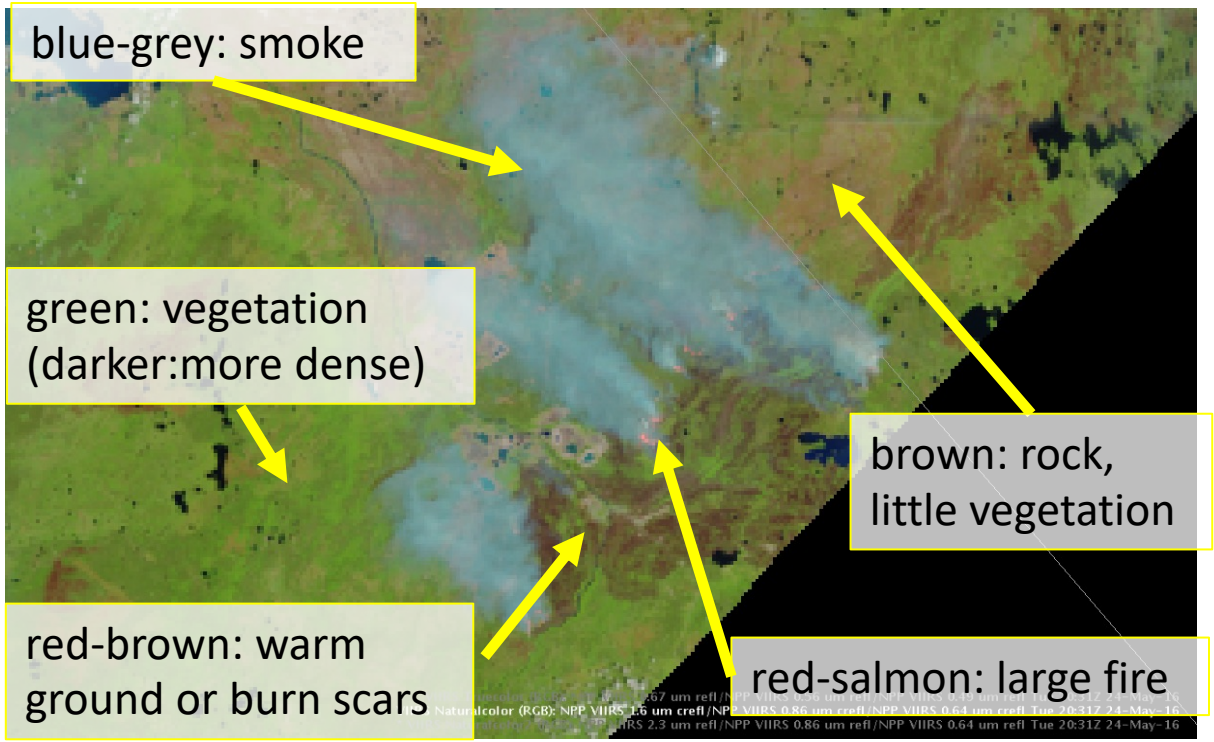


2106 UTC 23 Jul 2021

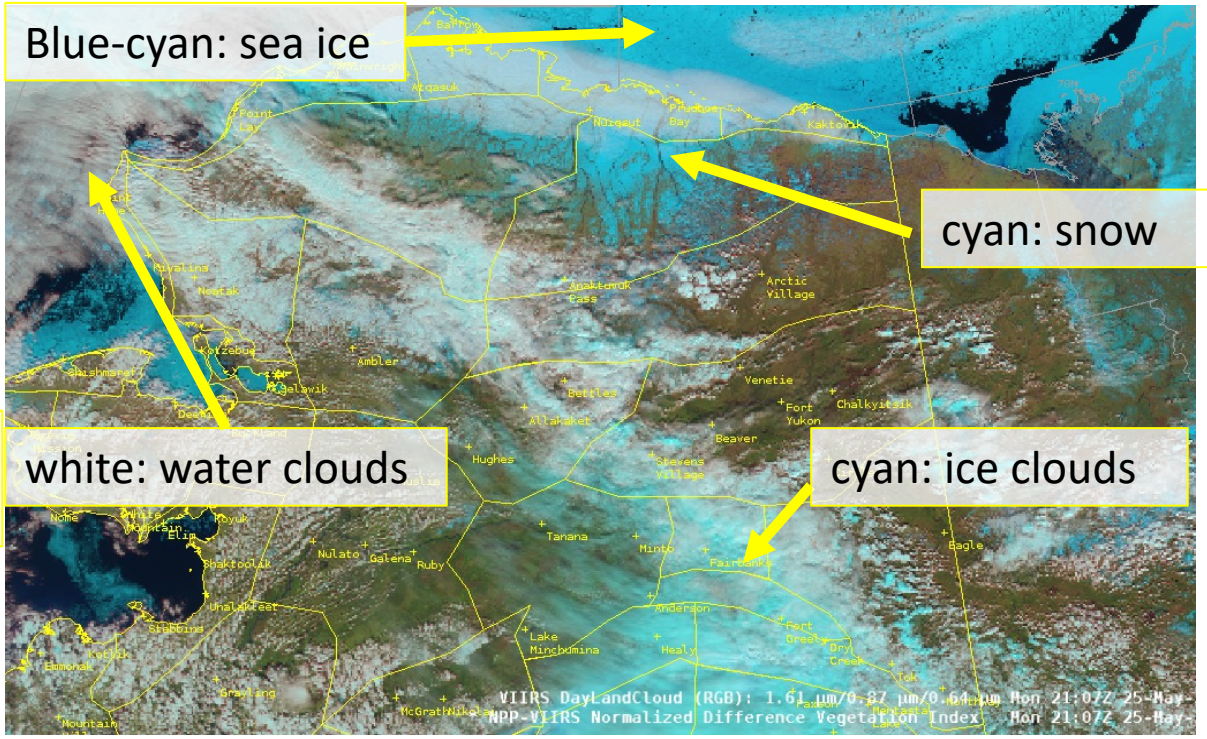
At times a detected heat point can seem suspicious in the shortwave IR when the thermal signal is weak and there are many other warm pixels from cloud reflectances in the area (left). The DayFire RGB (right) shows the warm pixel as faint red compared to the surroundings with no clouds are in the vicinity. The context suggests this fire detection is valid.

3. VIIRS DayLandCloud RGB

24 May 2016



25 May 2020



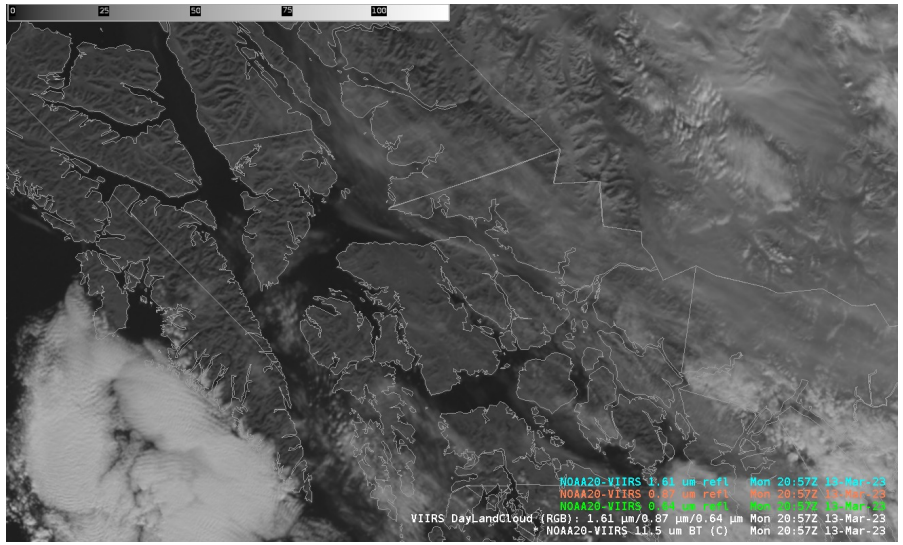
Similar to DayFire RGB <u>except uses S</u>now/ice band (1.61 µm) instead of Shortwave IR for red.

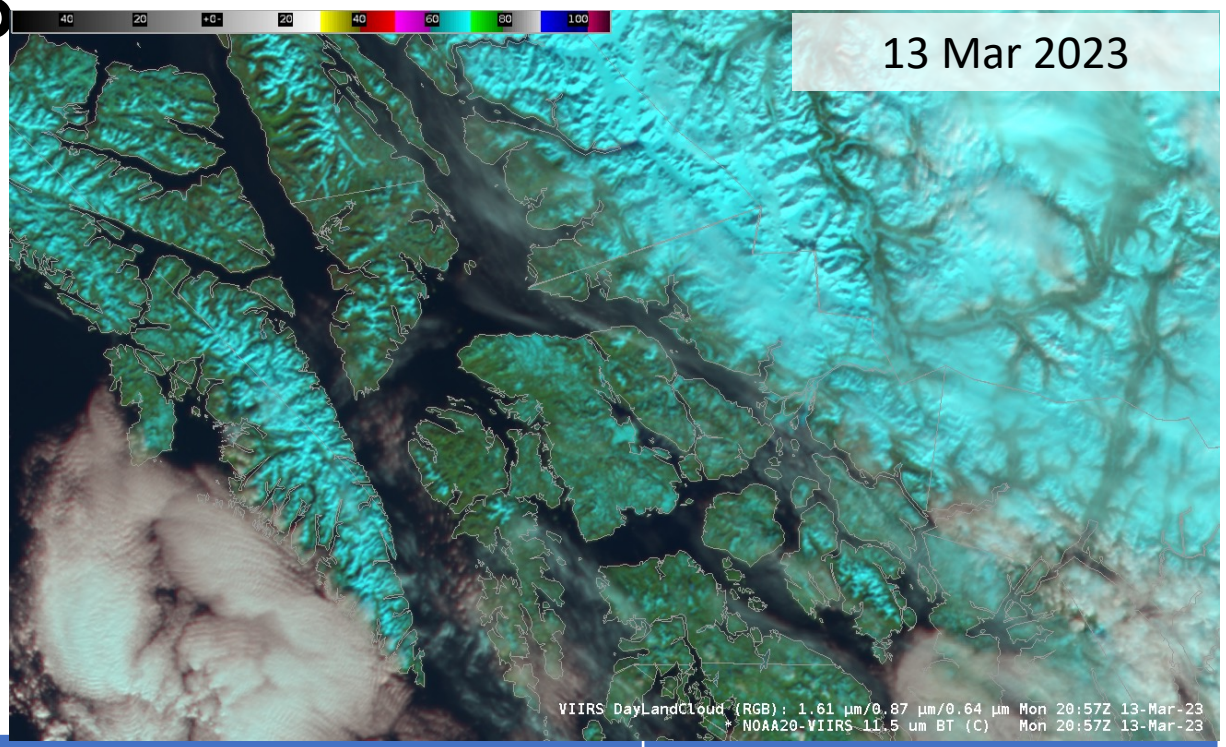
Identifies: Snow and ice (cyan – blue)

- Vegetation and land surface types (green – brown)
- Smoke (blue-grey) and large or Intense fires (red)
- Large, intense fires (red) … not as sensitive to fire as the Shortwave IR.

VIIRS DayLandCloud RGB

Aka: NaturalColor

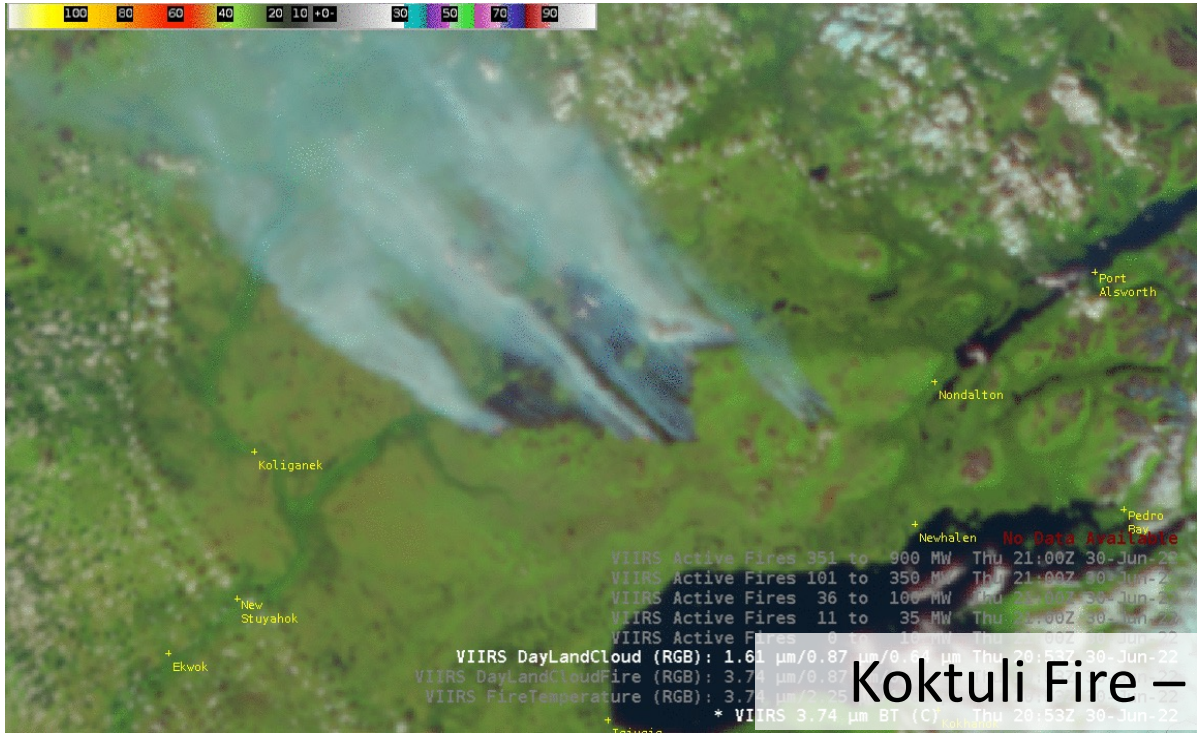




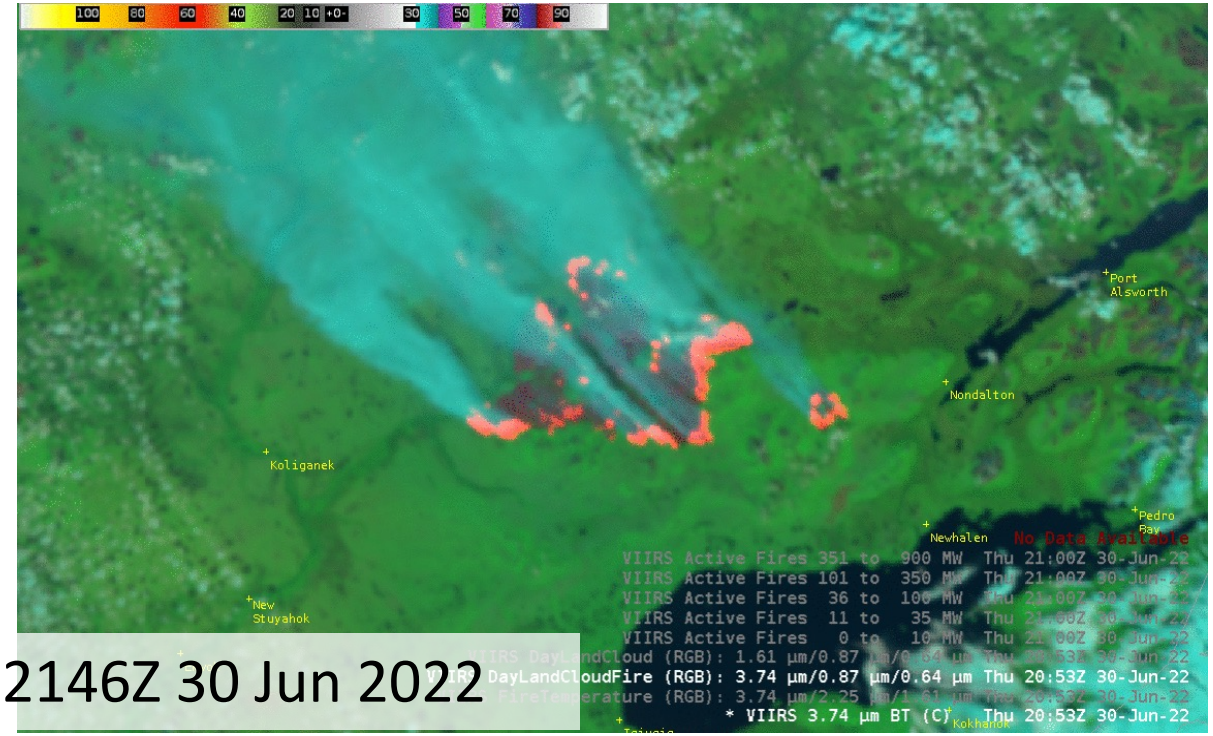
Color	Band (chnl)	Type	Res (m)	Large Contribution	Small Contribution
Red	1.61µm (i03)	Snow-Ice band (reflectance)	375	water clouds, desert, very large fires	snow , ice, water.
Green	0.87µm (i02)	Veggie band (reflectance)	375	thick clouds, vegetation, snow	water, bare ground, burn scars
Blue	0.64µm (i01)	Red visible (reflectance)	375	thick clouds, snow	water, bare ground, burn scars

DayLandCloud RGB vs DayFire RGB

DayLandCloud RGB



DayFire RGB



Koktuli Fire – 2146Z 30 Jun 2022

- Only sensitive to large or intense fires
- Easier to distinguish smoke from white cloud
- More color variation for ground and vegetation
- Better identification of snow and ice.

- Greater fire sensitivity for:
  - fire perimeter tracking
  - Identifying small fires
  - Identifying fires through thin clouds or smoke
  - Distinguishing smoke source

4. VIIRS i05 “Longwave IR” Band (11.5 µm)

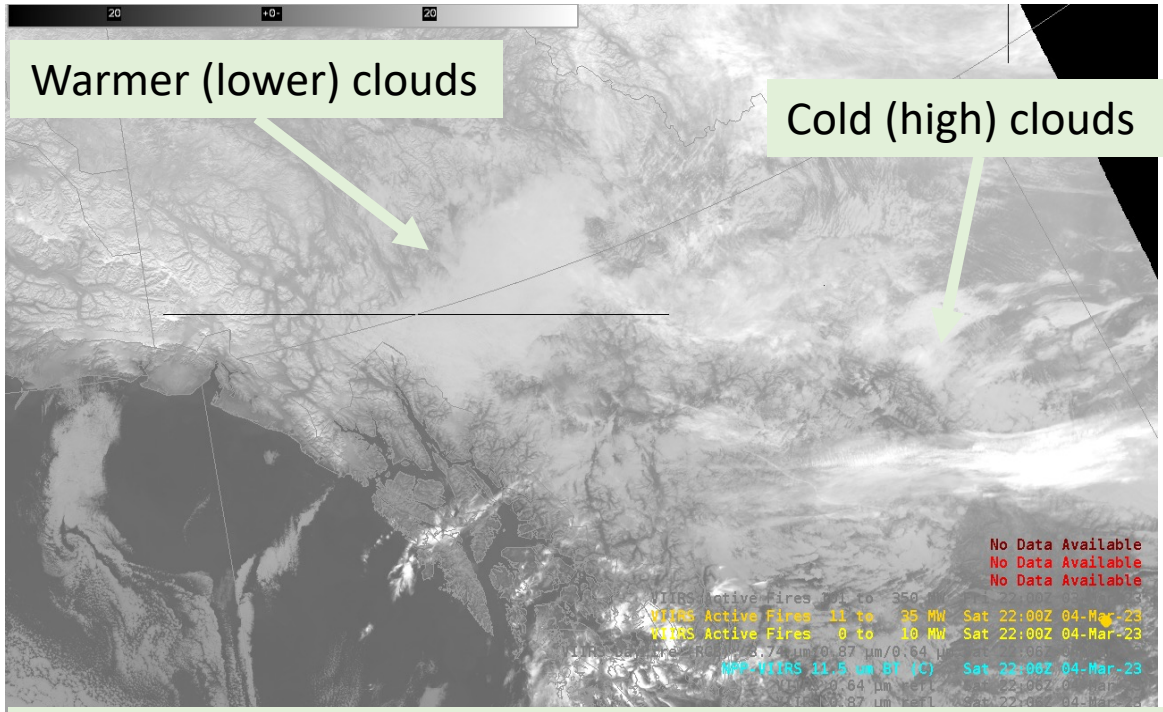
Colormap legend: colors assigned to Brightness Temperatures (BT)

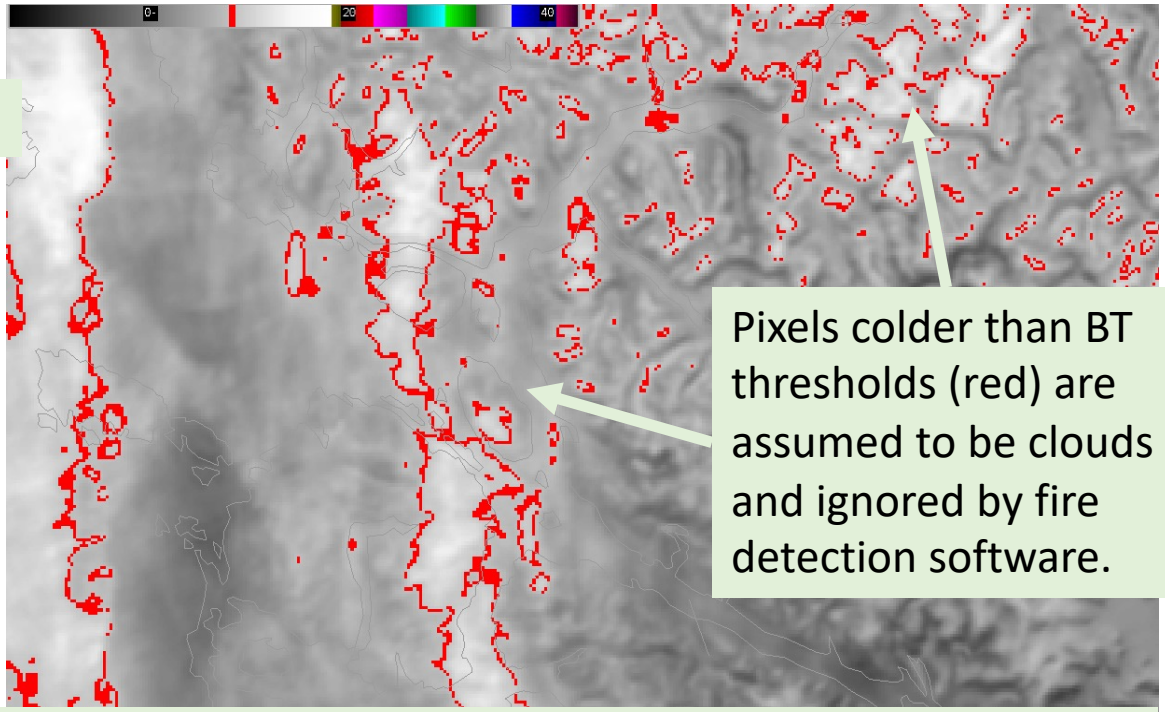
Max +55 °C

Min -109 °C

Hotter (+C°)

Colder (-C°)





- Shows location of clouds day or night that can obscure fires or look like smoke
- Emitted energy only – no solar reflectance
- Light shades (colder) = higher clouds; Dark shades (warmer) = lower clouds or ground
- Used by fire detection algorithm to identify clouds; Resolution: 375 m

Shortwave IR & Longwave IR: Verifying Fires

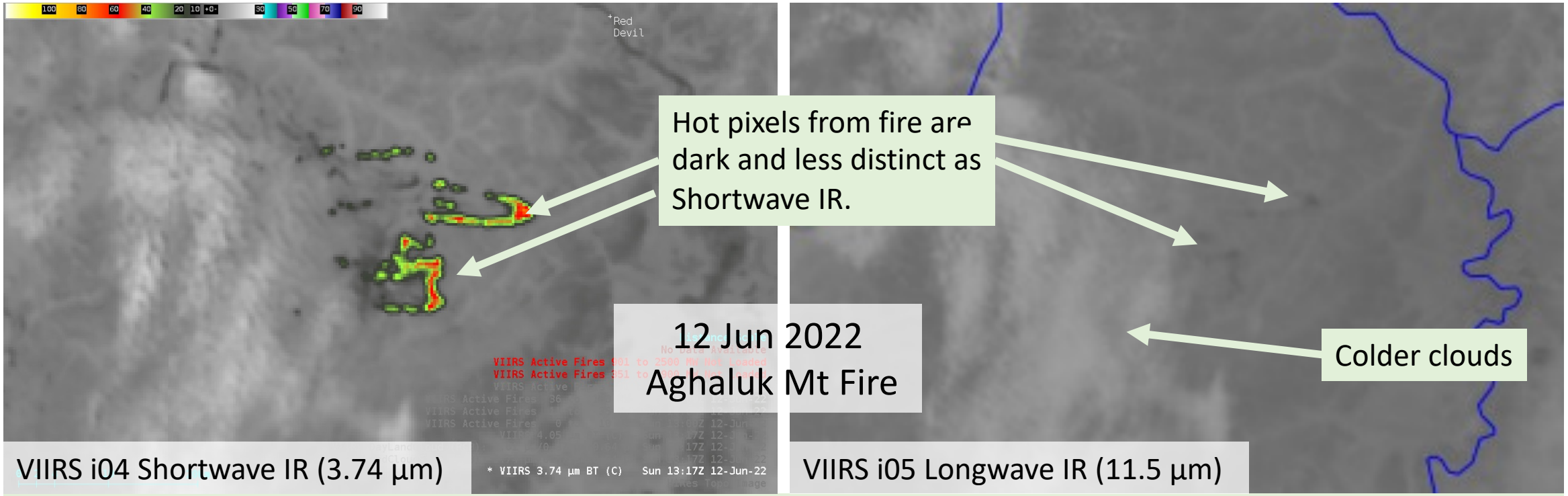
Colormap legend: colors assigned to Brightness Temperatures

Max +55 °C

Min -109 °C

Hotter (+C°)

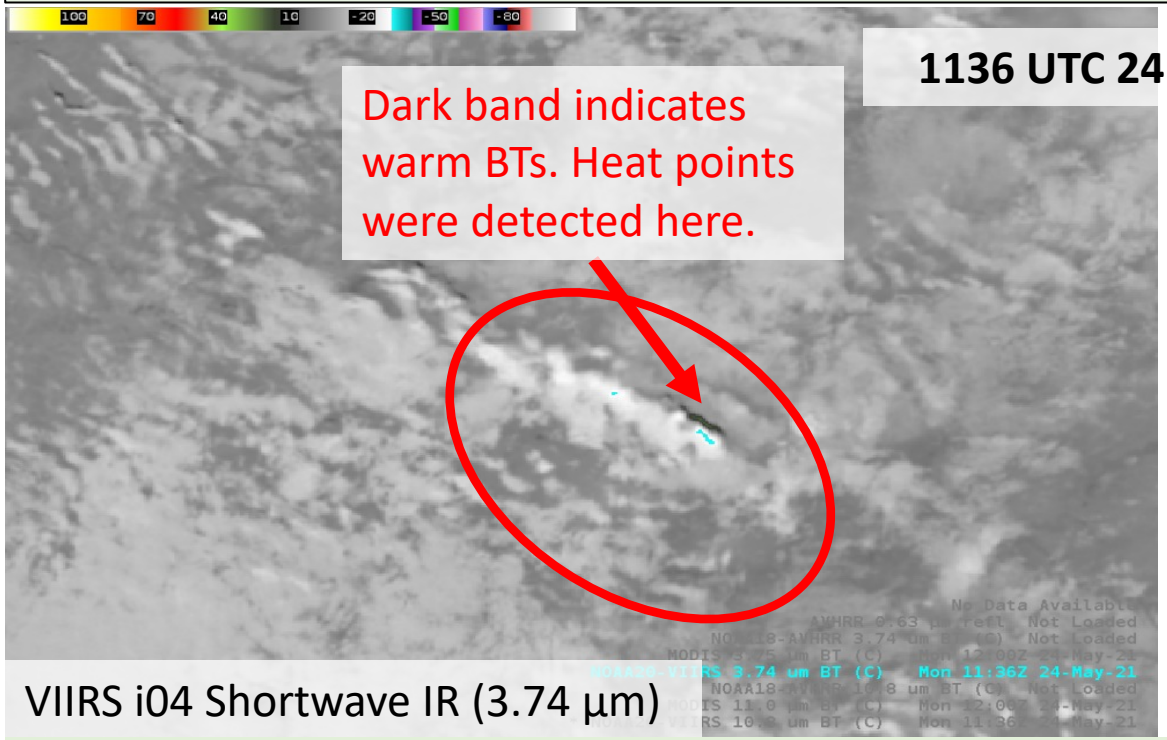
Colder (-C°)



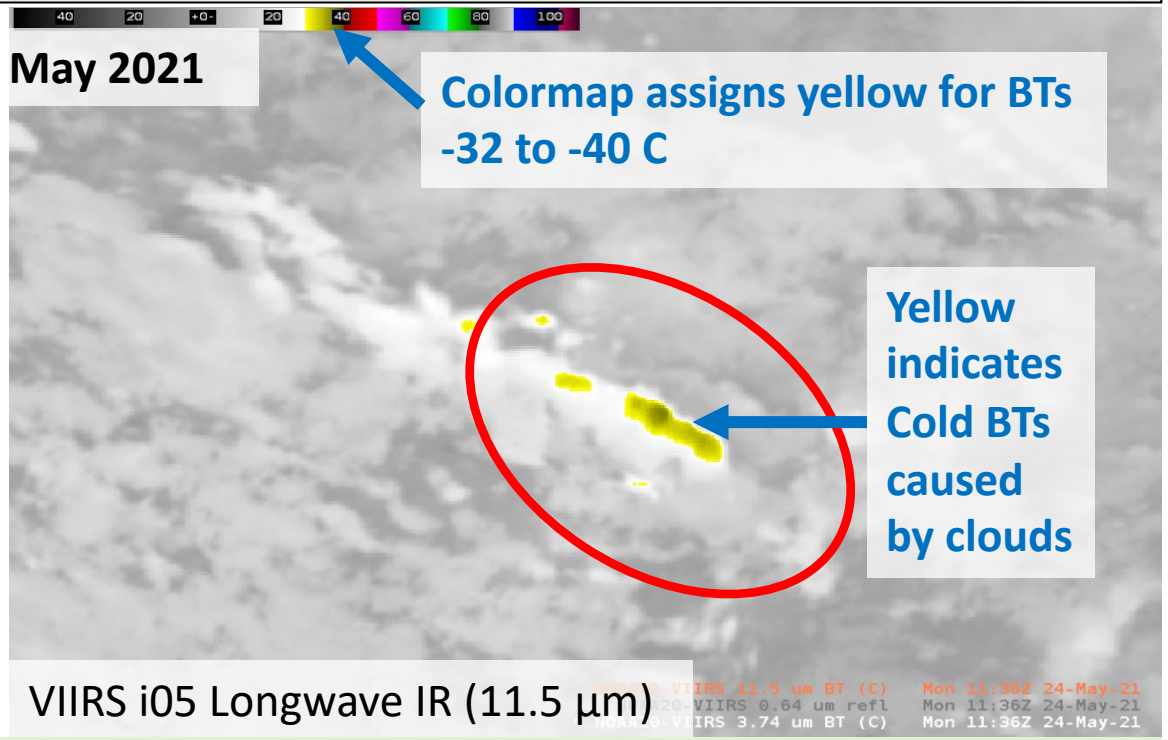
- Longwave IR helps to identify clouds that can obscure fires or be misinterpreted in the Shortwave IR
- Fires generate some longwave IR emissions: darker (warmer) pixels
- Lighter (colder) pixels indicate clouds (clouds will usually be colder than smoke)

Shortwave IR & Longwave IR: Verifying Fires

High latitude summer nights with steep sun angles can have exaggerated shortwave IR values (VIIRS i04 – 3.74 µm) due to cloud top reflectances.



VIIRS i04 Shortwave IR (3.74 µm)

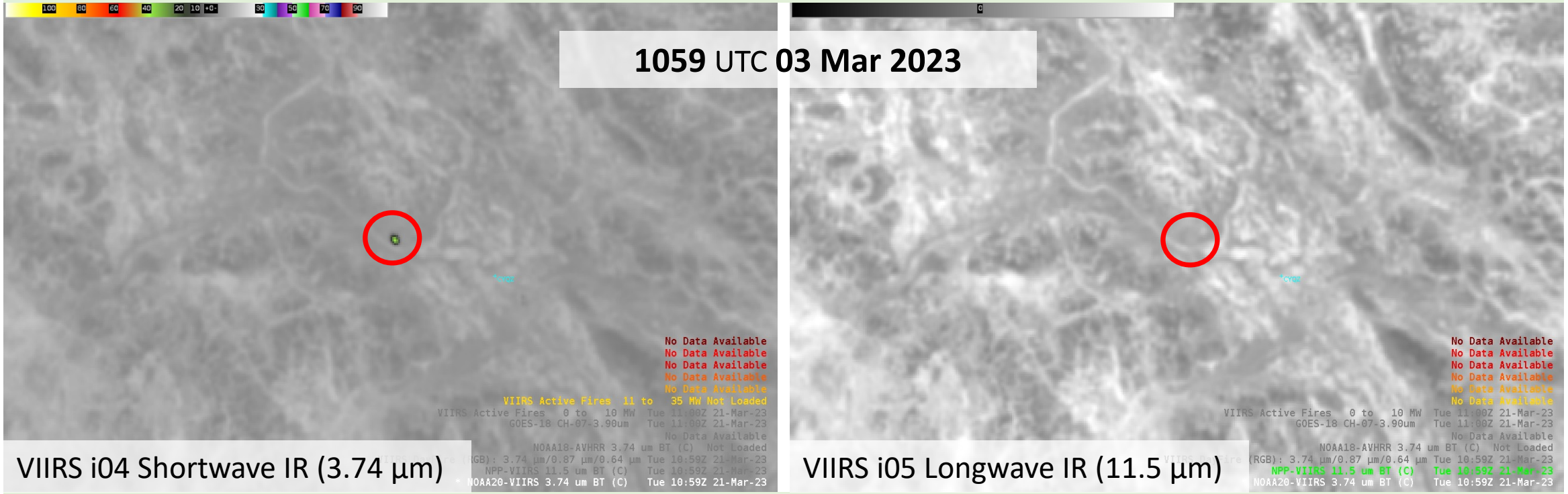


VIIRS i05 Longwave IR (11.5 µm)

Check for false detections due to cloud reflectances at night by comparing the VIIRS i04 Shortwave IR with the VIIRS i05 Longwave IR.

Shortwave IR & Longwave IR: Verifying Fires

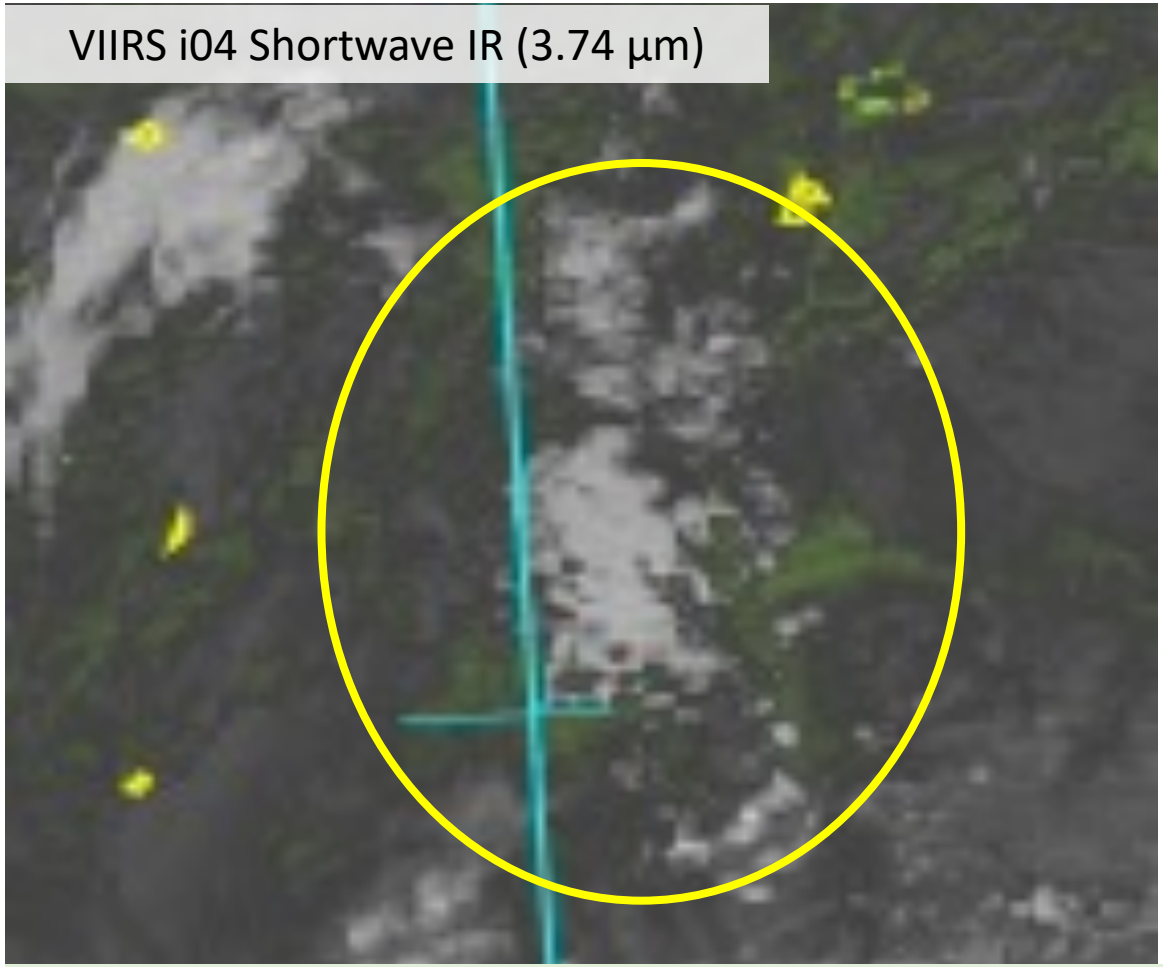
Left: the VIIRS i04 Shortwave IR (3.74 µm) shows a single hot pixel where a fire point was detected at night.

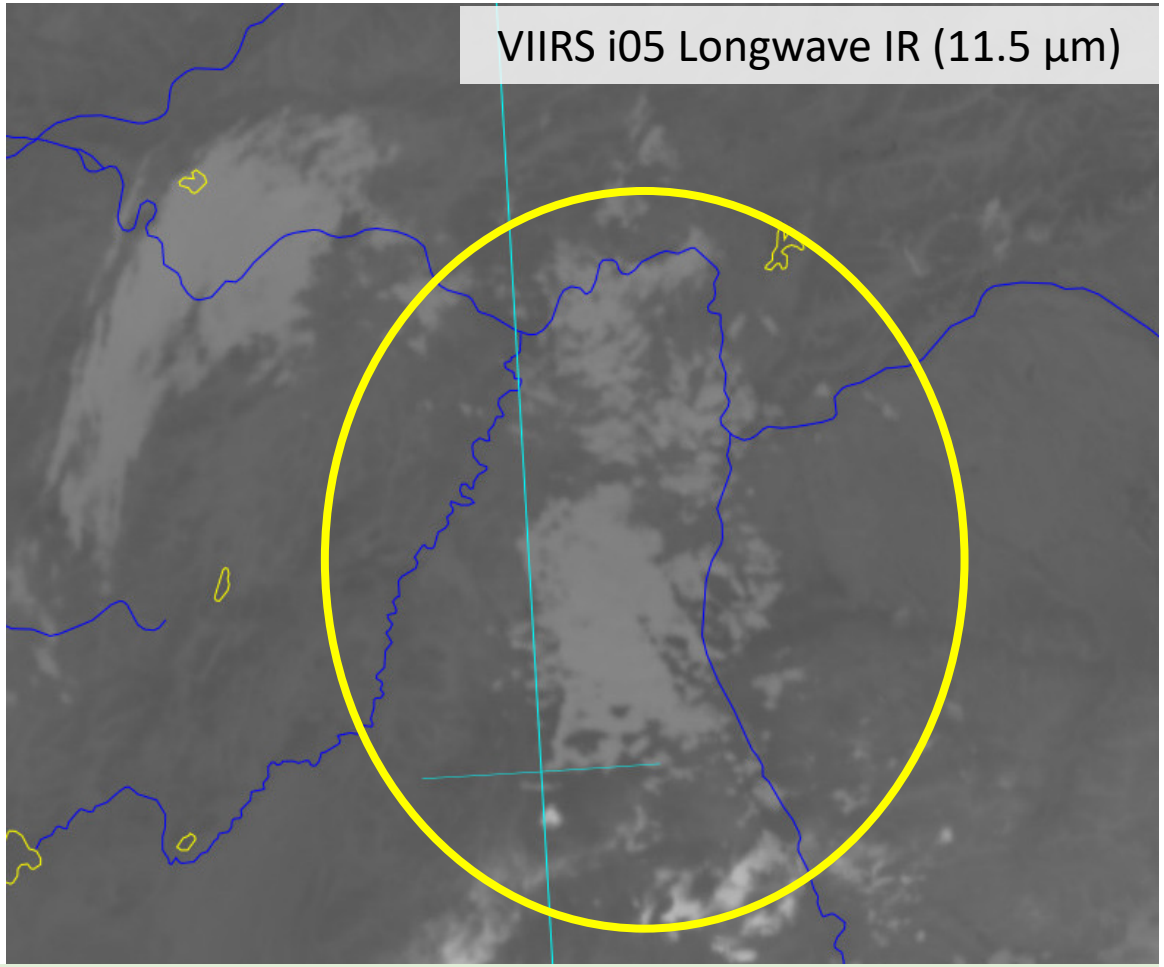


Right: the VIIRS i05 Longwave IR shows warm pixels in the same location and no cold cloud tops. Warm BTs and no clouds in the Longwave IR confirms the point is a valid fire.

Shortwave IR & Longwave IR: Hot Smoke

Clear Lake Fire 01 Jul 2022

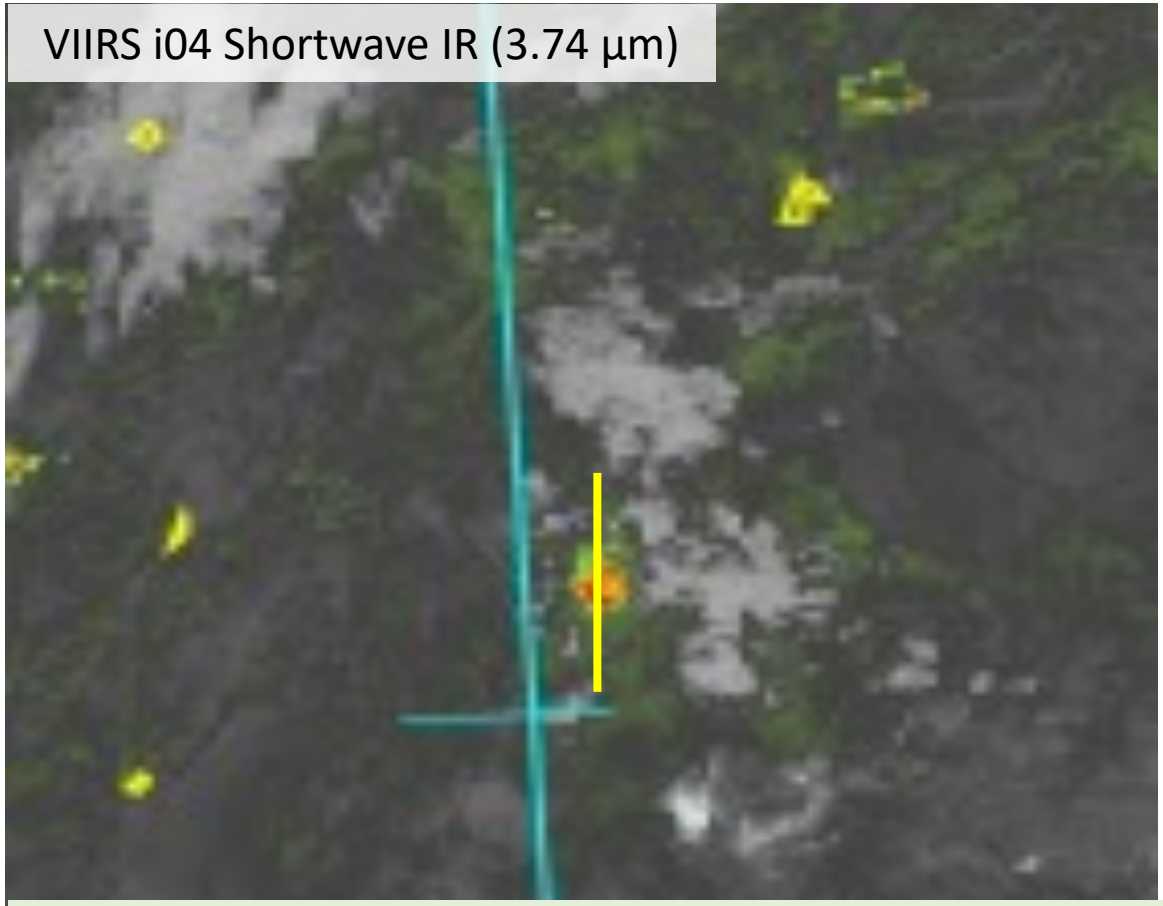


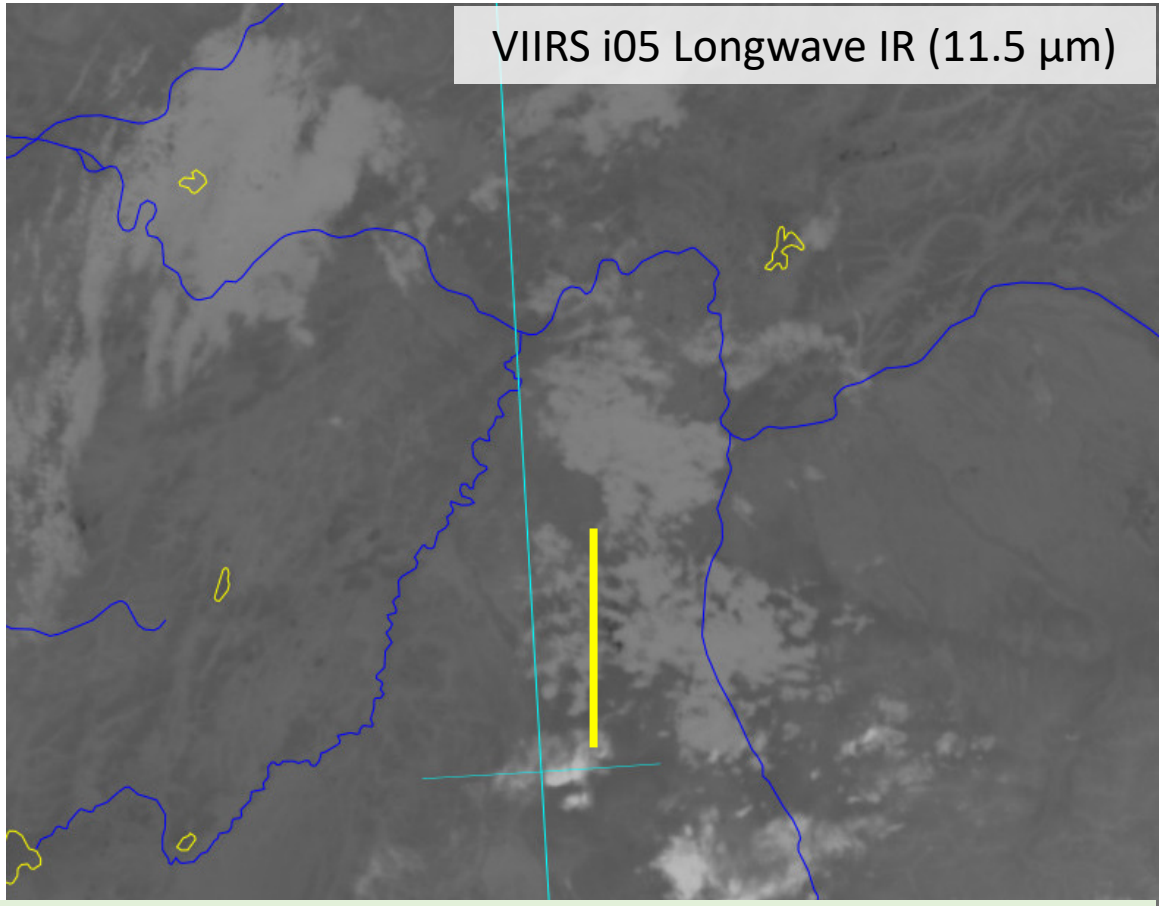


1041Z – Nighttime event, so no reflectance imagery available. Hot atmosphere and shaded ground from clouds creates unstable thermal layer

Shortwave IR & Longwave IR: Hot Smoke

Clear Lake Fire 01 Jul 2022

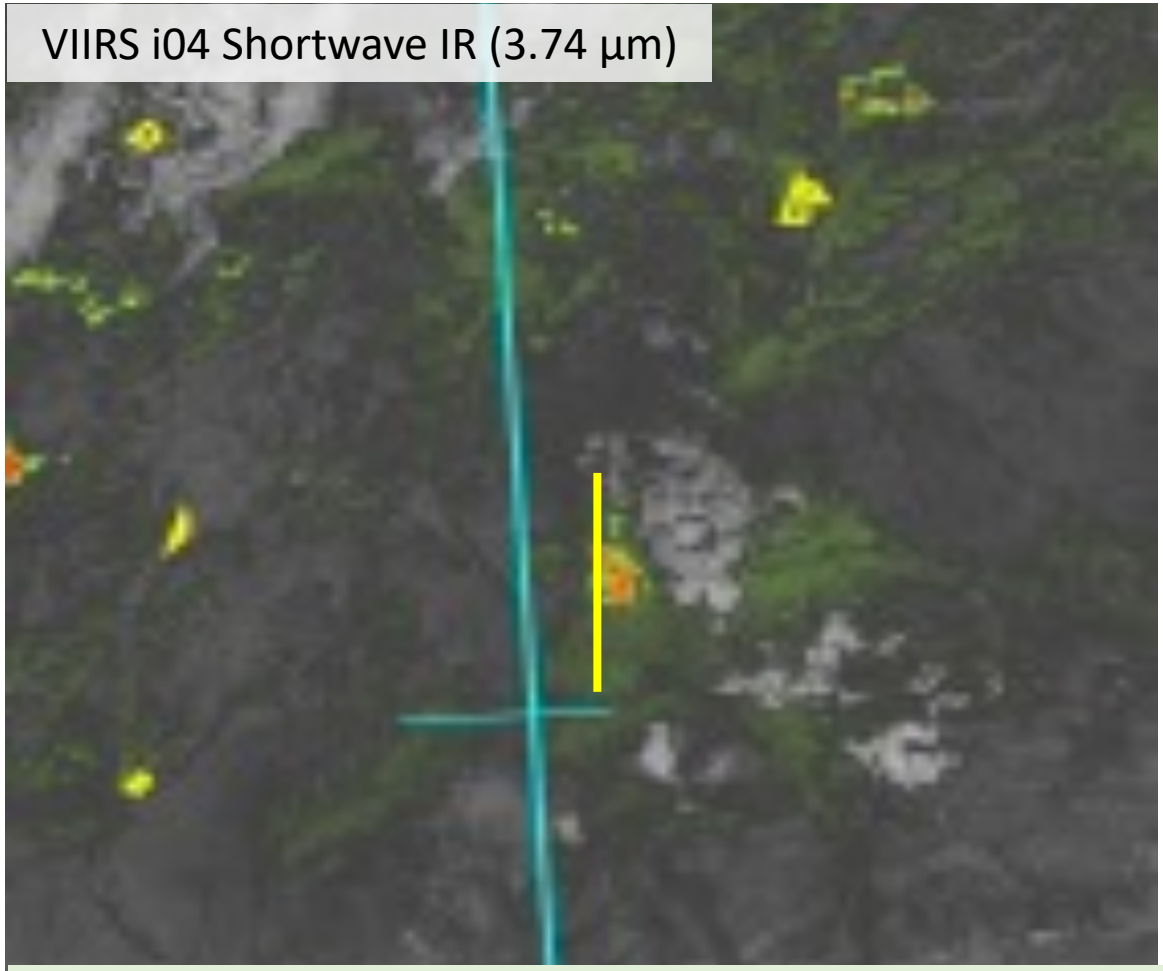


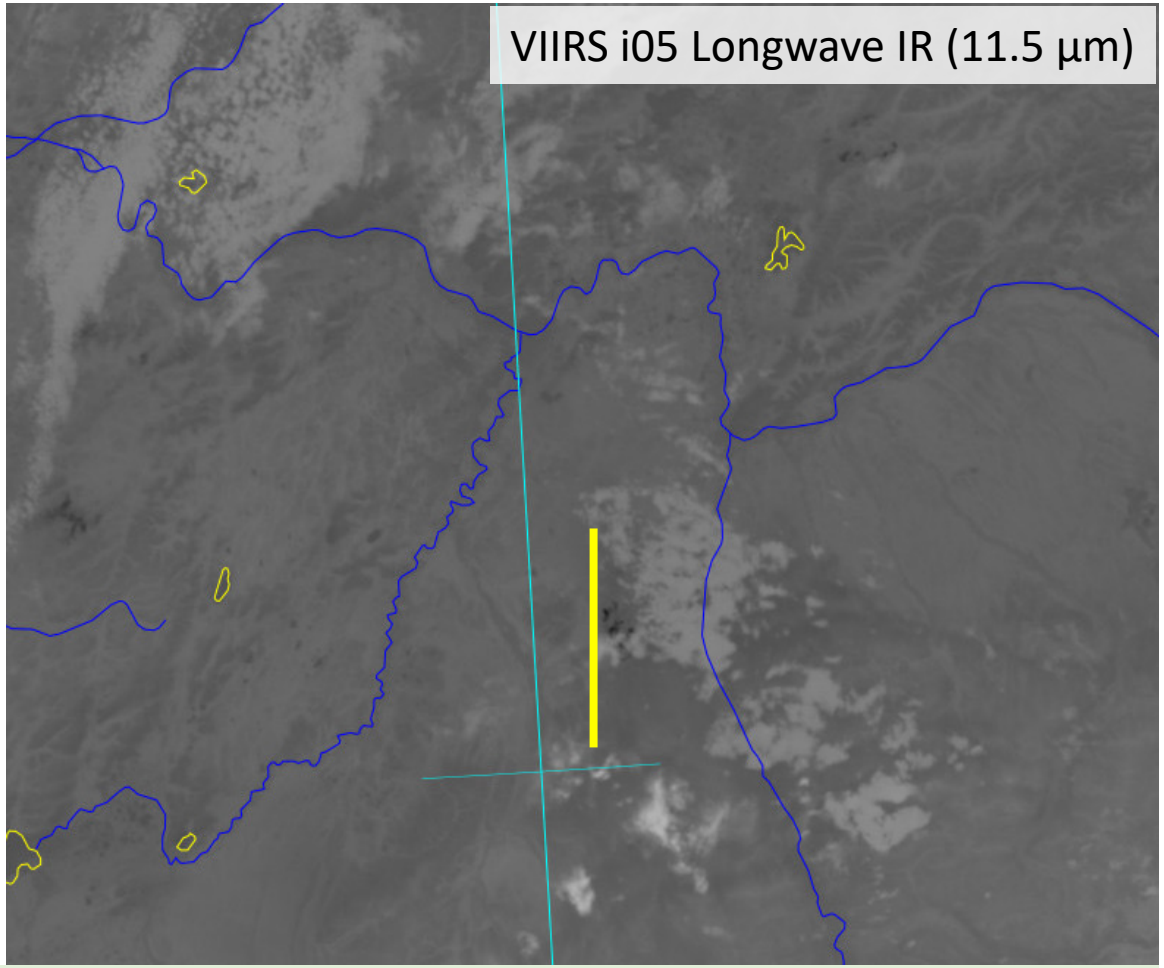


1131Z - Clearing skies increase updrafts and oxygen-rich inflow. Trapped pockets of flammable gas aloft are suddenly ignited. Note: West of the yellow line, Shortwave IR shows some hot fire pixels and Longwave IR shows fewer clouds.

Shortwave IR & Longwave IR: Hot Smoke

Clear Lake Fire 01 Jul 2022

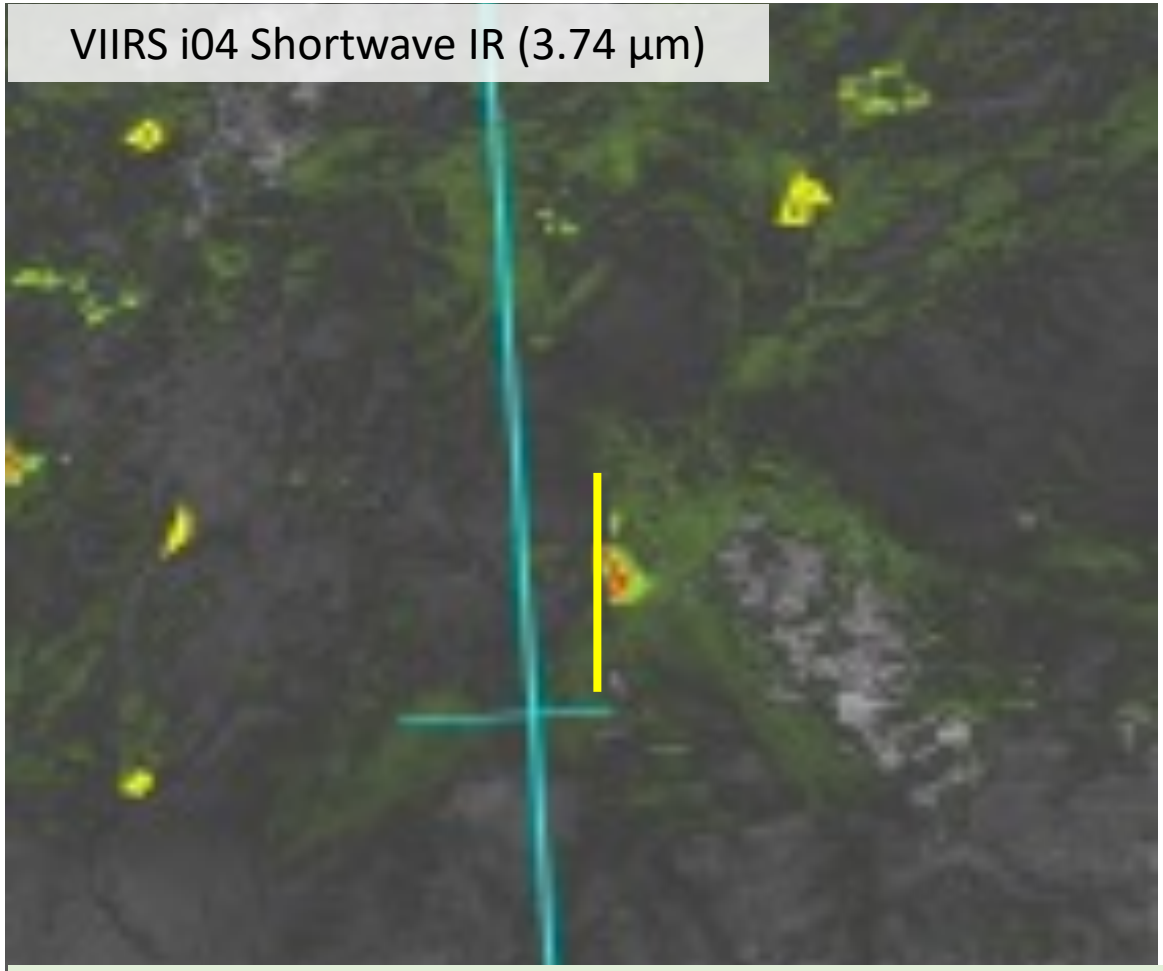


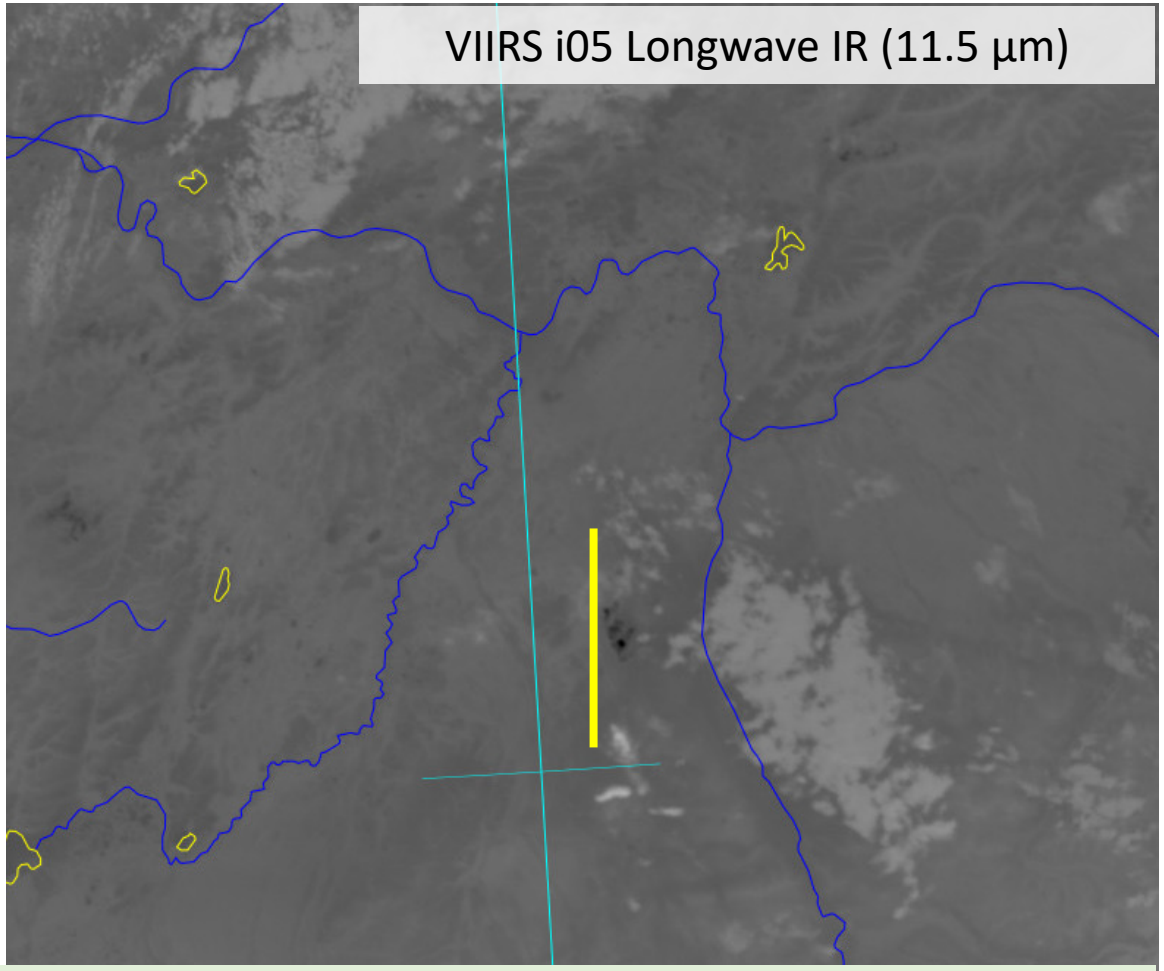


1220Z Clouds have moved east and fire pixels are now farther east. Note that dark hot pixels in the Longwave IR are east of the yellow line.

Shortwave IR & Longwave IR: Hot Smoke

Clear Lake Fire 01 Jul 2022

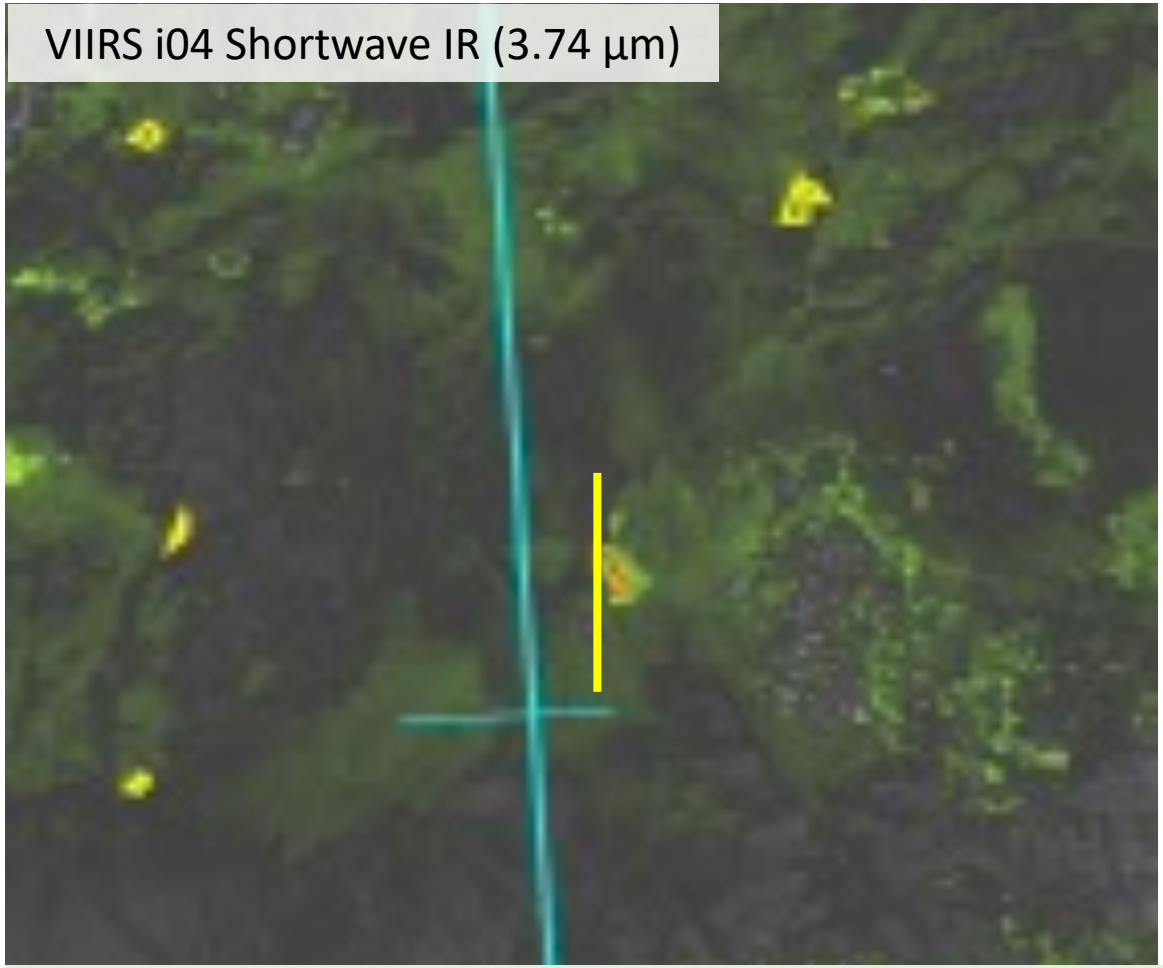


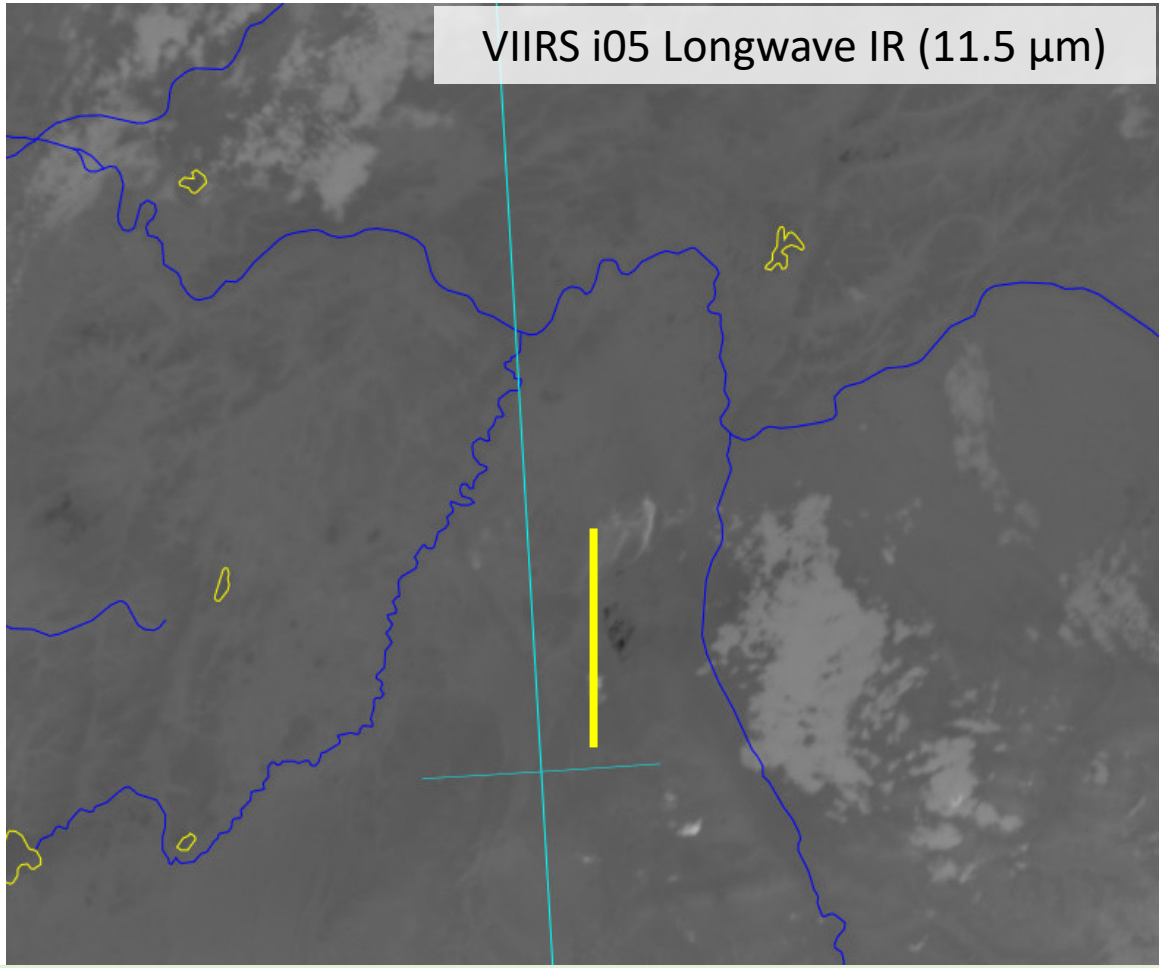


1310Z Clouds have moved well east and fire pixels are remain east of the yellow line. Note that dark hot pixels in the VIIRS i05 are also all east of the yellow line.

Shortwave IR vs Longwave IR: Hot Smoke

Clear Lake Fire 01 Jul 2022

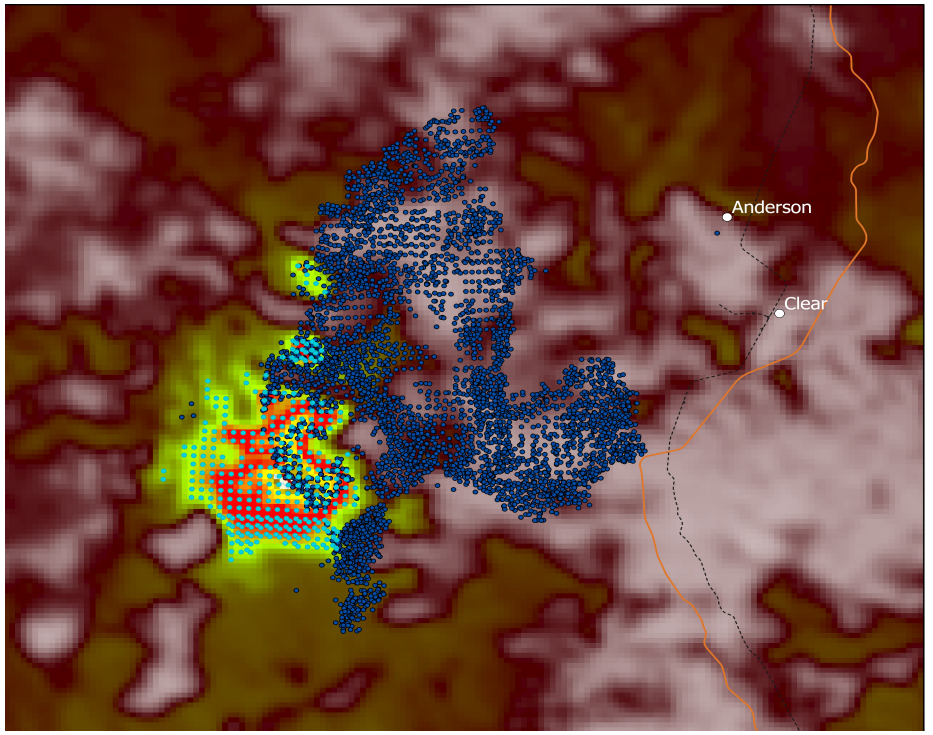




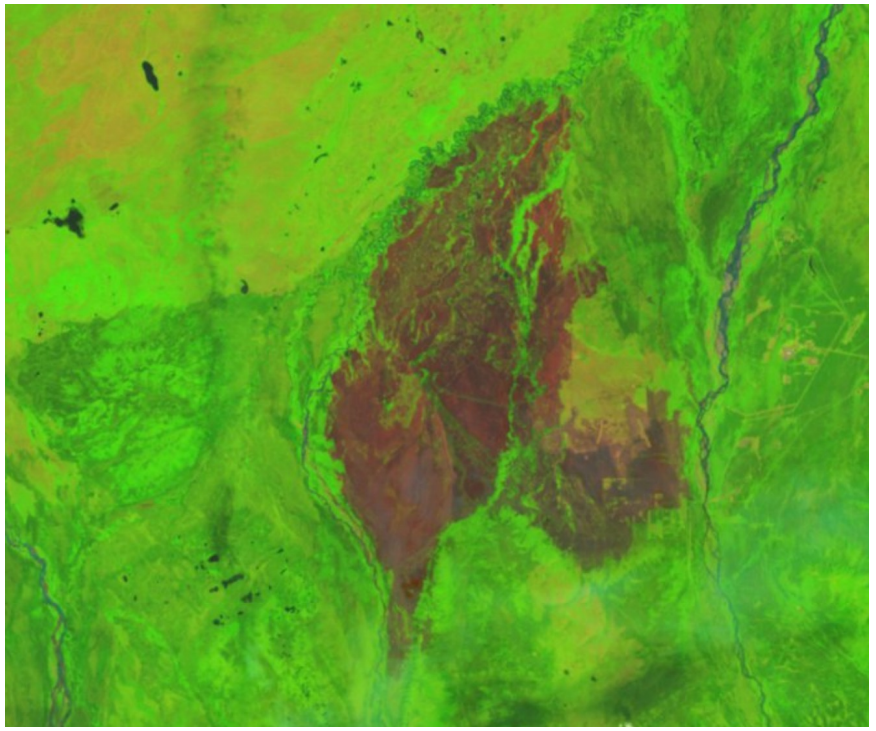
1401Z – Longwave IR shows clear skies in area of fire with all dark hot pixels east of the line. Shortwave IR also shows all fire pixels east of the yellow line.

Hot Smoke

Clear Lake Fire
01 Jul 2022



VIIRS Shortwave IR (3.74 µm)
1131 UTC 01 Jul 2022

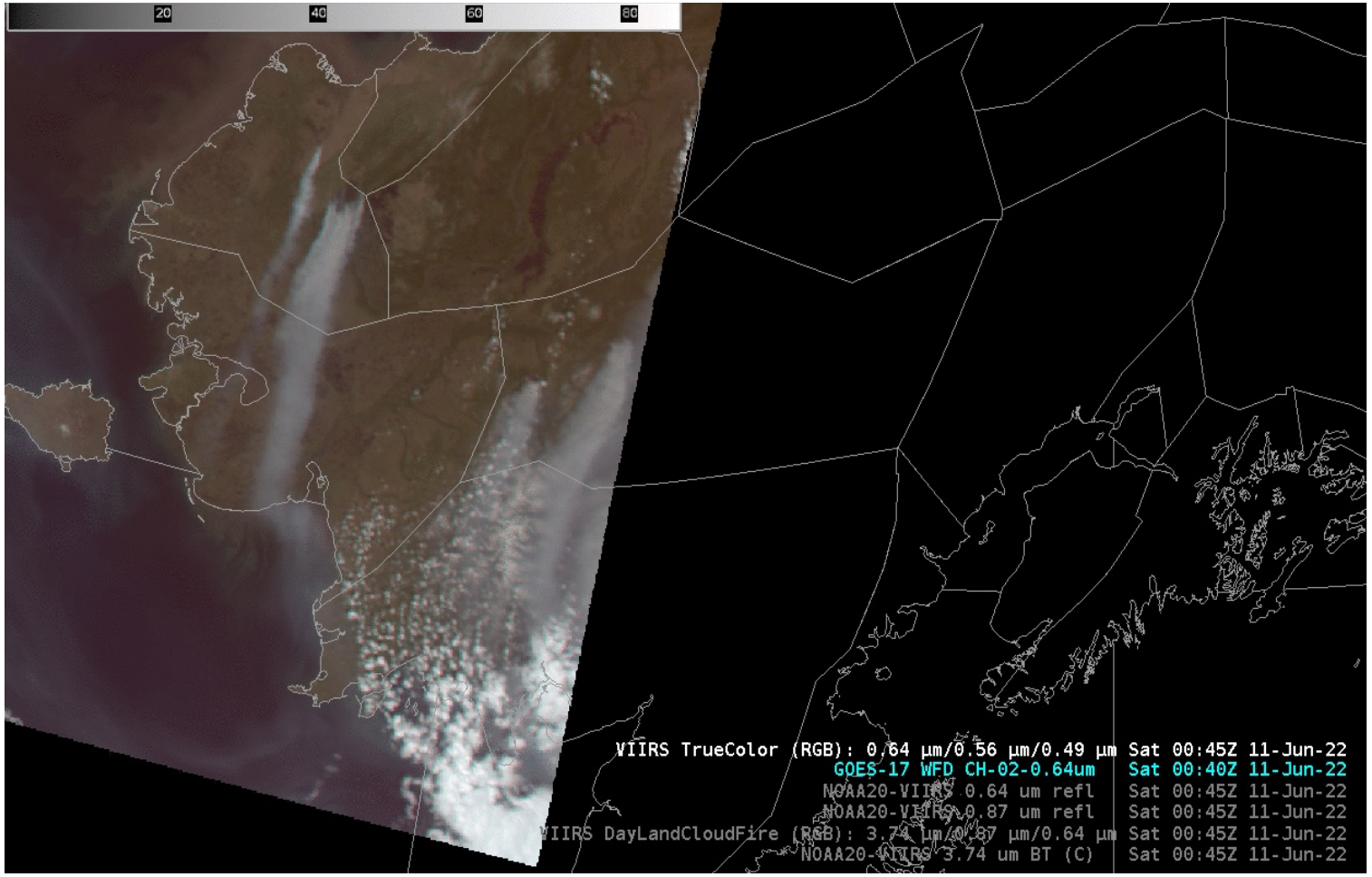


Landsat DayLandCloud RGB
21?? UTC 01 Jul 2022

- Difficult to diagnose. Often evaluated in terms of context or trends.
- The 1131Z VIIRS Shortwave IR above showed hot pixels well to the west of the previous known perimeter
- Nighttime events have no visible products or RGBs for analysis. Longwave IR can be helpful.
- Later in the day, burn scars in the DayLandCloud RGB confirms fire perimeter had not moved west.
- Compare previous and subsequent Shortwave IR/Longwave IR images for unusual perimeter movement

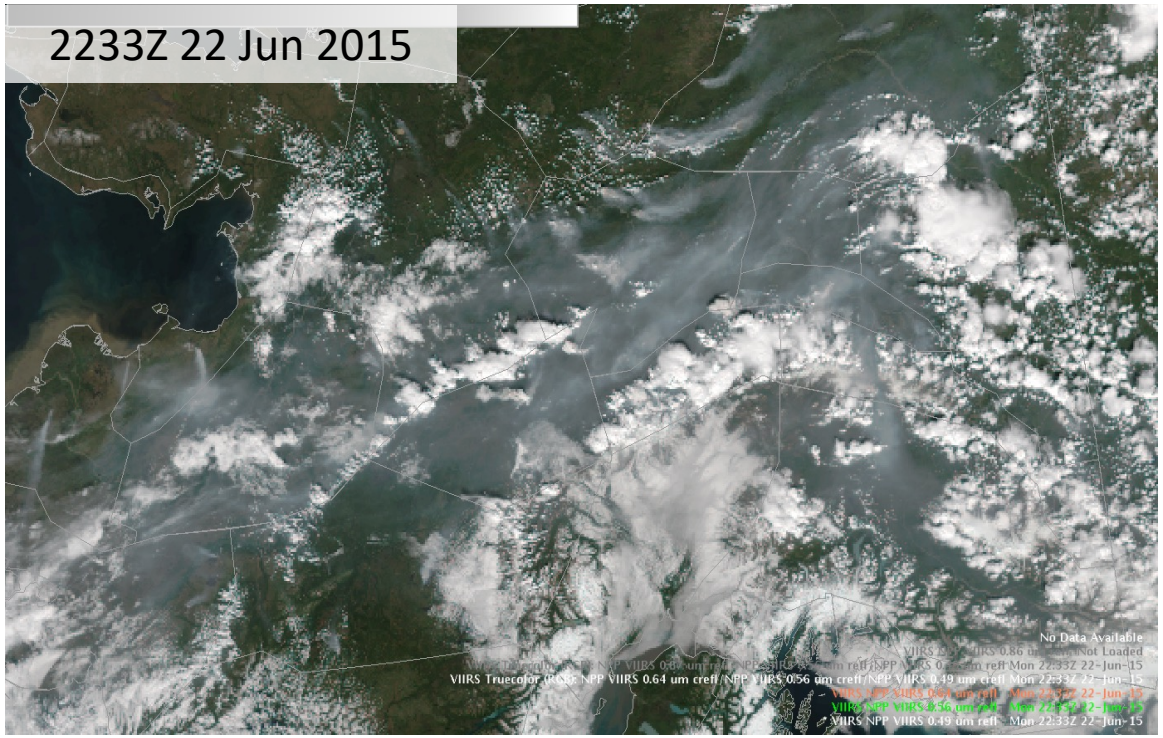
5. VIIRS TrueColor RGB

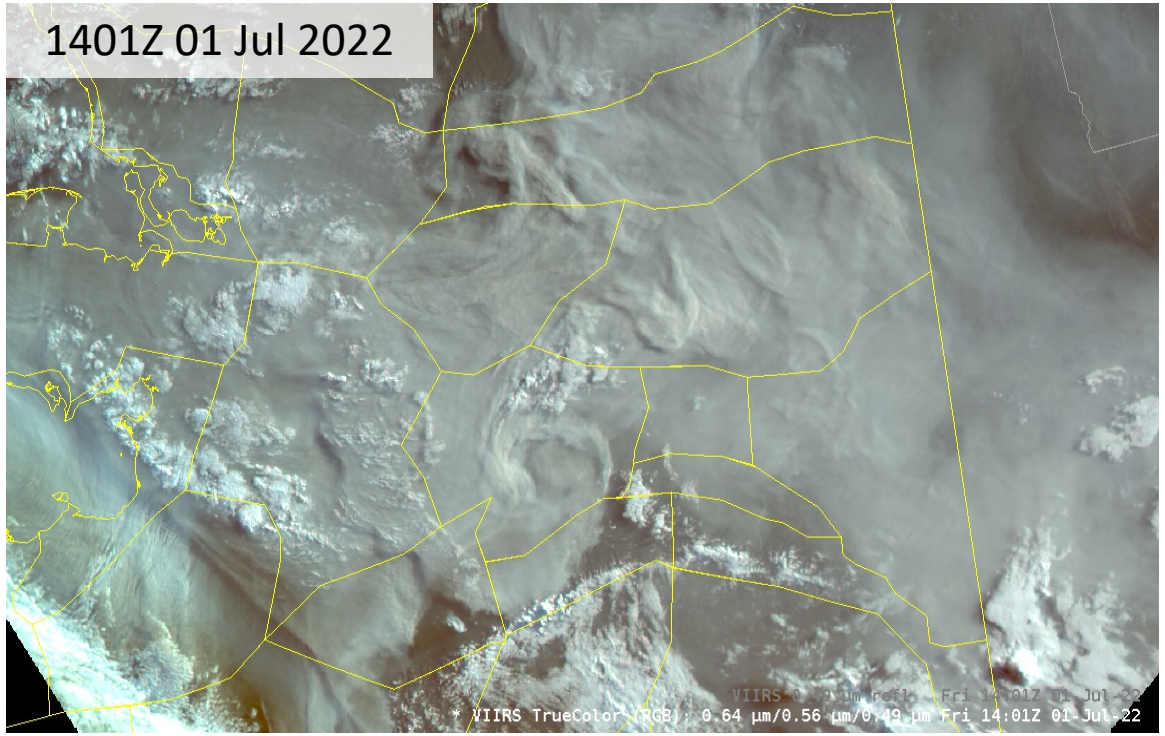
- Made from red, green and blue visible bands
- Similar to what the human eye sees
- Sensitive to smoke and aerosols
- Can be hazy unless atmospheric “Raleigh” scattering removed
- Resolution: 750 m (some sharpening possible with i01 band)



11 Jun 2022

5. VIIRS TrueColor RGB



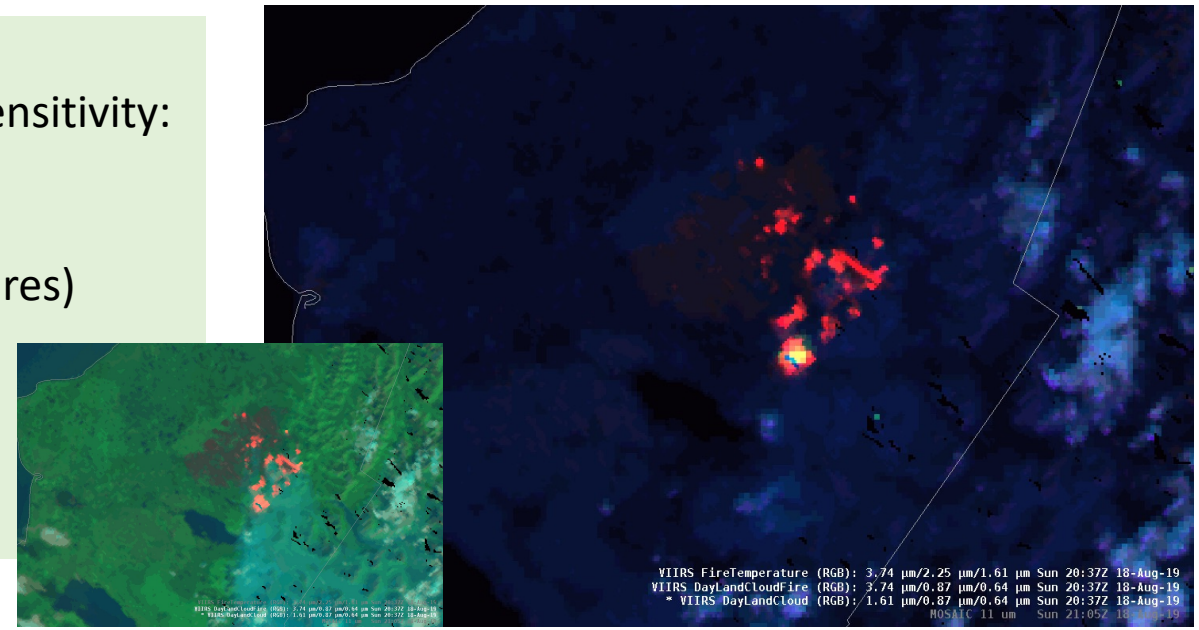


Color	Band (chnl)	Type	Res	Large Contribution	Small Contribution
Red	0.64µm (i01)	Red visible band	375	clouds, snow	water, bare ground
Green	0.57µm (m04)	Green visible band	750	clouds, snow, green vegetation	water, dry or bare ground
Blue	0.49µm (m03)	Blue visible band	750	clouds, snow, smoke & aerosols	water, bare ground

6. VIIRS FireTemperature RGB

- Provides qualitative estimate of fire intensity
- Color contribution from each band based fire sensitivity:
  - Red = most sensitive (all detectable fires)
  - Yellow = green + red (moderate fires)
  - White = red + green + blue (most intense fires)
- Color combination similar to real fires.
- Resolution: 750 m
- Daytime only (uses 1 reflectance bands)
- Does not show smoke

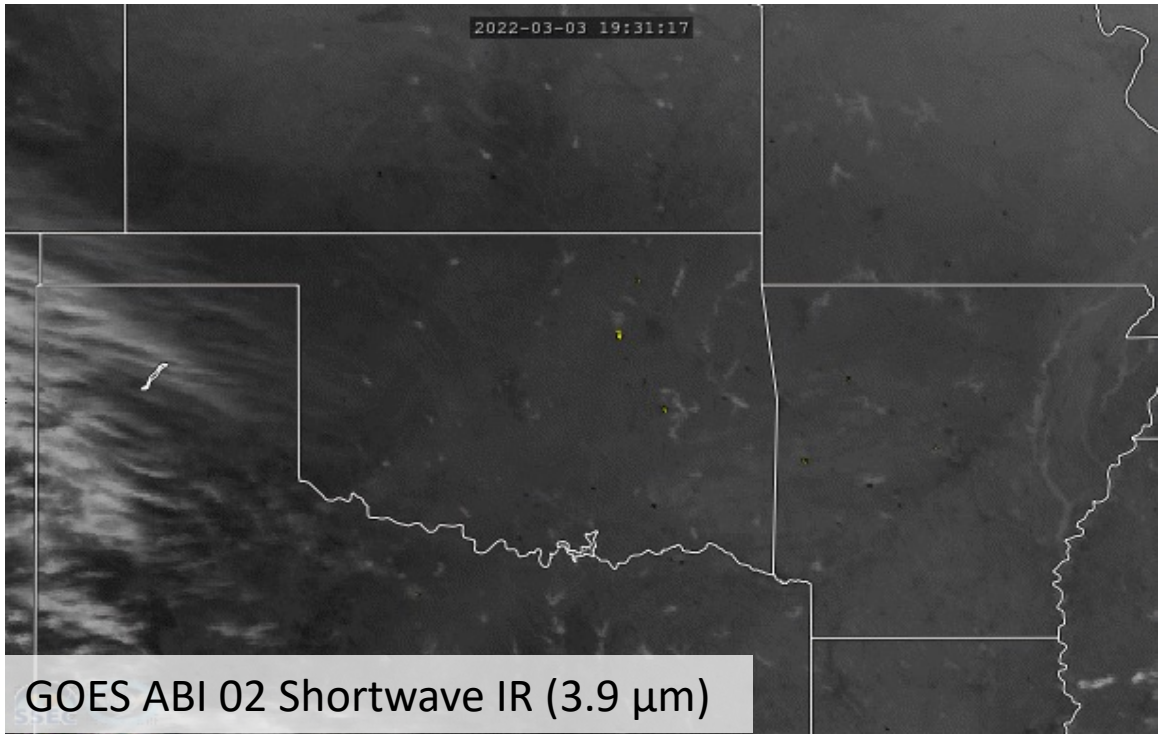
Swan Lake Fire



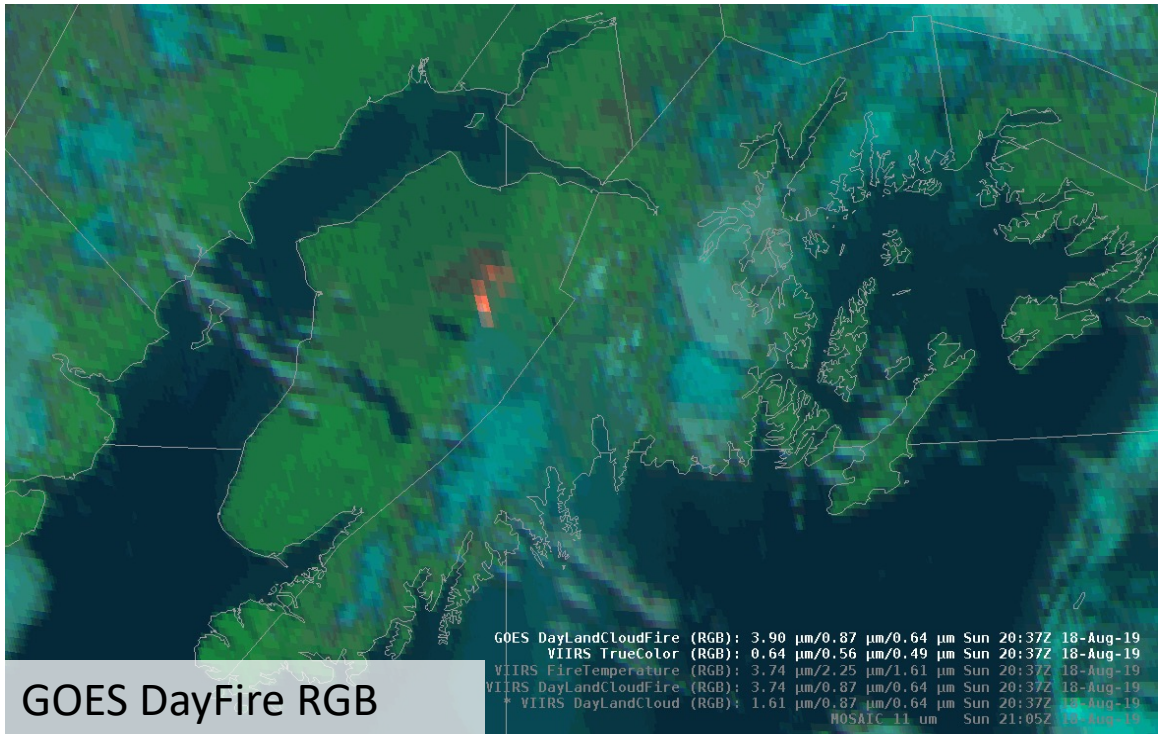
Color	Band (chnl)	Type	Large Contribution	Small Contribution
Red	3.74 µm (i04)	Shortwave IR band (infrared)	Warm land surfaces, hot spots or fires	Cold land surfaces, snow, ice, cold clouds.
Green	2.25 µm (m11)	Veggie band (reflectance)	Dry grass, bare ground, moderate fires, small cloud particles	Water, forests, snow, ice, large cloud particles
Blue	1.61 µm (i03)	Red visible (reflectance)	Dry vegetation, bare ground, very intense fires, liquid clouds	Snow, Ice, Green vegetation, water, ice clouds

Other Important Satellites, Sensors, and Fire Products

GOES Shortwave IR (3.9 µm) and DayFire RGB



GOES ABI 02 Shortwave IR (3.9 µm)

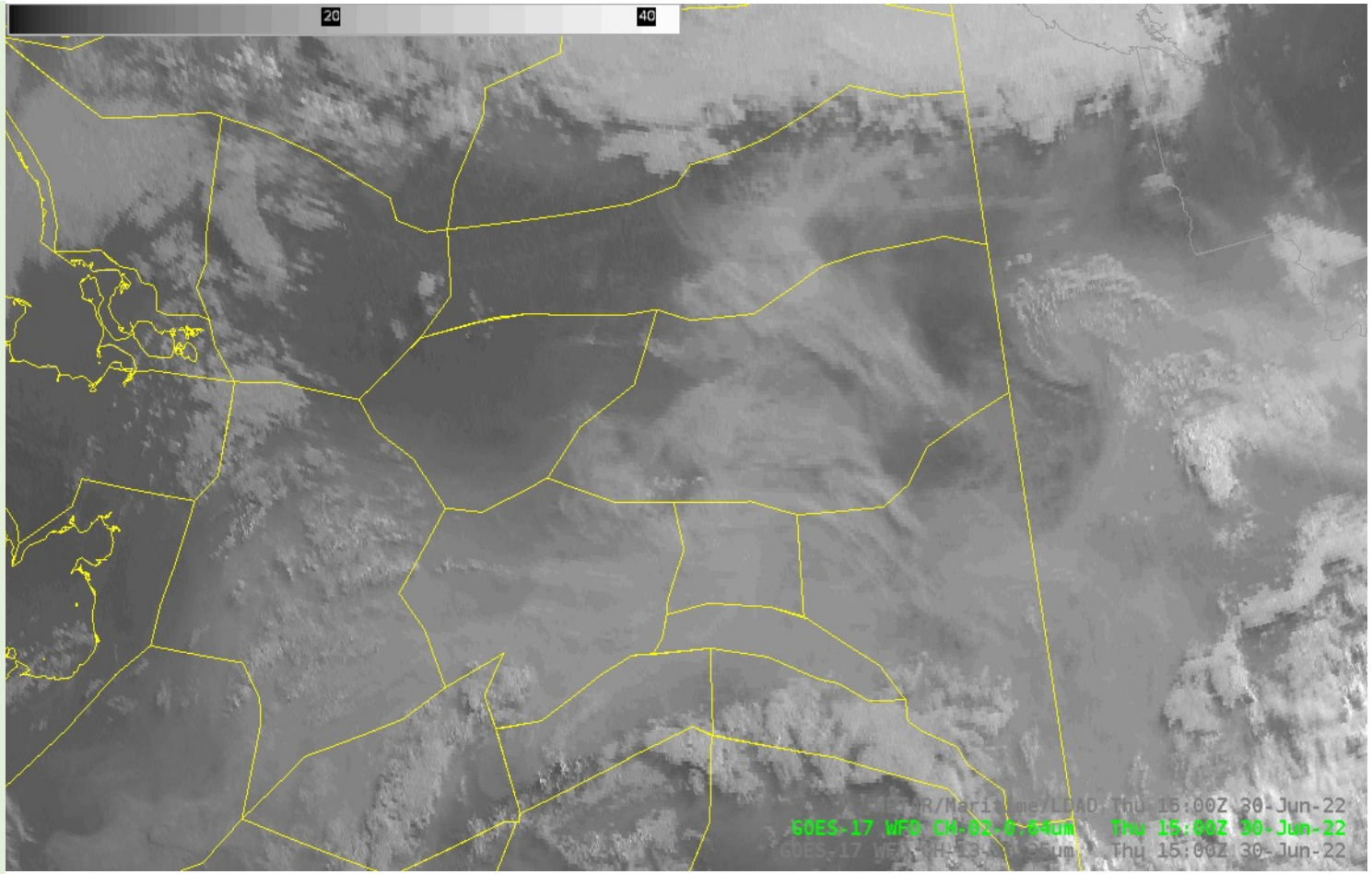


GOES DayFire RGB

- Similar characteristics as VIIRS i04 – Highly sensitive to shortwave emissions of fires, day or night.
- High frequency updates: 10 min – 30 sec
- Coarse resolution 6-10 km over interior Alaska (2 km at equator)
- Greater parallax for clouds, smoke and terrain: fires can be more easily obscured.
- Sensor saturation at 410K or 137 °C

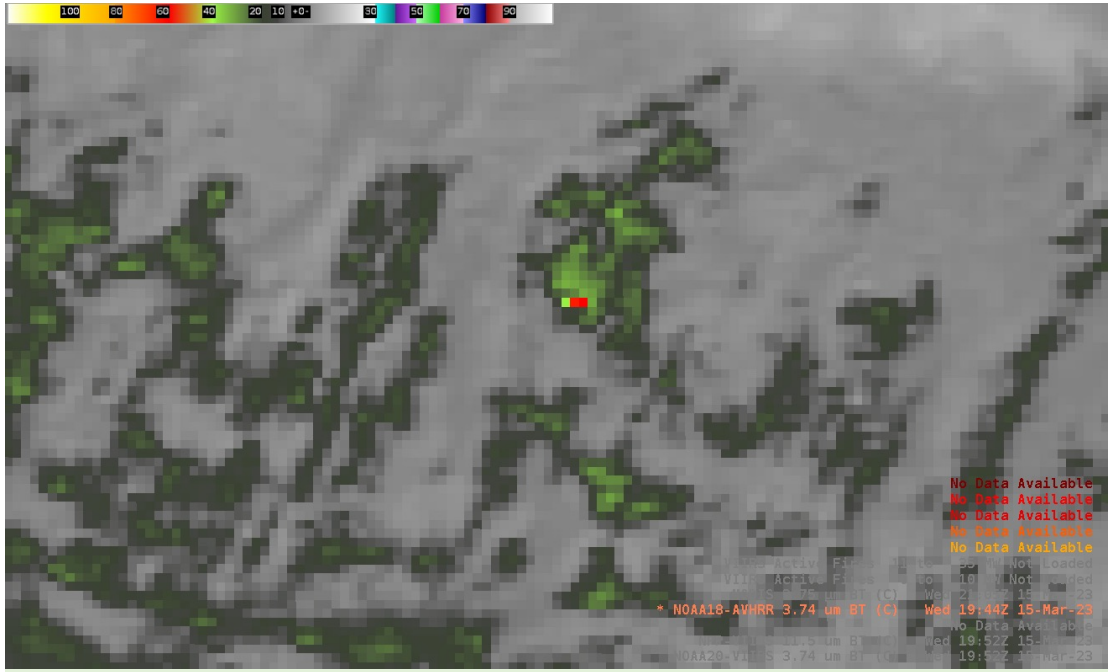
GOES ABI Red Visible (0.64 µm)

- Highest resolution visible band with some aerosol sensitivity:
  - 2-3 km AK interior
  - 0.5 km at nadir (equator)
- Blue visible band more sensitive to smoke but lower in resolution
- High frequency refresh:
  - Full disk: 10 min
  - Mesoscale sector: 1 min
- Helps identify pyrocumulus and other convective development



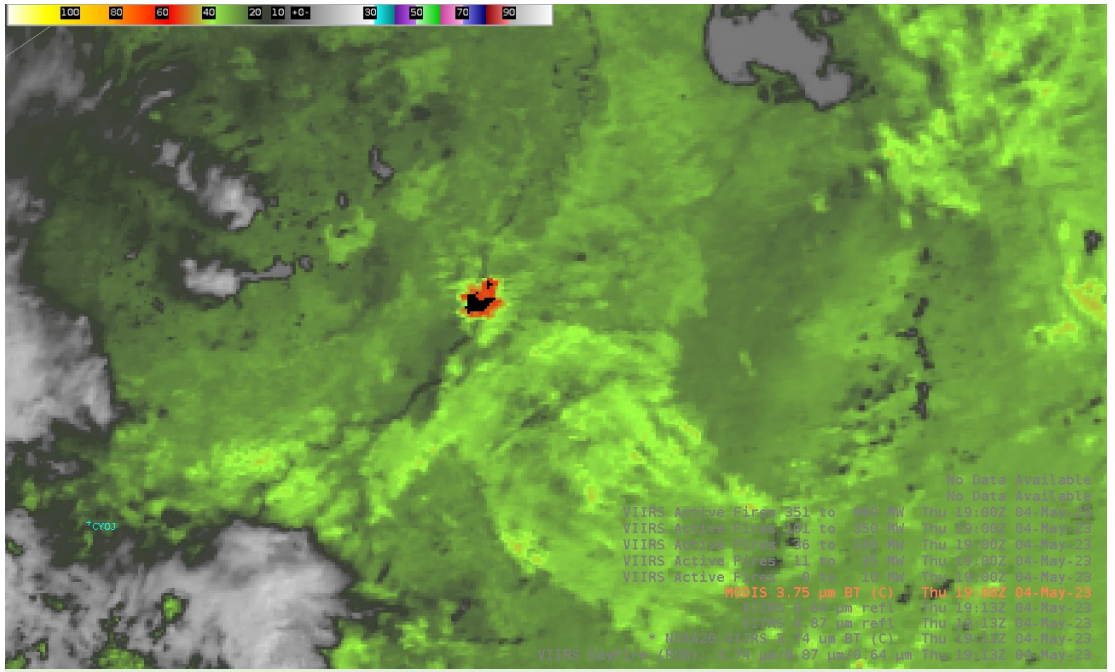
30 Jun 2022

Other Polar Satellites with Fire Channels



AVHRR

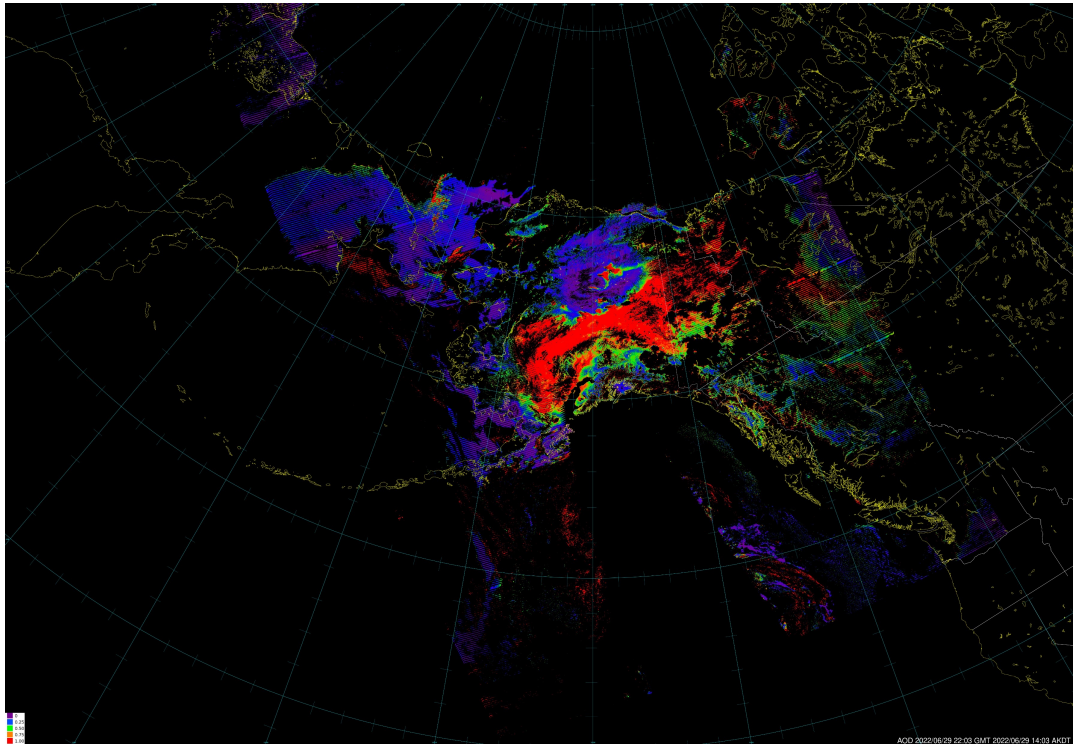
- Metop-B & C, NOAA 18 & 19
- Wavelength: 3.74 µm
- Resolution: 1km
- Sensor saturation temperature: 227 °C



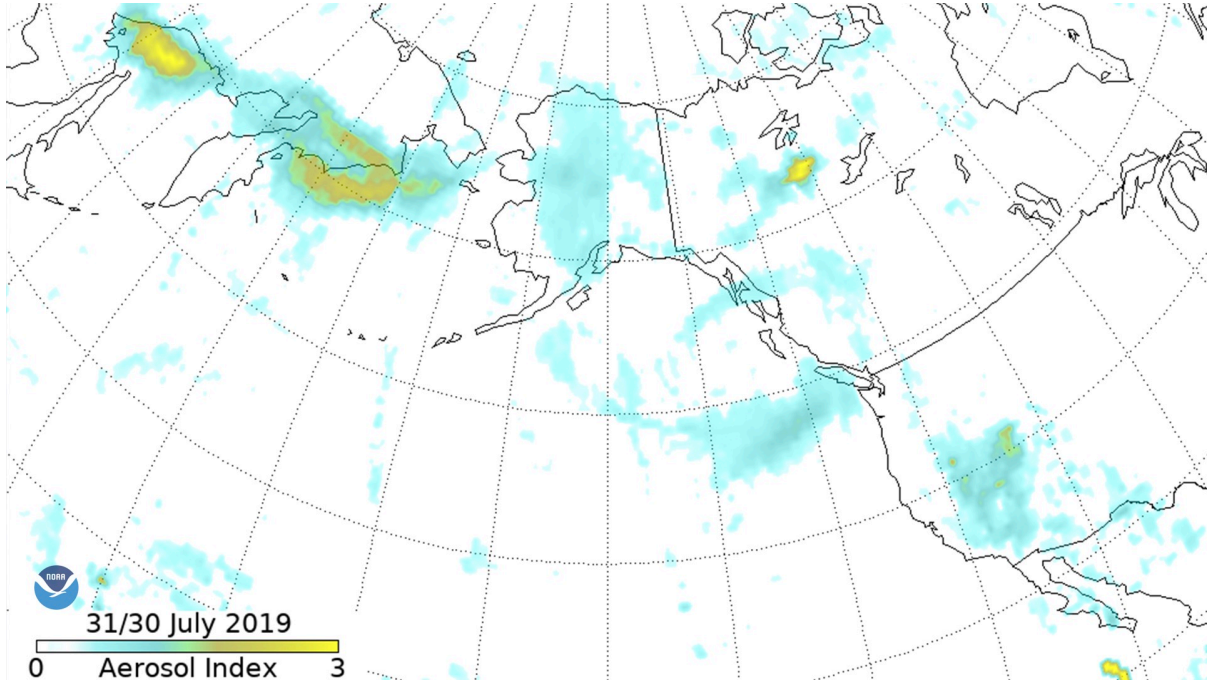
MODIS

- Aqua & Terra
- Wavelength: 3.75 µm (also 3.96 µm, 4.05 µm)
- Resolution: 1km
- Sensor saturation temperature: 137 °C

Other Satellite Products for Smoke



VIIRS Aerosol Optical Depth (AOD)



OMPS Aerosol Index

36

Summary: Fire Analysis with Polar Satellite Imagery

- Look for hot pixels in the Shortwave IR (VIIRS i04) imagery at night, (or) red pixels in the DayFire RGB (FireColor RGB) during the day:
  - ❑ Check how they compare with the surroundings.
  - ❑ Are there nearby clouds, terrain, or shadows that could be impacting the detection?
  - ❑ Are there other fires in the area?
  - ❑ Are there adjacent anomalously cold pixels suggesting fold-over from saturation?
  - ❑ Could they be from persistent anomalies such as volcanoes, industrial sites, solar farms, etc.
  - ❑ Remember during the day the Shortwave IR (VIIRS i04) will be warmer overall due to reflected solar energy.
  - ❑ Keep in mind that fires near the swath edge will have pixels with a larger footprint and a greater chance of being affected by obscurations.
- Examine the Longwave IR (VIIRS i05) at the location of the hot pixel for clouds. This is especially important at night when reflectance bands are not available:
  - ❑ If the corresponding pixels are also warm it would support the existence of a fire. Cold pixels in the Longwave IR would likely be caused by cloud tops.
  - ❑ Are there low clouds (darker grey) around the hot pixel obscuring adjacent pixels? This could make a single pixel appear to stand out from its surroundings.

Summary: Fire Analysis with Polar Satellite Imagery

Continued

- Examine the DayLandCloud RGB (day)
  - ❑ Check for clouds in the proximity of the hot pixels.
  - ❑ Look for other causes of high reflectances, such cloud tops, sun glint, solar farms, etc.
  - ❑ Look for burn scars or vegetation
- Examine the TrueColor RGB for evidence of smoke. Other products to check include: red visible bands (0.64 µm) from GOES ABI or VIIRS (i01), or DayLandCloud RGB:
  - ❑ Smoke will have a grey thin wispy appearance compared to the opaque brighter clouds.
  - ❑ Check the trajectory and dispersion of the smoke from the fire source for changing wind direction/speed.
  - ❑ Look for sudden surge of fire detections in areas with significant smoke which could be caused by hot smoke.
  - ❑Keep in mind that elevated smoke and clouds near the edge of a swath will have some parallax displacement away from the center of the pass.

Online Data Links

- Alaska Interagency Coordination Center Dashboard: https://blm-egis.maps.arcgis.com/apps/dashboards/a23a625f4d18412ea13cffeefcbe7f5e
- GINA ESRI Map Service: https://www.arcgis.com/home/webmap/viewer.html?webmap=d7e7050c4b34437c938c3b1de5e6314e
- RealEarth: https://realearth.ssec.wisc.edu/
- CIRA Slider (imagery only): https://rammb-slider.cira.colostate.edu
- GINA Alaska Direct Broadcast Satellite Data Portal: http://feeder.gina.alaska.edu/

References

- C. J. Seaman, W. Line, R.. Ziel, J. Jenkins, C. Dierking, G. Hanson, (2023), Multispectral Satellite Imagery Products for Fire Weather Applications*, J. Atmos. Ocean. Technol*., https://doi.org/10.1175/JTECH-D-22-0107.1
- VIIRS 3.74µm Shortwave IR Band for Fire Detection https://gina.alaska.edu/wp-content/uploads/2021/07/VIIRS_3_74 um_FireDetection_Quick_Guide.pdf
- VIIRS DayFire RGB Quick Guide, available from: https://rammb2.cira.colostate.edu/wp-content/uploads/2020/01/VIIRS_Day_Fire_RGB_Quick_Guide_v1.pdf
- VIIRS TrueColor RGB Quick Guide, available from: https://gina.alaska.edu/wp-content/uploads/2023/02/QuickGuide_True_Color_Final.pdf
- DayLandCloud RGB Quick Guide, available from https://gina.alaska.edu/wp-content/uploads/2020/11/DayLandCloud_QuickGuide_JPSS_final.pdf
- [CIRA blog post] A Wild Week of Wildfires, available from: https://rammb.cira.colostate.edu/projects/npp/blog/index.php/uncategorized/a-wild-week-of-wildfires/
- [CIRA blog post] The Land of 10000 Fires, available from: https://rammb2.cira.colostate.edu/viirsblogs/the-land-of-10000-fires/
- [CIRA blog post] Funny River Isn't Laughing, available from: https://rammb2.cira.colostate.edu/viirsblogs/funny-river-isnt-laughing/

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Cooperative Institute for Meteorological Satellite Studies (CIMSS)