Geostationary Fire Detection Using the GOES-R Series Advanced Baseline Imager

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GOES-16 Fire Detection and Characterization Algorithm

- Geostationary fire detection and characterization has been available 24/7 since 2002 when the Wildfire Automated Biomass Burning Algorithm (WFABBA) was made an operational product by NOAA/NESDIS
- The WFABBA produces fire location and characterization data for all data received from current GOES, Meteosat Second Generation, COMS, the formerly operational MTSAT series, and the Advanced Himawari Imager (AHI) on Himawari-8
- The experience with current generation geostationary platforms informed the requirements for the Advanced Baseline Imager (ABI) on GOES-R, and the WFABBA was adapted to the instrument and is a baseline product (under the name **Fire Detection and Characterization Algorithm** [FDCA])
- The WFABBA's legacy as an algorithm for multiple instruments allows for excellent continuity as we transition to the new generation of geostationary imagers represented by ABI and AHI

Omnibus caveat: All GOES-16 data herein are preliminary, non-operational data and are undergoing testing. Users bear all responsibility for inspecting the data prior to use and for the manner in which the data are utilized.

Fire Detection and Characterization

The Fire Detection and Characterization Algorithm (FDCA) uses infrared data, the ~4 µm and ~11 µm bands (7 and 14) from ABI, to locate and determine the size, temperature, and fire radiative power (FRP) output of fires within the satellite's field of view

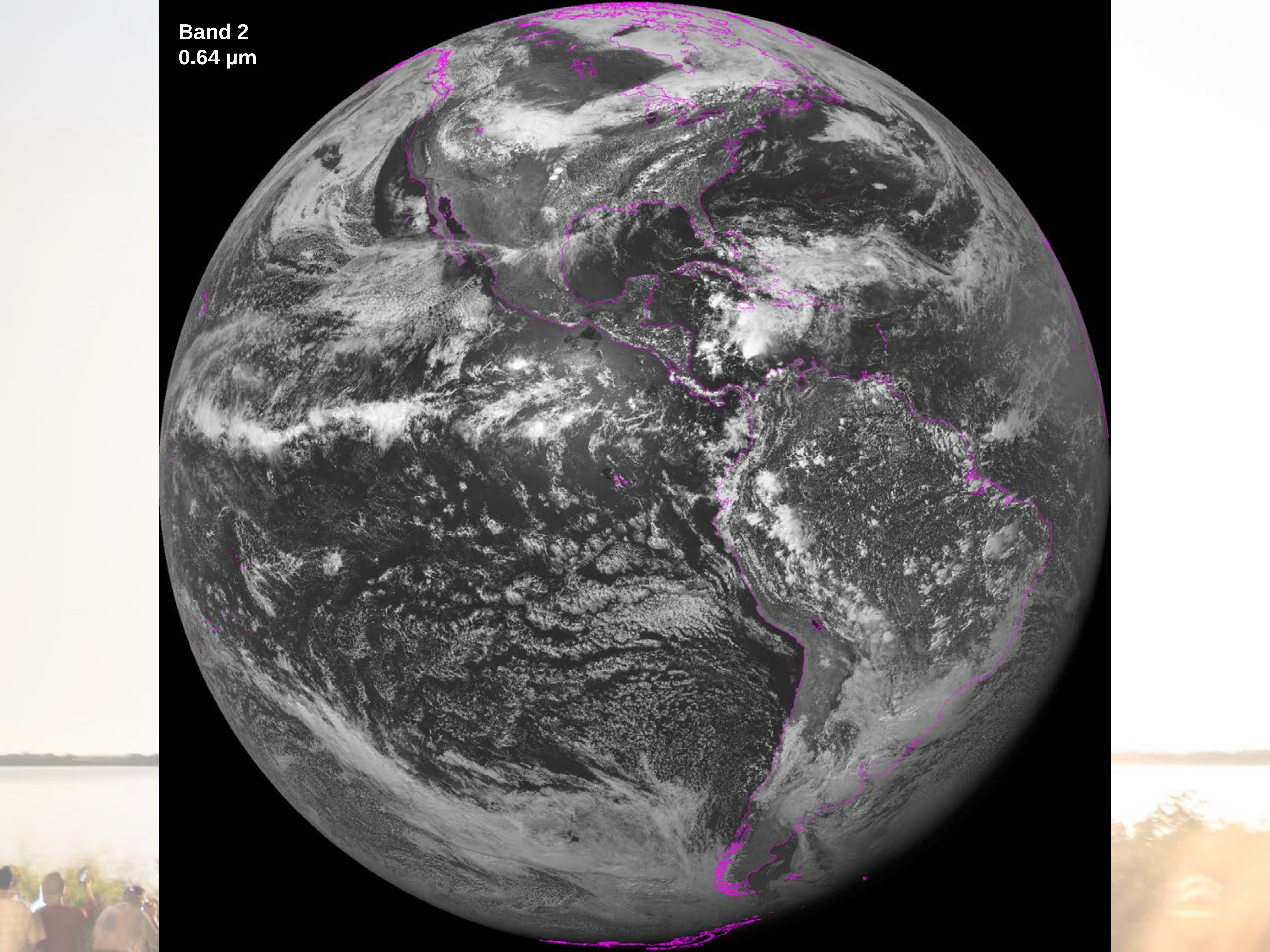
With at least 384 looks per day, geostationary fire detection provides continuous of location and intensity on short time scales

The fire's radiative power (FRP), size, and temperature can be used to estimate intensity and emissions (FRP is related to the mass consumed by the fires)

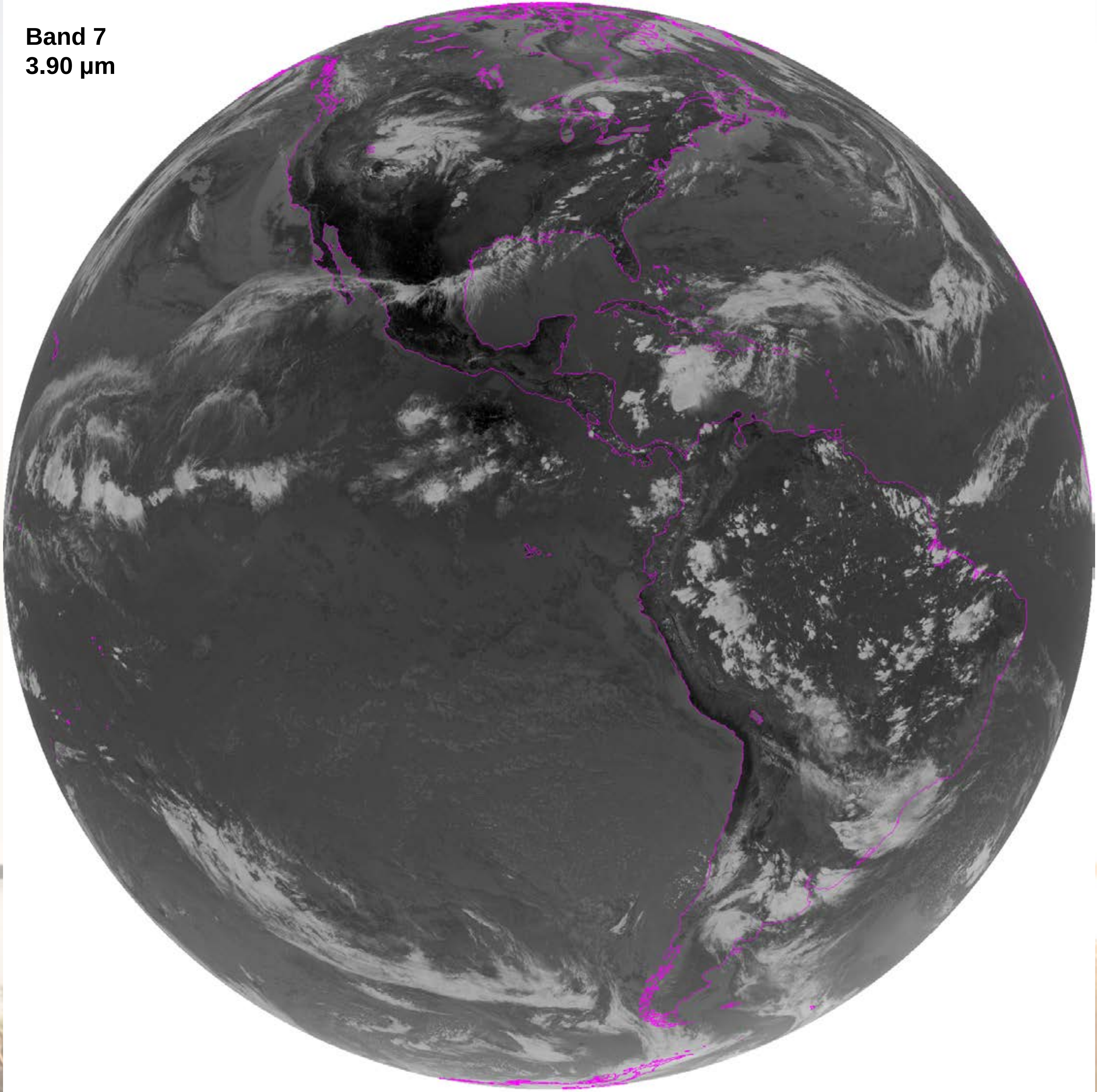
The algorithm also tracks what we cannot see – with so many "looks" we know more about the fires we can't detect

How Does Fire Detection and Characterization Work?

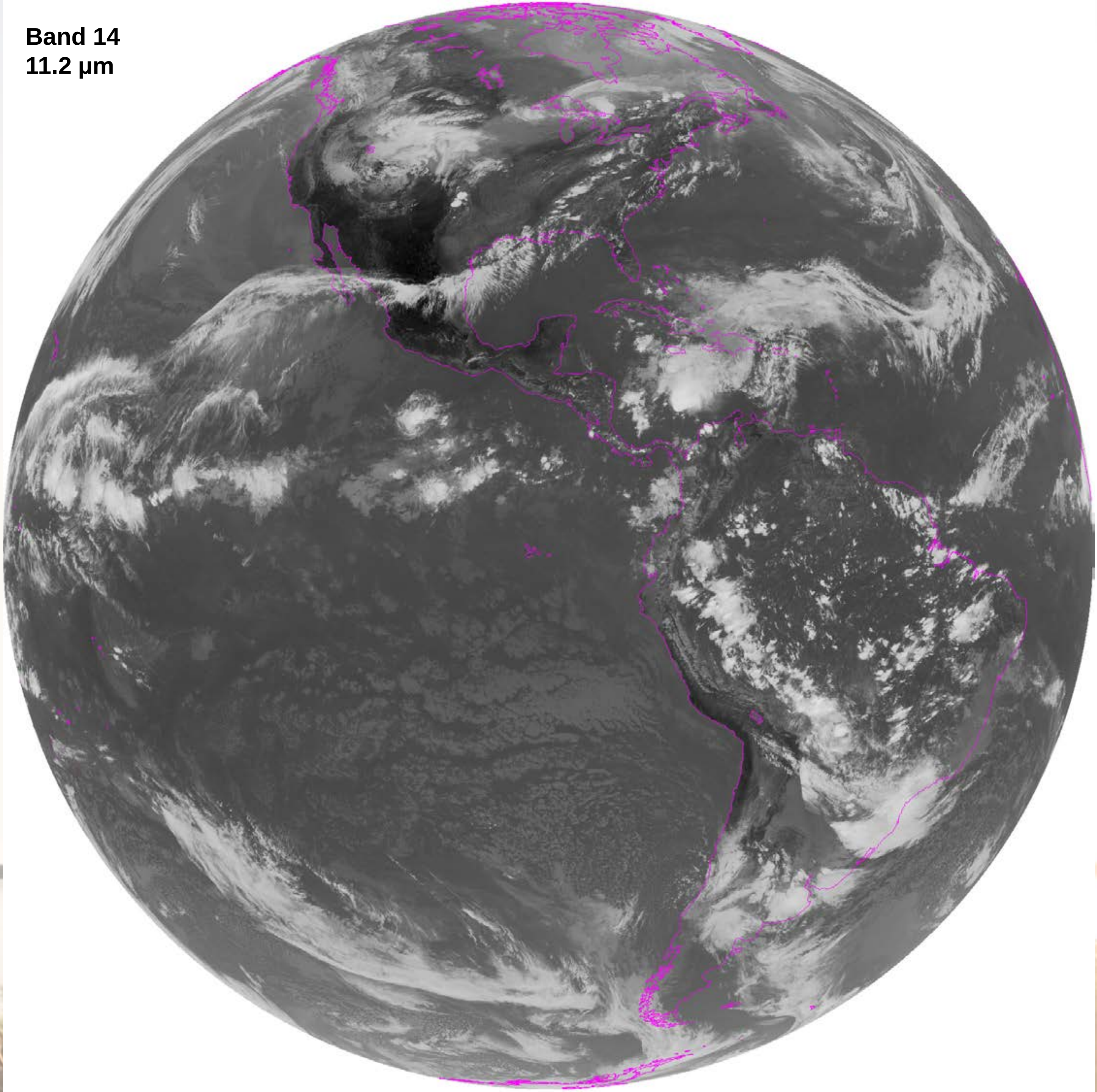
- Almost all fire algorithms use at least 2 IR bands: ~4 µm and ~11 µm. The FDCA also uses the 0.64 µm and 12.3 µm bands for cloud screening.
- Fire characterization requires some additional information data (amount of water in the atmosphere, the surface composition).
- The algorithm is contextual to best handle estimating what the surface looks like without a fire – we need to know that if we want to estimate the intensity of the fire.
- Fires are always smaller than a GOES pixel, so there are limits to how well we can characterize them. Diffraction of the infrared light into the detector and uncertainty in the satellite navigation are the biggest factors.
- Remapping can distort fire data, and has been observed for ABI, Himawari-8 AHI, Meteosat-8/-9/-10, and COMS-1.
- The ABI FDCA is the ABI implementation of the WFABBA, which runs on current GOES, Meteosat Second Generation, and Korea’s COMS.


Band 2
0.64 µm

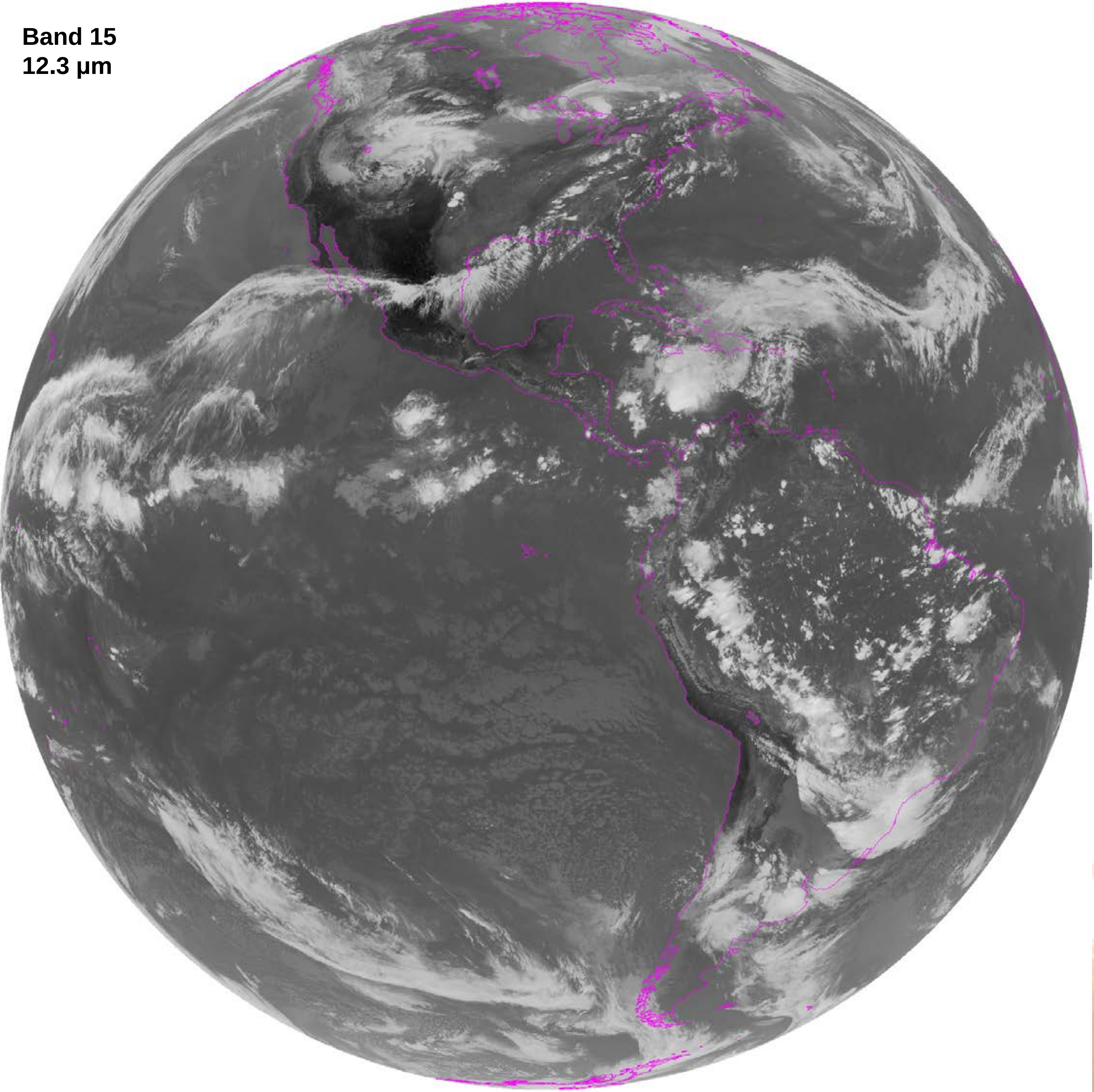
Band 7
3.90 μm



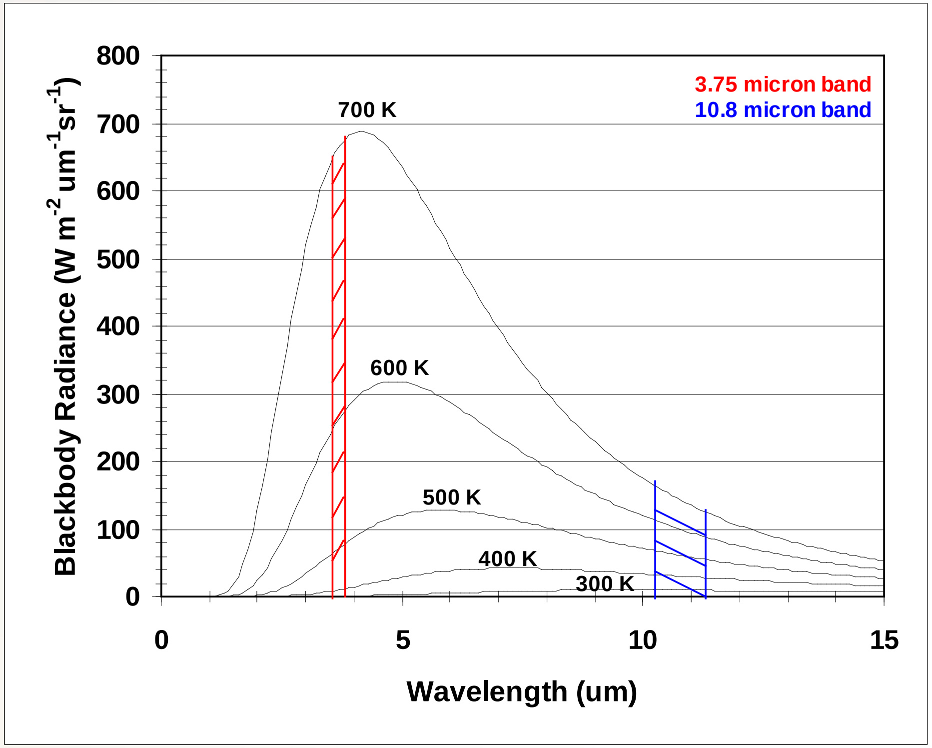
Band 14
11.2 µm



Band 15
12.3 µm



Fire Detection and Characterization



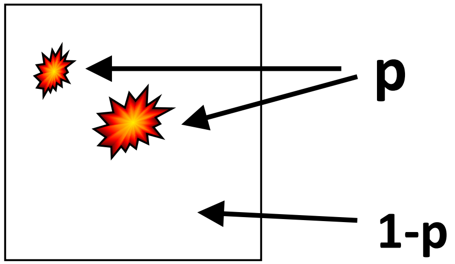
As the surface temperature increases, the peak of the Planck function shifts toward shorter wavelengths, so the radiance increases more rapidly at ~4 µm than ~11 µm. The different brightness temperature responses in these two infrared windows and background conditions can be used to detect fires and estimate sub-pixel fire size, temperature and fire radiative power (FRP).

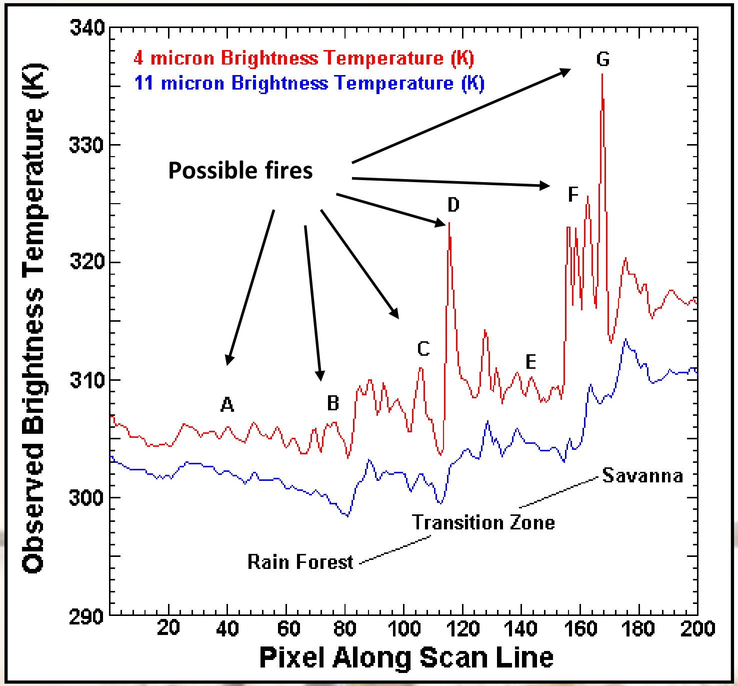
The Planck function: Describes emitted energy at a given temperature and wavelength.
Radiance: A measure of the emitted energy.
Brightness Temperature: The temperature sensed by the detector, it is wavelength dependent and not the same as the bulk temperature of the surface or fire.

Fire Detection and Characterization

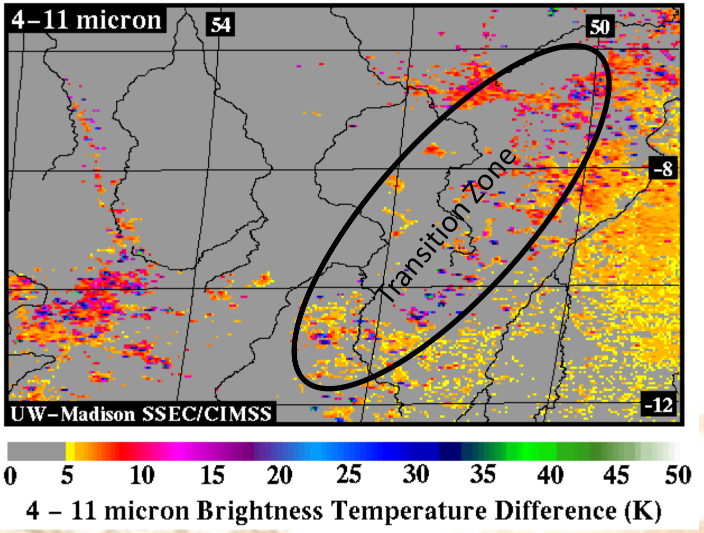
Typically, the difference in brightness temperatures between the two infrared windows is due to ***reflected solar radiation***, ***surface emissivity*** differences, and ***water vapor attenuation***. This normally results in brightness temperature differences of 2-4 K.

Larger differences occur when one part of a pixel (p) is substantially warmer than the rest of the pixel (1-p). The hotter portion will contribute more radiance (energy) in shorter wavelengths than in the longer wavelengths.





Brightness temperatures along a scan line in NE Brazil



NE Brazil along the transition zone between forest and savanna

Fire Detection and Characterization

The ~4 µm and ~11 µm bands used to locate and characterize the properties of fires look pretty similar overall. However, the ~4 µm band has a reflected solar component that the ~11 µm lacks, there is the fire signal, and also fog looks somewhat different. A side-by-side is shown below, with the same enhancement applied to both. Examples of each scenario appear in the scenes.

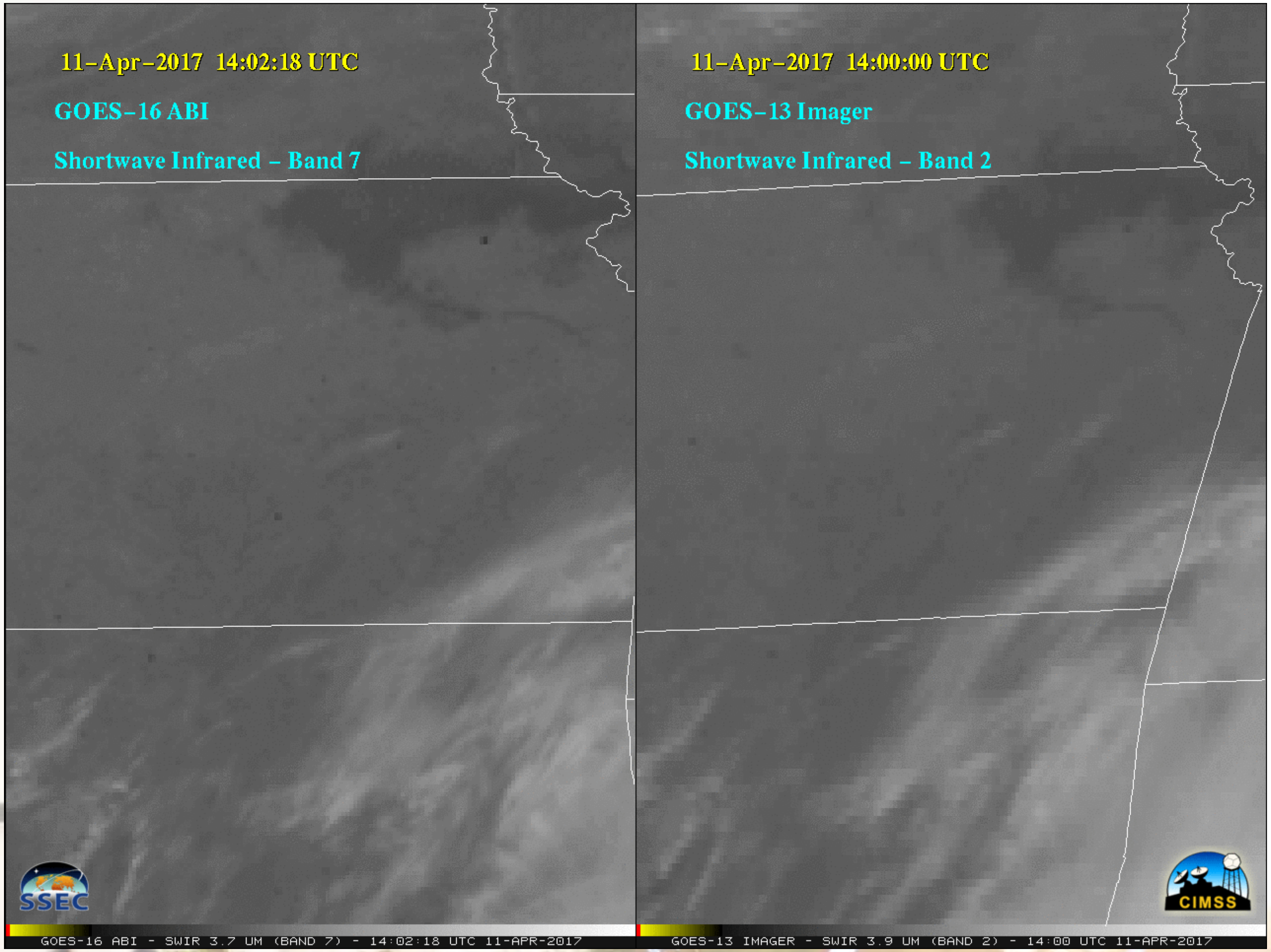
GOES-16 vs GOES-13

- GOES-13 and GOES-15 cover the US, nominally every 15 minutes
- GOES-16 operational FDCA coverage includes full disk (15 minute) and CONUS (5 minute) sectors (but *not* the MESO sector)
- Over the US current GOES pixels cover ~20-30 km^2 and GOES-16 pixels cover ~5-8 km^2

GOES-16 provides higher temporal and spatial resolution than current GOES, and the 3.9 µm band was specified to meet or exceed the fire detection accuracy achieved with current GOES.

GOES-16 vs GOES-13

GOES-16 has higher fidelity, higher spatial resolution, and higher temporal resolution



See the full case at:
http://cimss.ssec.wisc.edu/goes/blog/archives/23732

Winds whipping on the Oklahoma Plains

The tails of the Planck functions grew with target temperature - can we see fires in other bands? Sometimes, yes.

The following case is over Oklahoma on 1 March 2017 at 20:01:49 UTC (peak temperature for this fire)

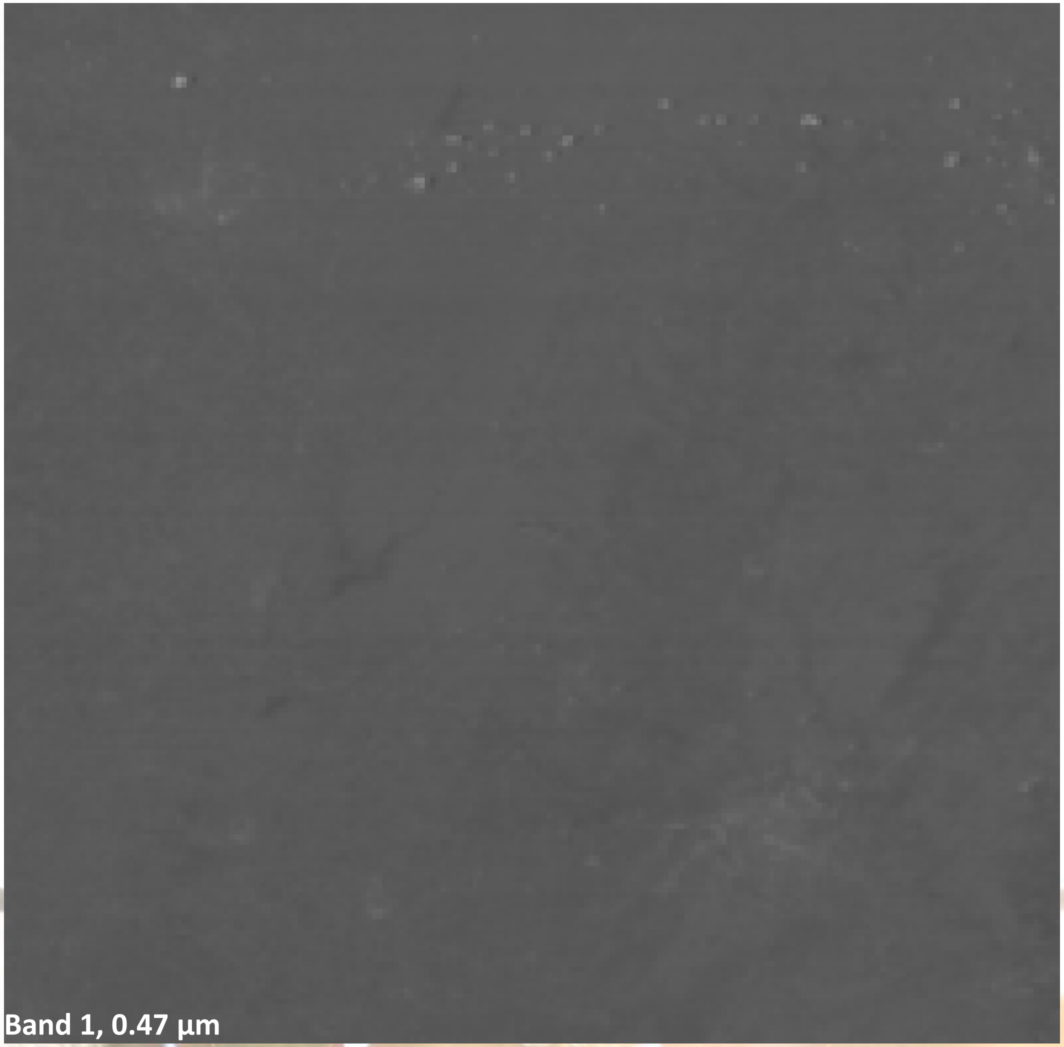
Grass fires were breaking out during high wind conditions, nighttime lows were near freezing and daytime highs were high and dry. This fire lasted about 5 hours in the afternoon and went from its peak temperature to undetectable in less than 15 minutes.

Winds whipping on the Oklahoma Plains

Oklahoma

1 March 2017 @ 20:01:49 UTC

The “blue” band shows few features over land, slight darkening where the fire is at the center of the frame

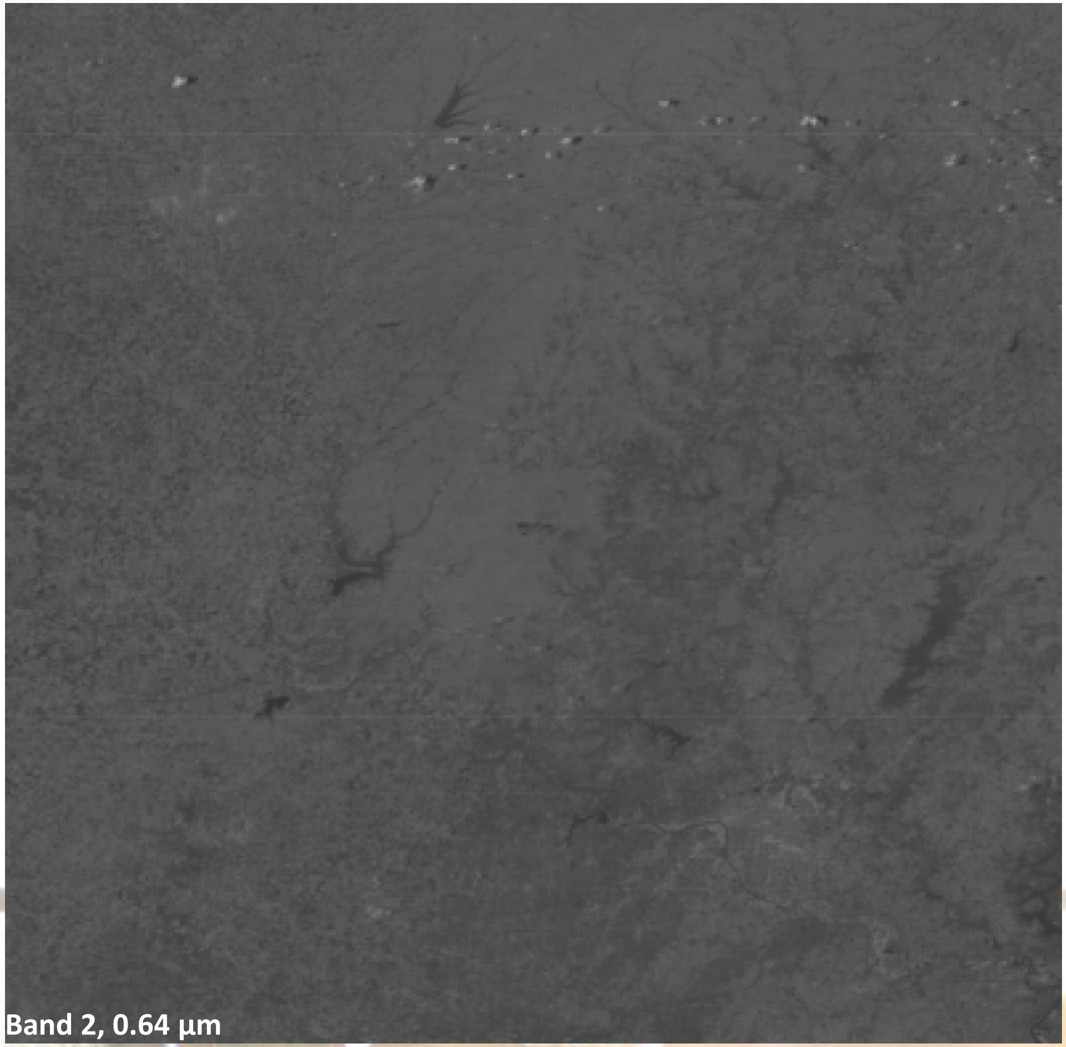


Winds whipping on the Oklahoma Plains

Oklahoma

1 March 2017 @ 20:01:49 UTC

The “red” band. It shows more variation than blue. Still dark near the fire.

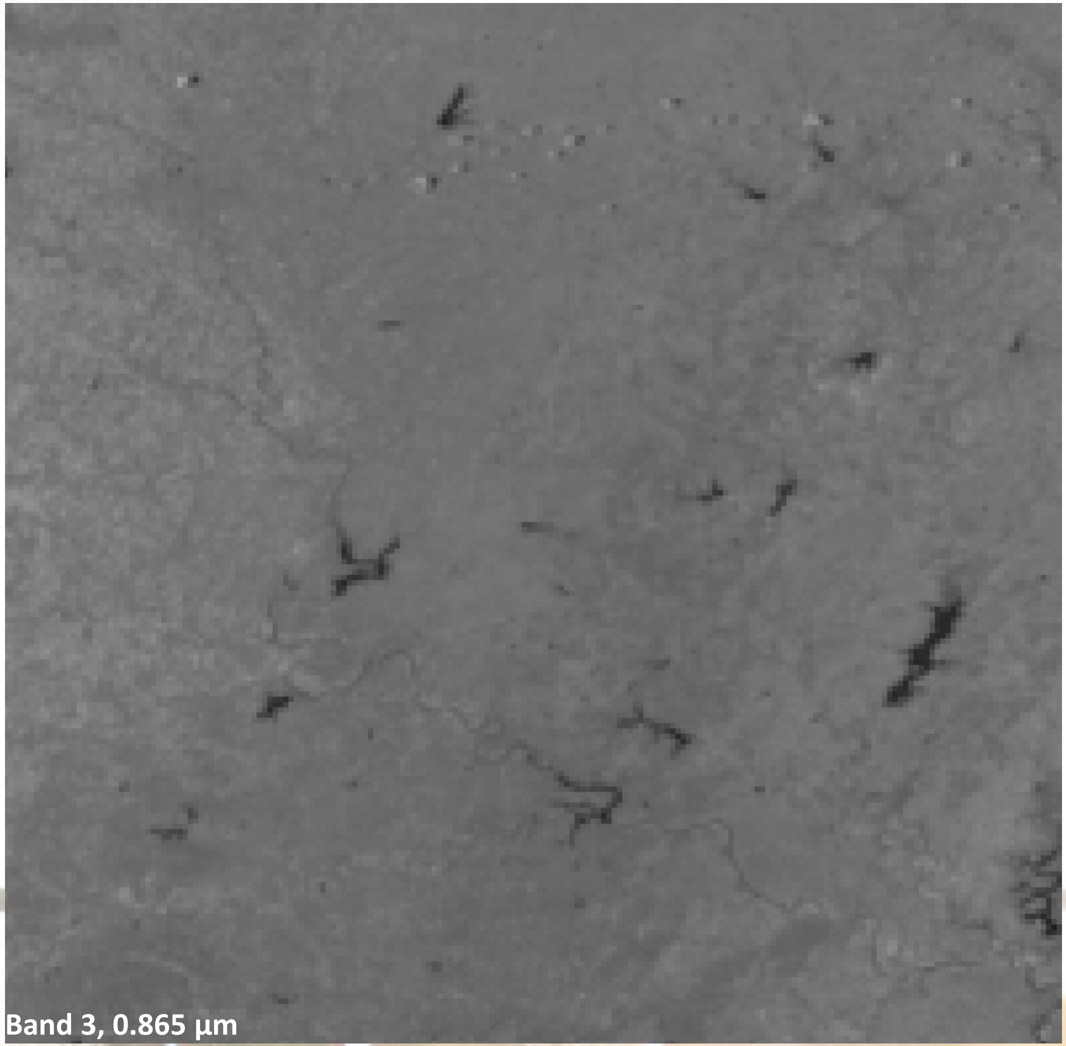


Winds whipping on the Oklahoma Plains

Oklahoma

1 March 2017 @ 20:01:49 UTC

Near infrared, reflects strongly off of chlorphyl.



Winds whipping on the Oklahoma Plains

Oklahoma

1 March 2017 @ 20:01:49 UTC

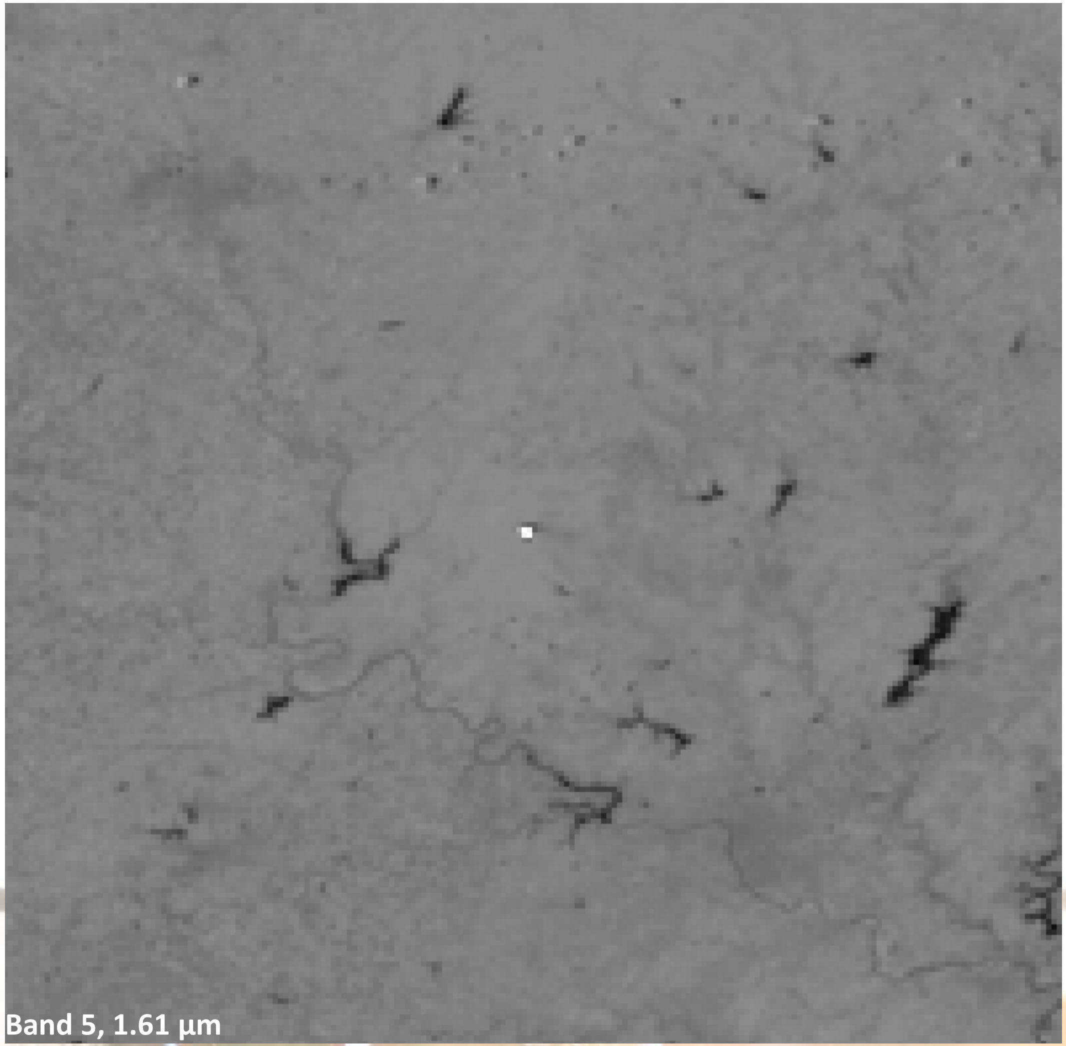
This band is sensitive to ice clouds.
Very tiny signal from the fire.

Winds whipping on the Oklahoma Plains

Oklahoma

1 March 2017 @ 20:01:49 UTC

The first band to show the fire. The fires appear as high reflectances in this band. The sun likely swamps the signal from most fires.



Winds whipping on the Oklahoma Plains

Oklahoma

1 March 2017 @ 20:01:49 UTC

The last shortwave "reflective" band. Fire extent may be a remapping artifact.

Winds whipping on the Oklahoma Plains

Oklahoma

1 March 2017 @ 20:01:49 UTC

The “fire band”

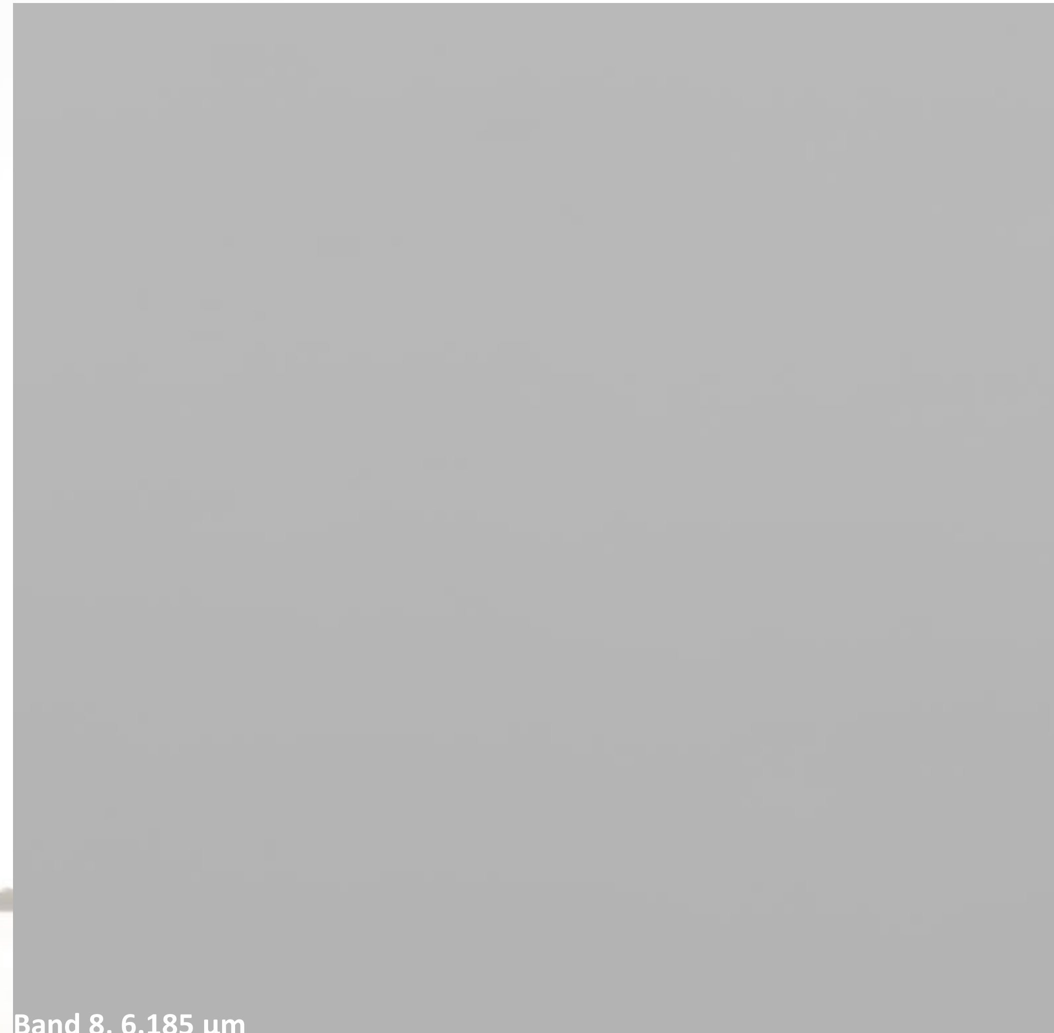
Remapping artifacts are visible

Winds whipping on the Oklahoma Plains

Oklahoma

1 March 2017 @ 20:01:49 UTC

No fire signal

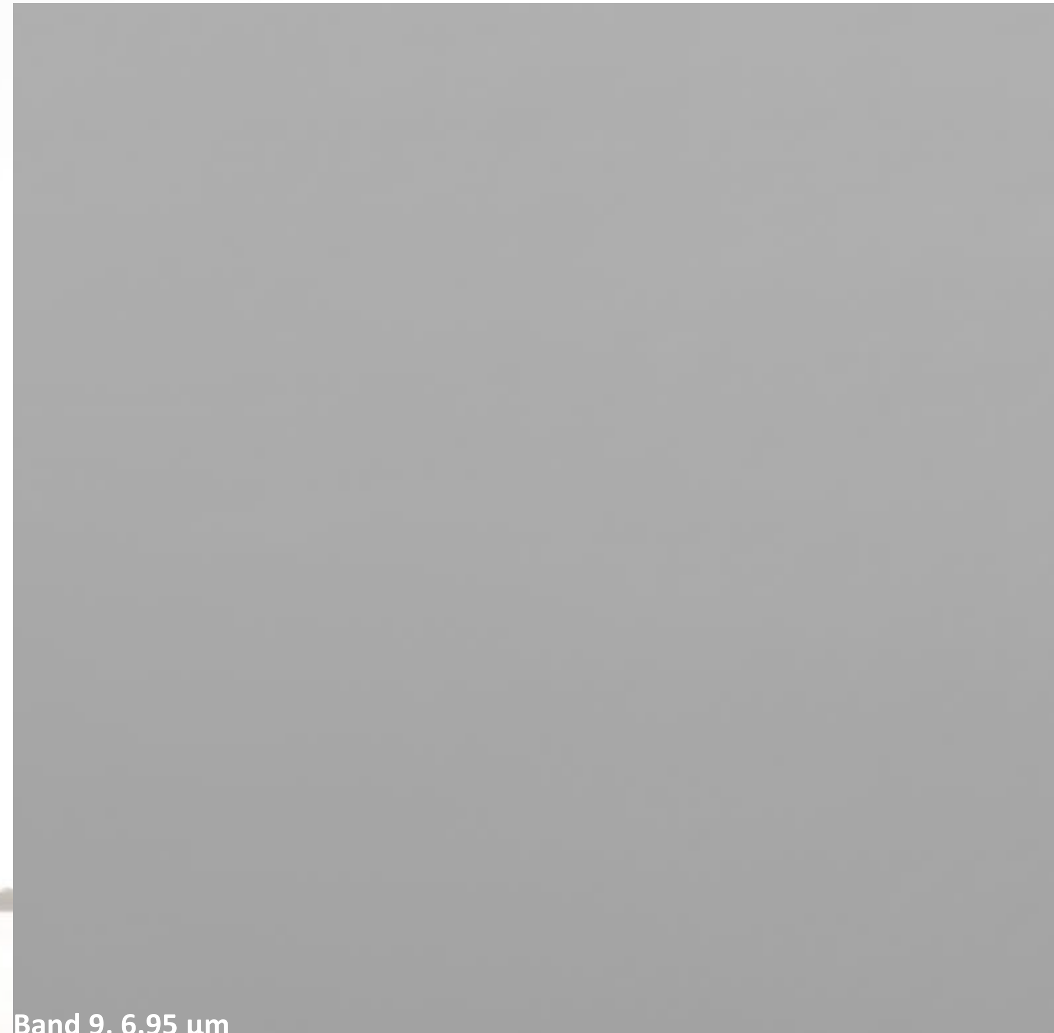


Winds whipping on the Oklahoma Plains

Oklahoma

1 March 2017 @ 20:01:49 UTC

No sign of the fire.



Winds whipping on the Oklahoma Plains

Oklahoma

1 March 2017 @ 20:01:49 UTC

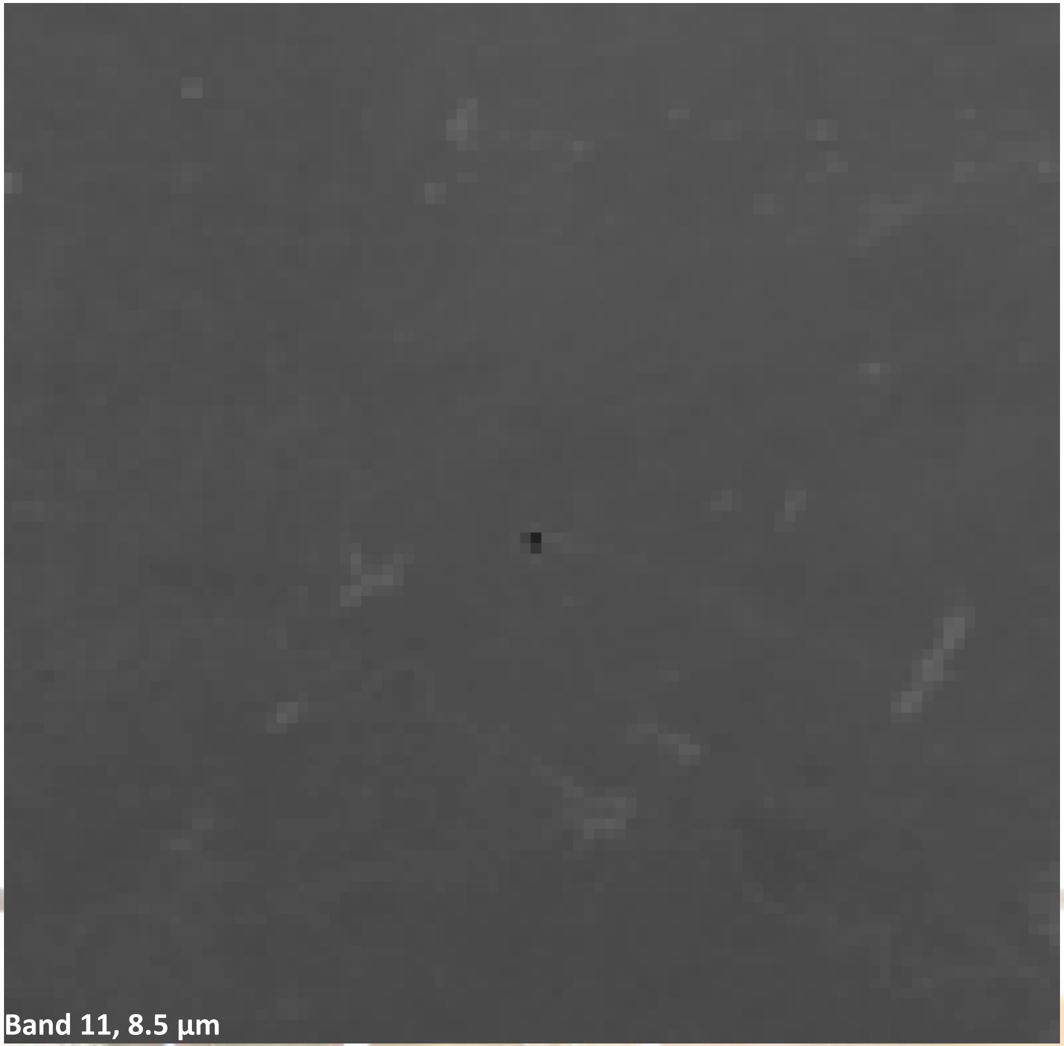
As very subtle hint of the fire. The signal is strong enough to been seen though the water vapor that otherwise obscures the surface.

Winds whipping on the Oklahoma Plains

Oklahoma

1 March 2017 @ 20:01:49 UTC

The first window band.

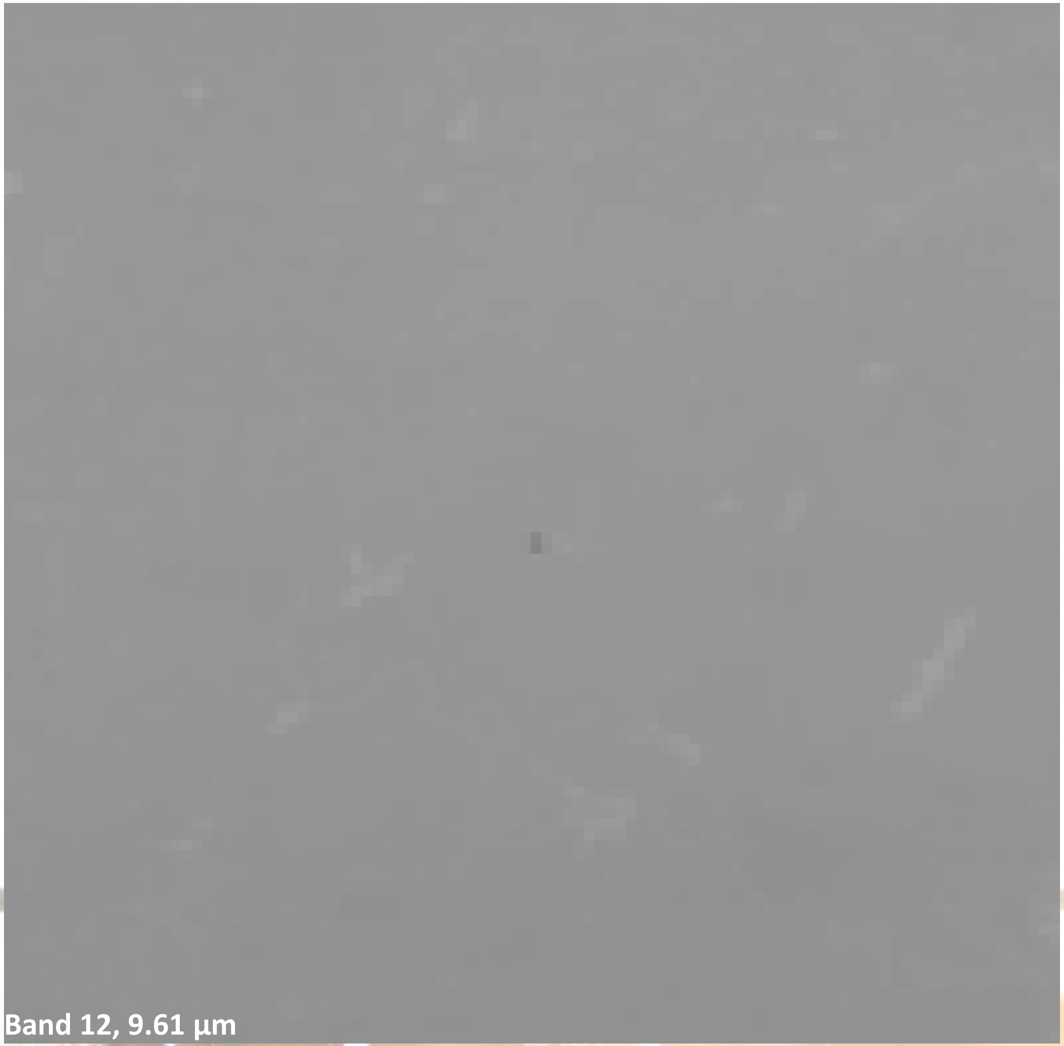


Winds whipping on the Oklahoma Plains

Oklahoma

1 March 2017 @ 20:01:49 UTC

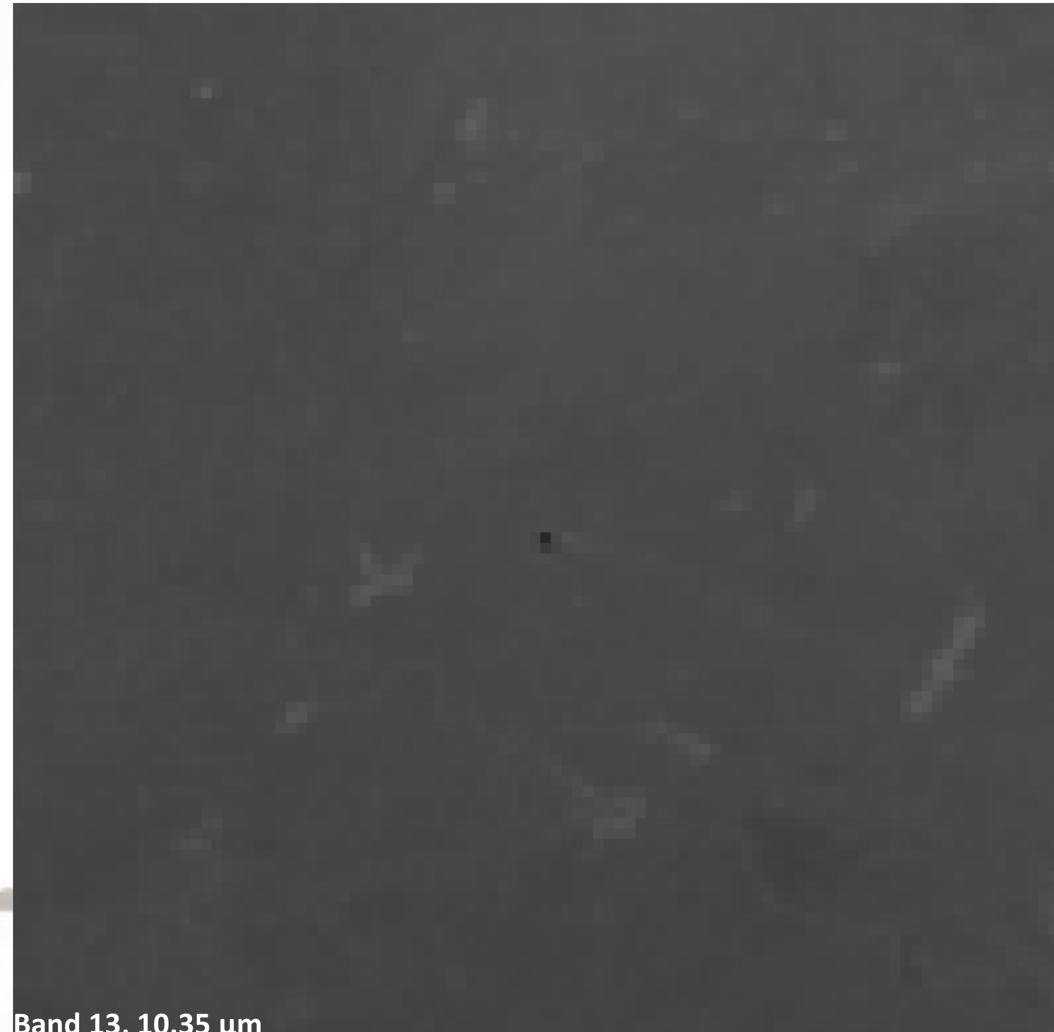
Fire is still visible despite ozone absorption.



Winds whipping on the Oklahoma Plains

Oklahoma

1 March 2017 @ 20:01:49 UTC

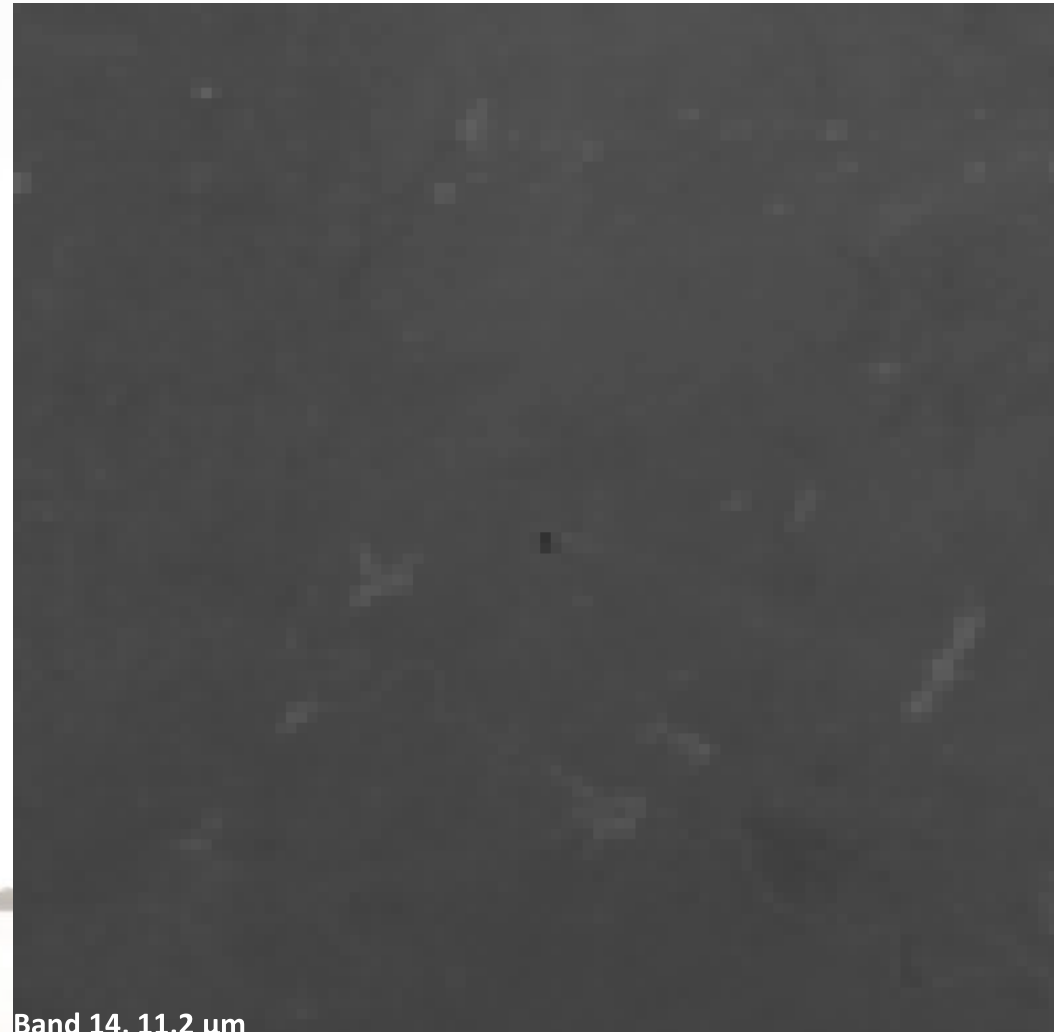


Winds whipping on the Oklahoma Plains

Oklahoma

1 March 2017 @ 20:01:49 UTC

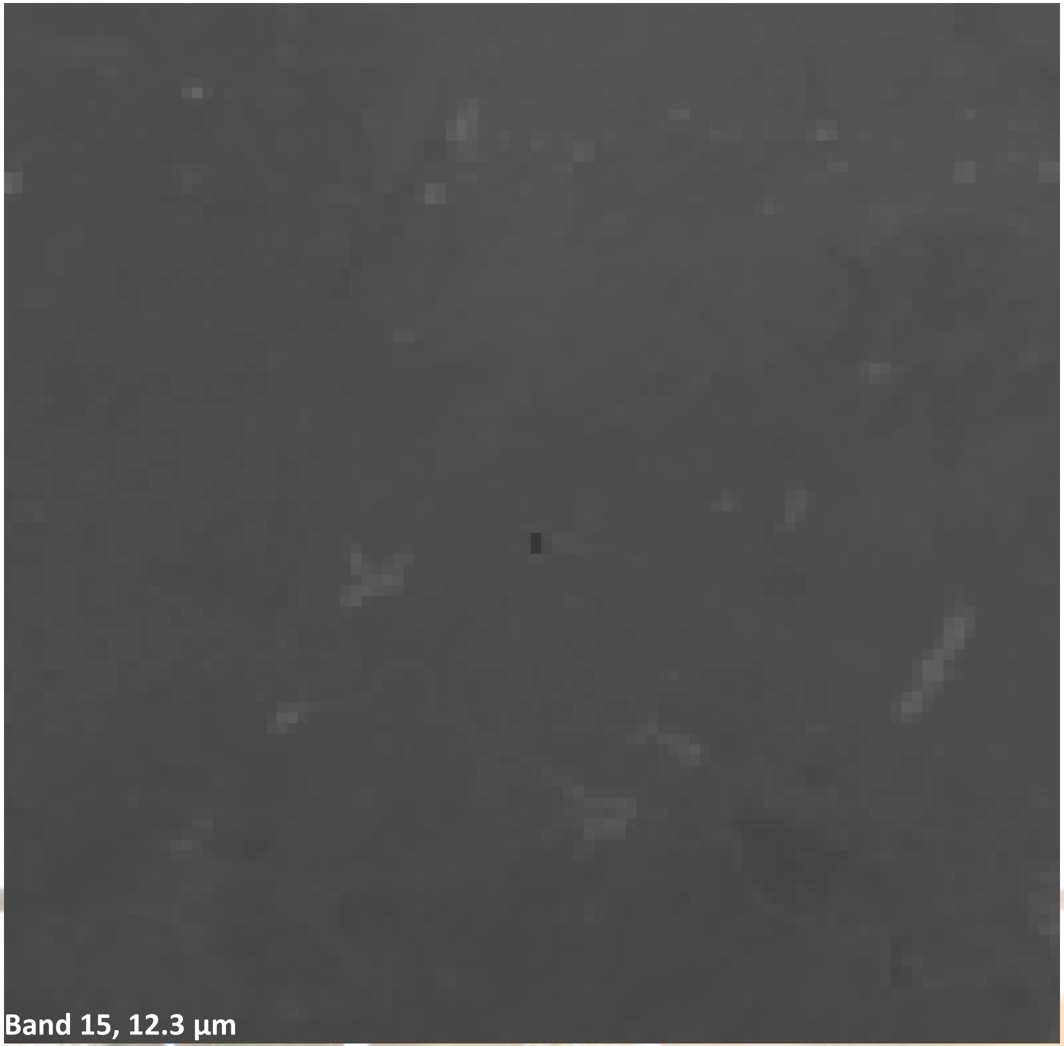
This is a hot fire.



Winds whipping on the Oklahoma Plains

Oklahoma

1 March 2017 @ 20:01:49 UTC

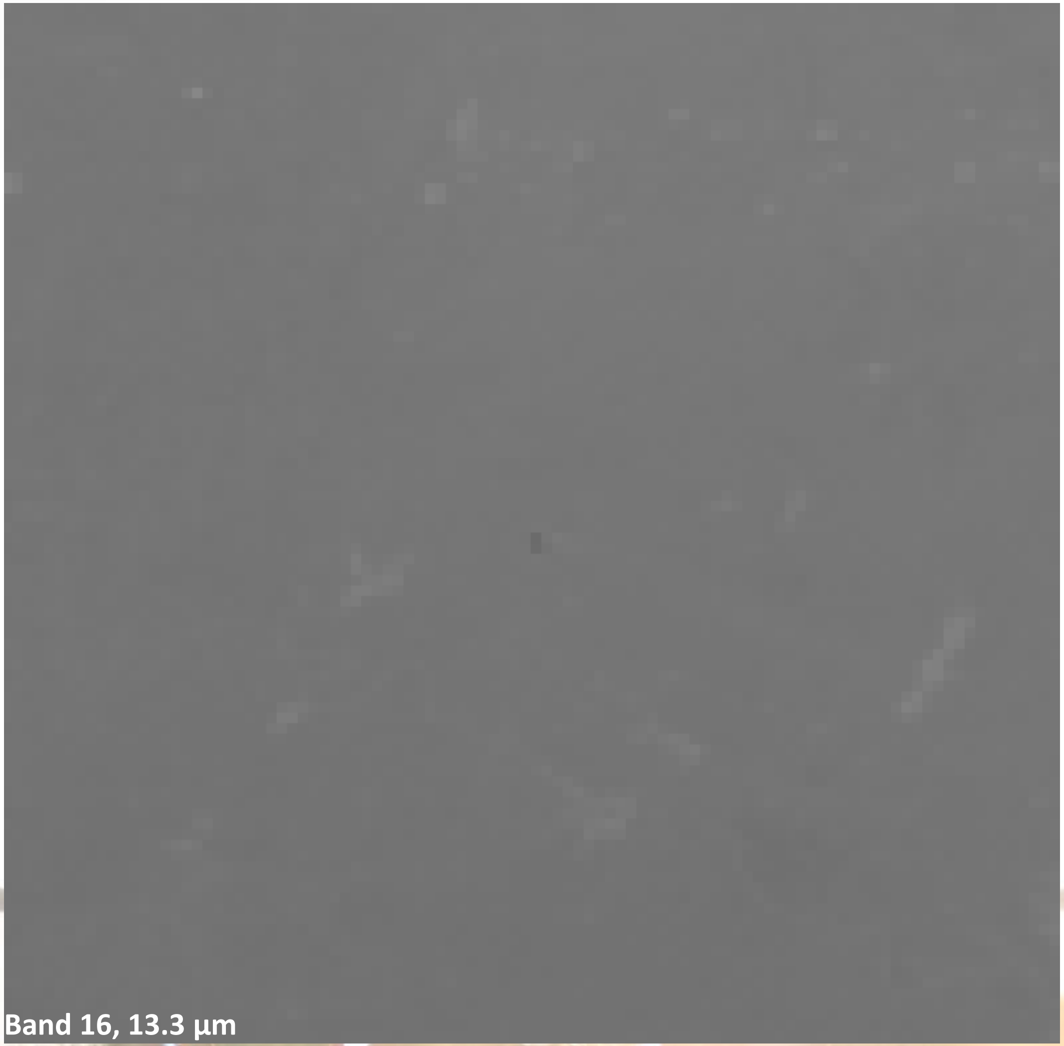


Winds whipping on the Oklahoma Plains

Oklahoma

1 March 2017 @ 20:01:49 UTC

Continues to be visible even with CO_2 absorbtion.

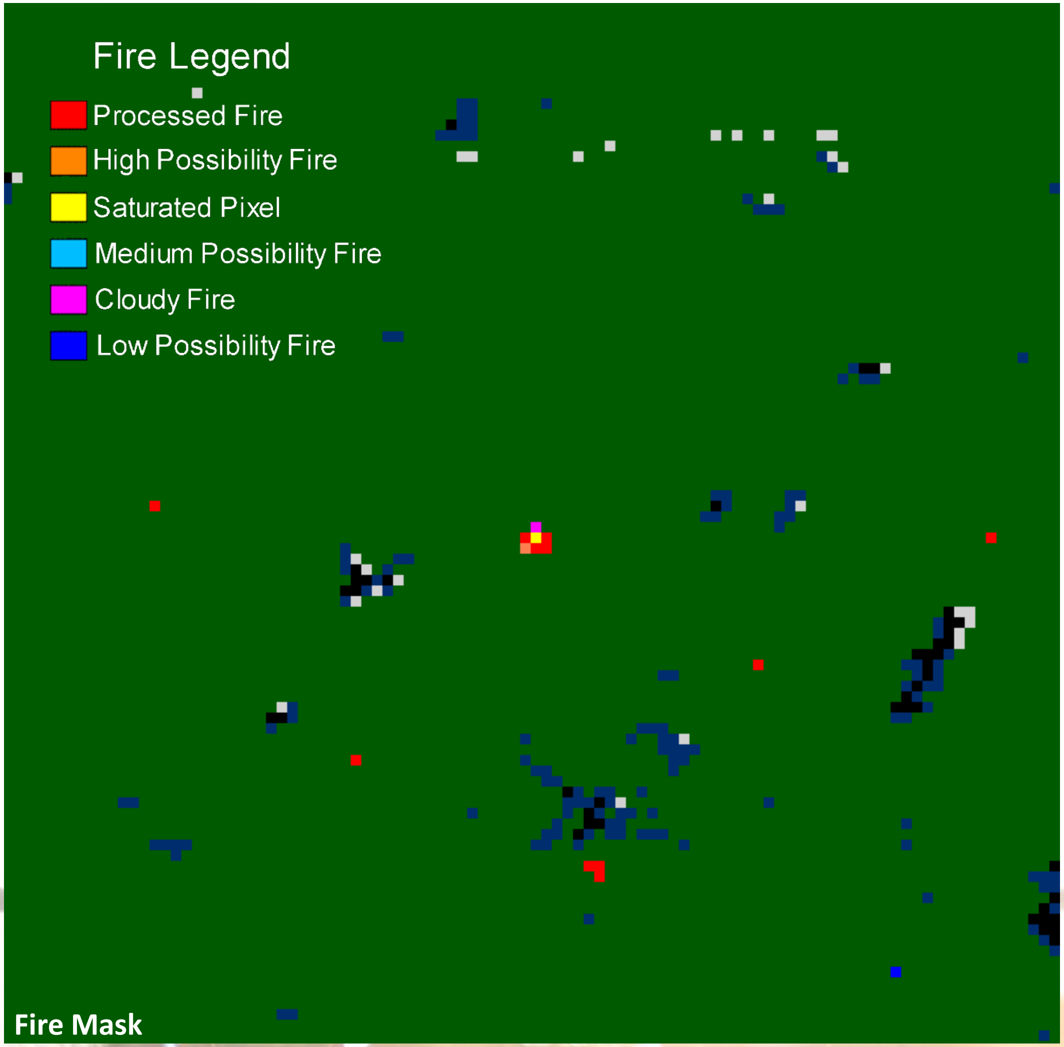


Winds whipping on the Oklahoma Plains

Oklahoma

1 March 2017 @ 20:01:49 UTC

The algorithm found the fires we could see ourselves.



Using the Fire Detection and Characterization L2 Product

Going back to the example earlier from 3 September 2017 between 18 and 19 UTC, we'll compare the fire mask to the raw imagery. Below is the mask output for that time period. Note that in addition to the fire legend green is fire-free land, light gray indicates cloud or smoke, and very dark blue is water.

There are blank frames in this sequence. At this time, the GOES-16 ground system is dropping large blocks of coverage in the L2 products, including fires. That gives the appearance of algorithm failure but actually means the data was never processed by the fire algorithm. The fix for this problem is anticipated in October, though it may come as late as 2018.

Using the Fire Detection and Characterization L2 Product

The ~4 µm band is compared to the fire mask. Detected fire pixels line up with the darker (hotter) pixels. Some appear to be missed and there are a lot of cloudy/smokey pixels that do not show up in the band 7 image. This may indicate smoke or it may mean the algorithm has to be adjusted. (As the product is still in beta, that is not out of the question)

Using the Fire Detection and Characterization L2 Product

The band 2 visible data shows higher albedos where the algorithm labelled the pixels as cloudy/smoky, so in this case it appears the algorithm is correct.

Using the Fire Detection and Characterization L2 Product

The fire product includes more than the mask, it also includes instantaneous fire size, temperature, and fire radiative power (FRP)

FRP is related to size times temperature to the fourth power times the Stephan-Boltzman constant

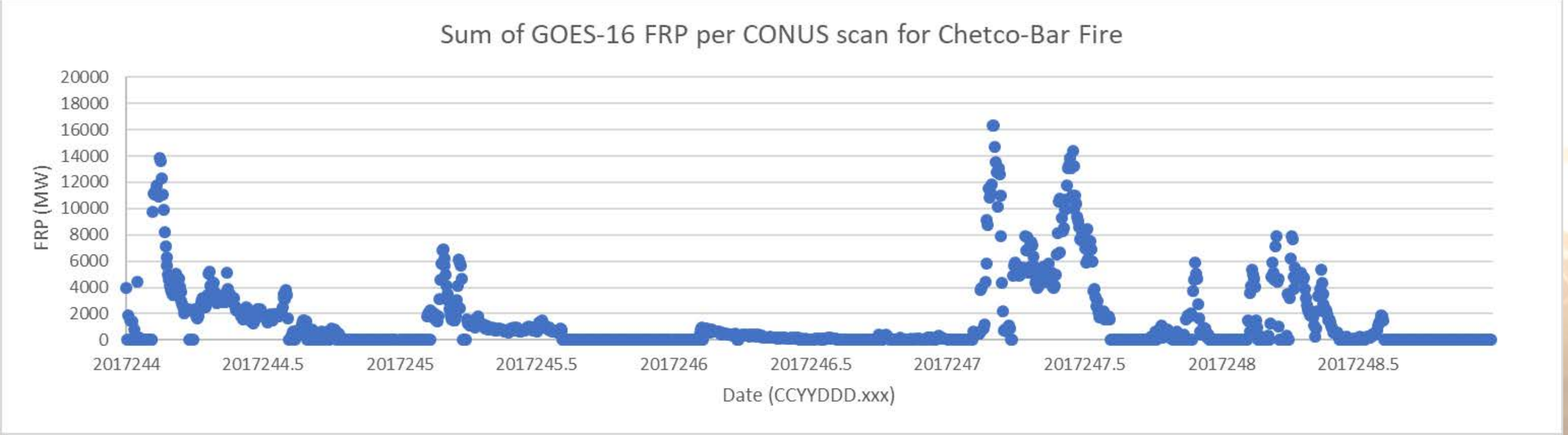
We will talk about FRP here:

- **It is the time derivative of fire radiative energy (FRE)**
- **FRE is related to mass consumed by the heat of combustion of the material**
- **Most biomass has pretty similar heat of combustion**
- **Mass consumed is directly related to smoke and aerosol production**

Using the Fire Detection and Characterization L2 Product

Band 7 (enhanced) is on the right, total FRP for the area in the green square (the Chetco-Bar Fire) for the same time period is below. Despite dropped frames and other quirks the FRP data tracks our expectations pretty well. Red frames represent missing L1b radiance data in this region of the scan.

FRP has not been validated for ABI, that will commence this fall. Use it with caution, even when fully validated FRP from GOES-16 will, due to diffraction, have substantial error bars on any given measurement. Trends will tend to be more useful than single measurements.



FDCA data availability

- Provisional FDCA L2 data will be available in early 2018
- Currently will be produced from the Ground System (GS) for Full Disk (FD) and CONUS sectors
- It will **not** be produced by the GS for MESO sectors
- Fire weather is in the priority list for calling MESO sectors

Questions?

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