Indonesia peatland fire detection with nighttime Landsat- Preliminary results

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June 24, 2014

NGDC VIIRS Data Products

- Regional data service covering Indochina (including Vietnam) with many day and night data products in geotiff format: http://ngdc.noaa.gov/eog/viirs/download_thailand.html
- VIIRS low light imaging monthly composites:

  http://ngdc.noaa.gov/eog/viirs/download_monthly.html
- VIIRS Nightfire (VNF): http://ngdc.noaa.gov/eog/viirs/download_viirs_fire.html
- Regional subset of VNF covering Vietnam is available at: http://ngdc.noaa.gov/eog/viirs/download_thailand.html

Riau Fires – June 2013.

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Singapore chokes on haze as Sumatran forest fires rage

By **Peter Shadbolt**, CNN
updated 1:32 PM EDT, Fri June 21, 2013

Students wear masks as haze shrouds Kuala Lumpur on June 23. Many schools in Malaysia were closed on Monday after air pollution caused by forest fires in Indonesia spiked to hazardous levels.

HIDE CAPTION

Malaysia chokes on smoke

<< < 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 > >>

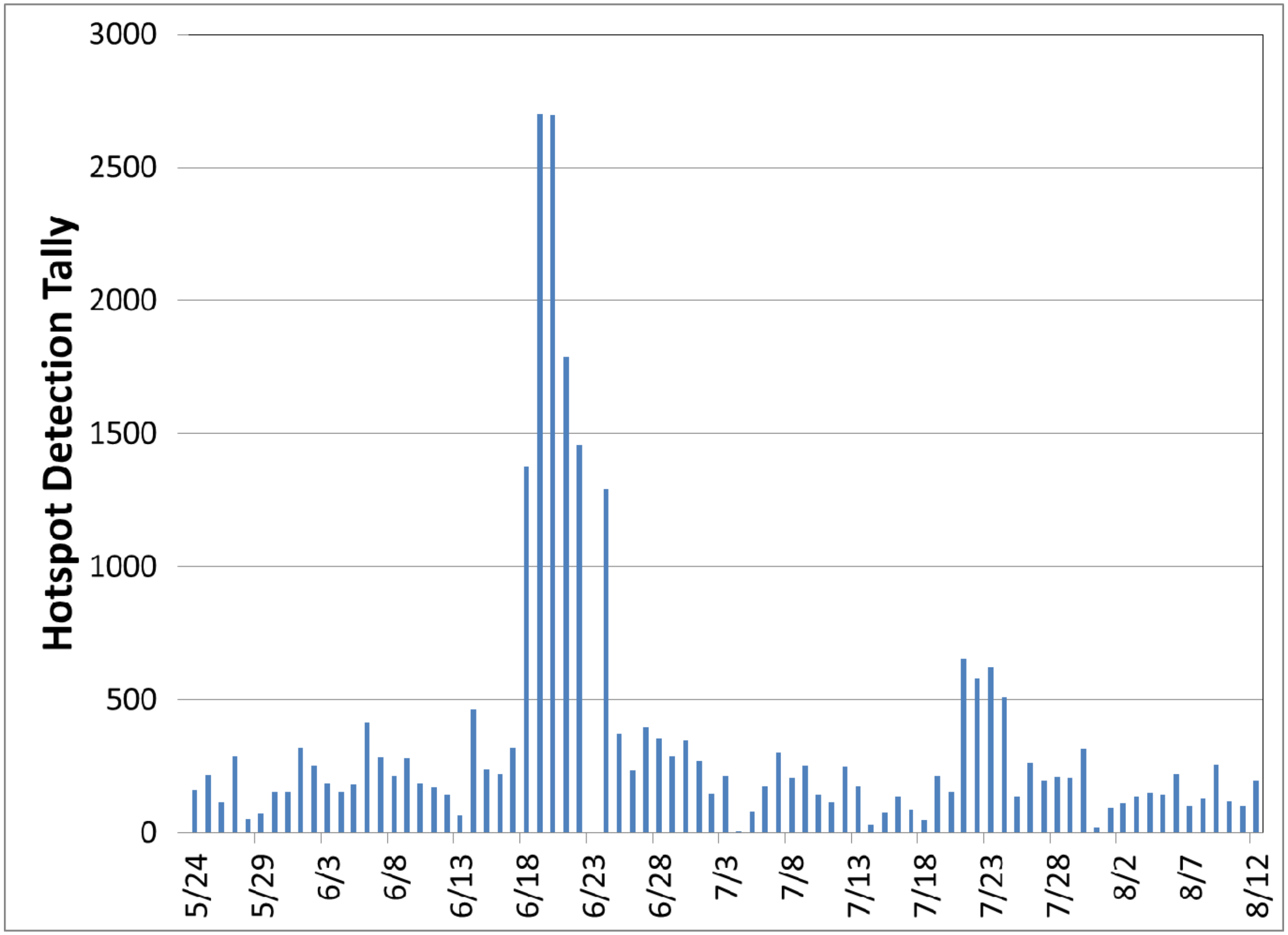
STORY HIGHLIGHTS

- Singapore enveloped in a thick pall of wood smoke caused by forest fires in Sumatra
- Pollution index reaches 371 on Wednesday, the worst level since 1997 when it reached 226

(CNN) -- Singapore was shrouded in haze on Wednesday as smoke from forest fires in nearby Sumatra drifted across the Malacca Strait in the city's worst pollution crisis in more than a decade.

Buildings in the city of 5.3 million people have been enveloped in a smoky haze since the beginning of the week as illegal burn off in nearby Indonesia and prevailing winds were causing a smoke crisis

VIIRS Nightfire Detections in Sumatra - 2013



Fires were detected.
But were peat fires detected?

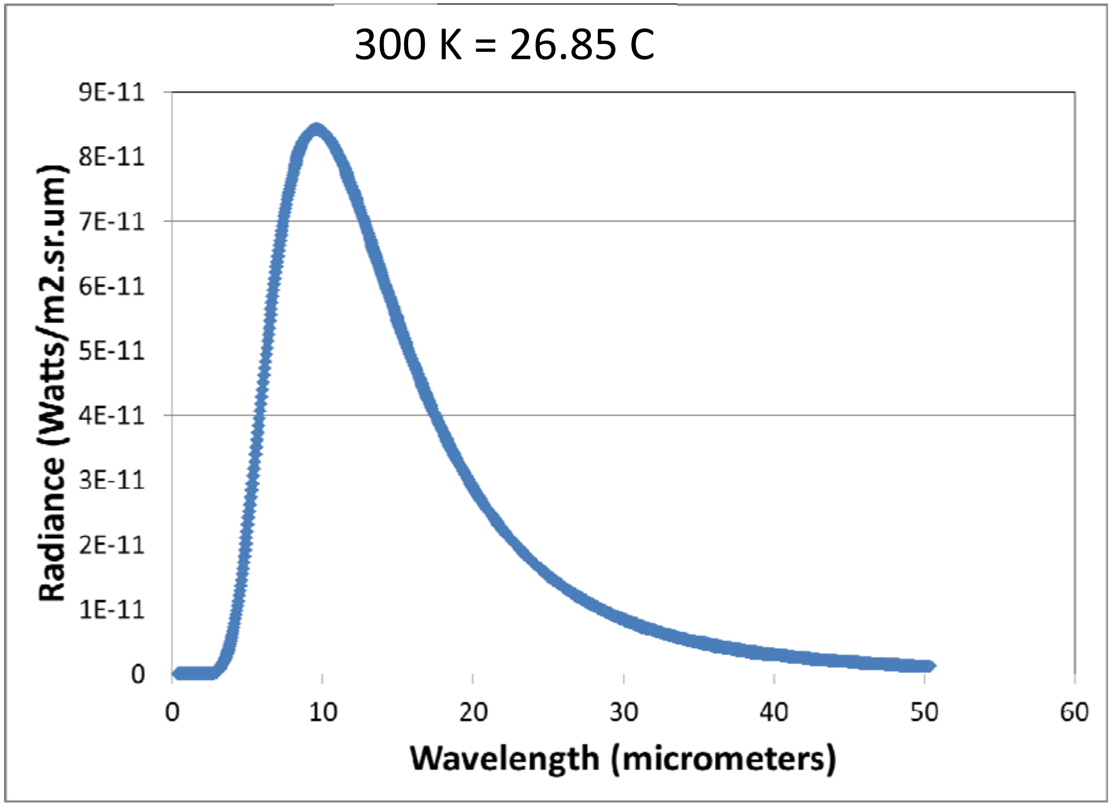
NGDC Indonesia Fire Project

- One year project funded by the U.S. Forest Service.
- Objectives:
  - Explore the remote sensing of peat fires
  - Develop daily and seasonal GHG and particulate daily emission estimates from 2013 & 2014 fires
- Team members:
  - NGDC: remote sensing research & tech transfer
  - LAPAN: field validation
  - NCAR: emission modeling

The Challenges of Peatland Burning

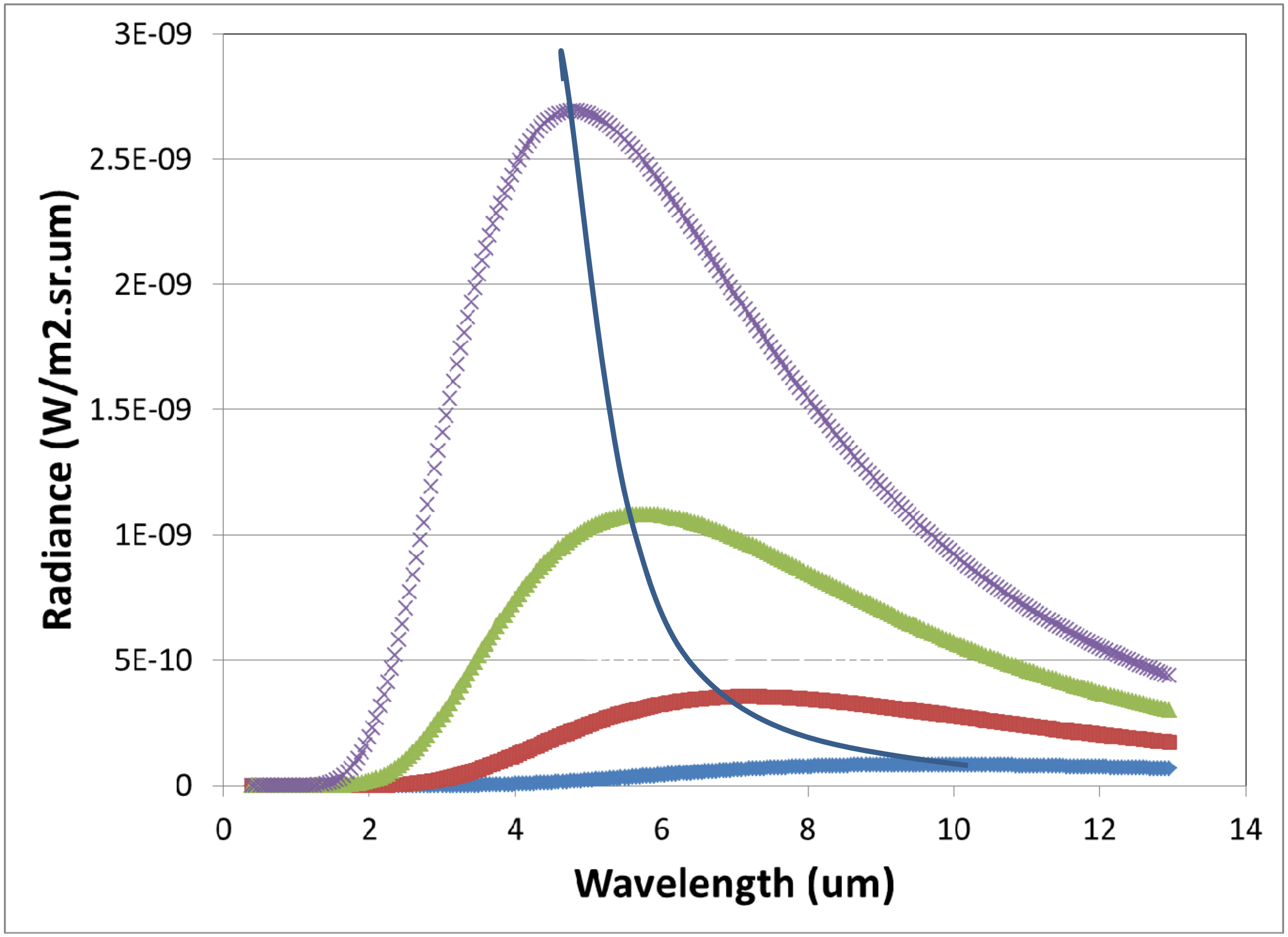
- Peatland fires are a mixture of flaming and smoldering fires. 600 K is considered the break point between flaming (~800 K) and smoldering (~400 K).
- Emissions are distinctly different for flaming versus smoldering peatland fires.
- Satellite detection works reasonably well for detection of flaming fires.
- Detection and characterization of smoldering peat fires from satellites is challenging:
  - Much of the burning is underground – while satellites observe the surface.
  - Detection of low temperature sources requires large source areas to yield sufficient infrared emissions.
  - Some satellite fire detection algorithms rely on a background radiance subtraction derived from analysis of pixels surrounding suspected fire pixels. Undetected smoldering fires can corrupt the background radiance subtraction.

Planck's Law



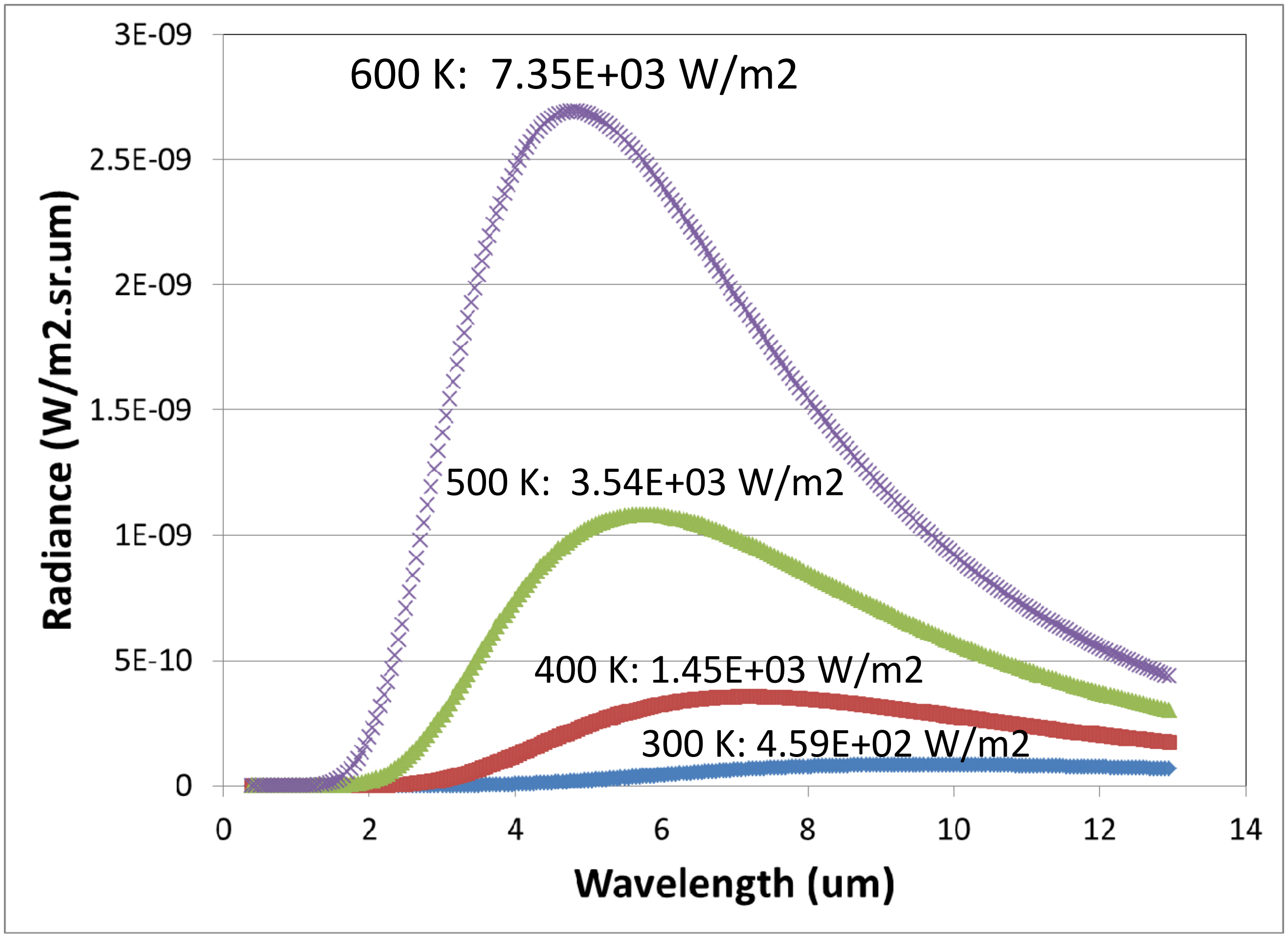
- Developed by Max Planck in 1900.
- States that all objects above absolute zero emit radiation and that the emission can be modeled based on temperature and emissivity.
- Clouds, water, and green vegetation behave as blackbodies in mid- and long-wave infrared.

Wein’s Displacement Law



Wavelength of peak radiant emissions is calculated based on temperature = 2898 (um.k) /K

Stefan Boltzmann Law – Remember T^4

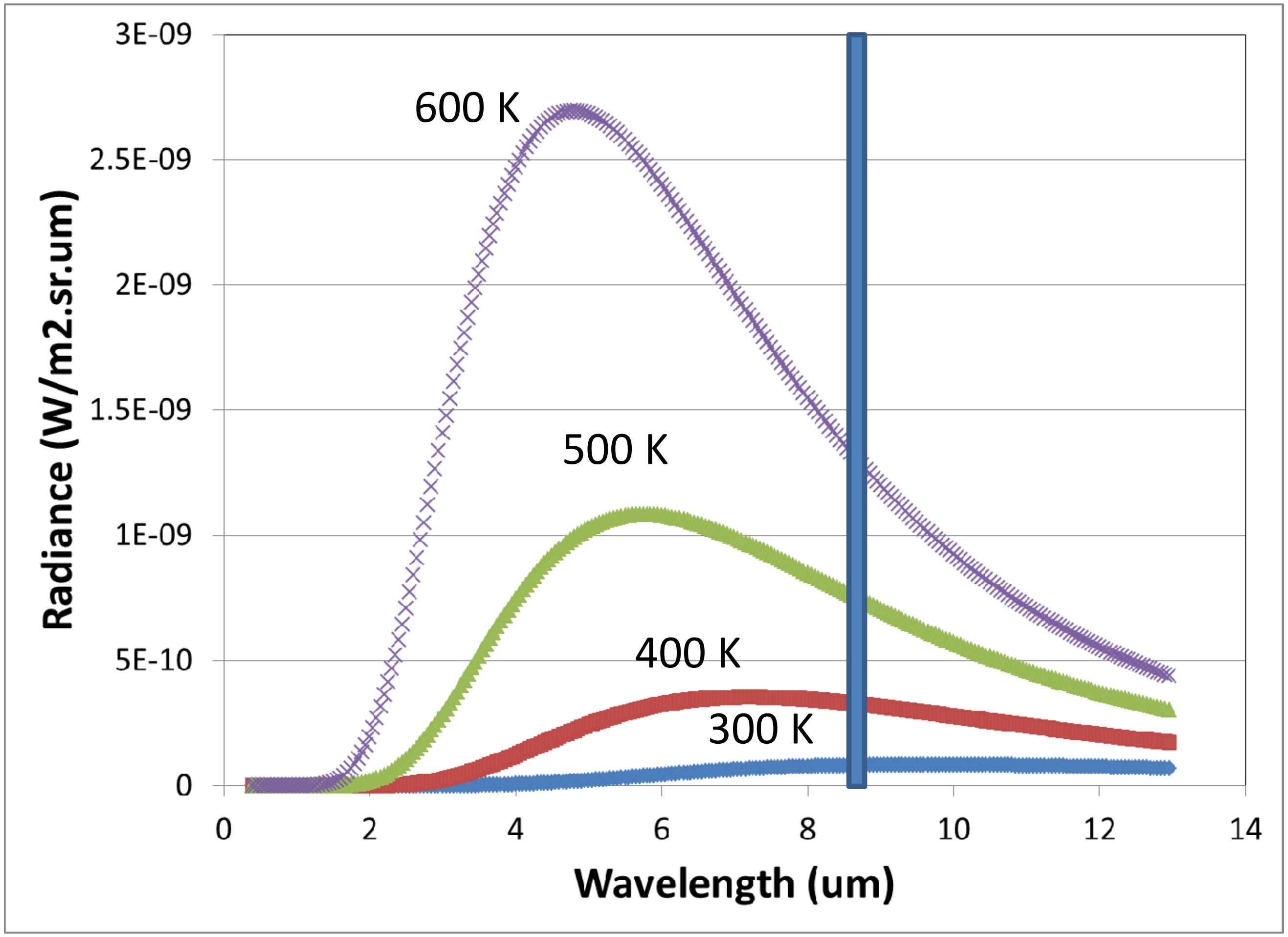


Total radiant power (area under the Planck curve) can be calculated from temperature^4.

Stefan-Boltzmann constant (S) = 5.67E-08W/m^{2}K^4

Radiant power = S*K^4

Measuring the temperature of an object that fills the field-of-view

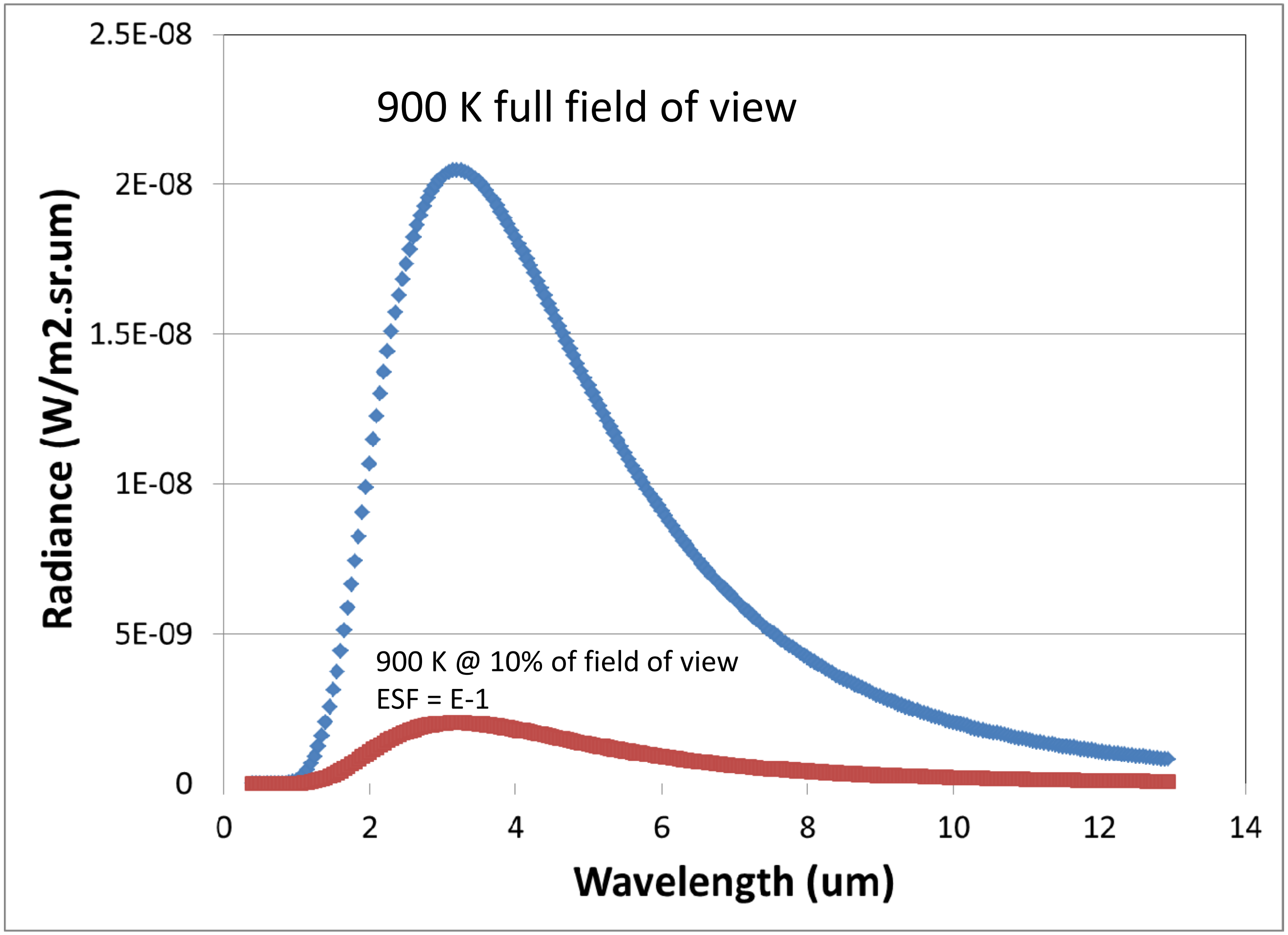


Can be done with a single spectral band.

Why?

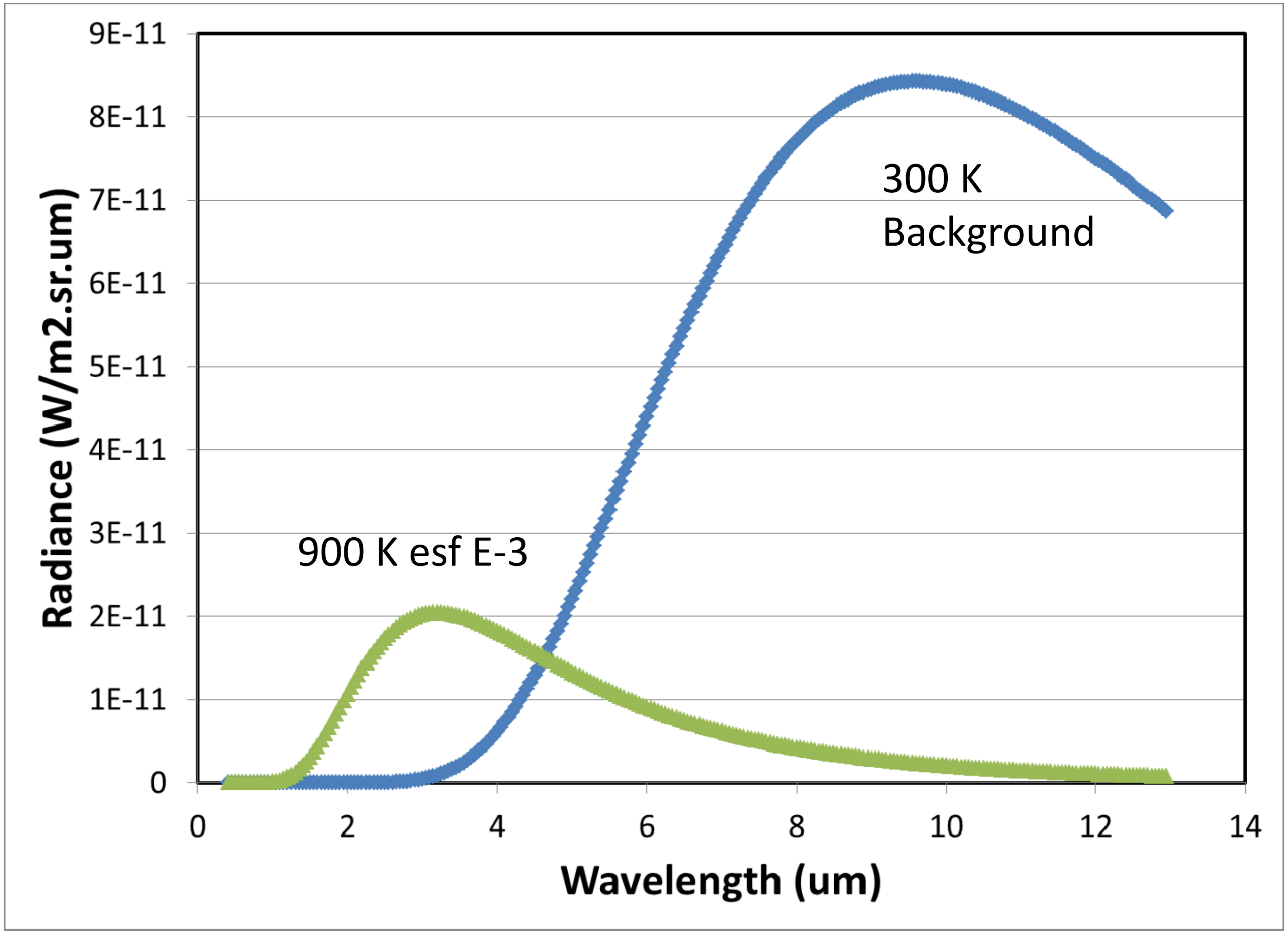
Because the Planck curves always go up as temperature increases. The lines do not cross each other.

Sub-pixel source look like “graybodies”

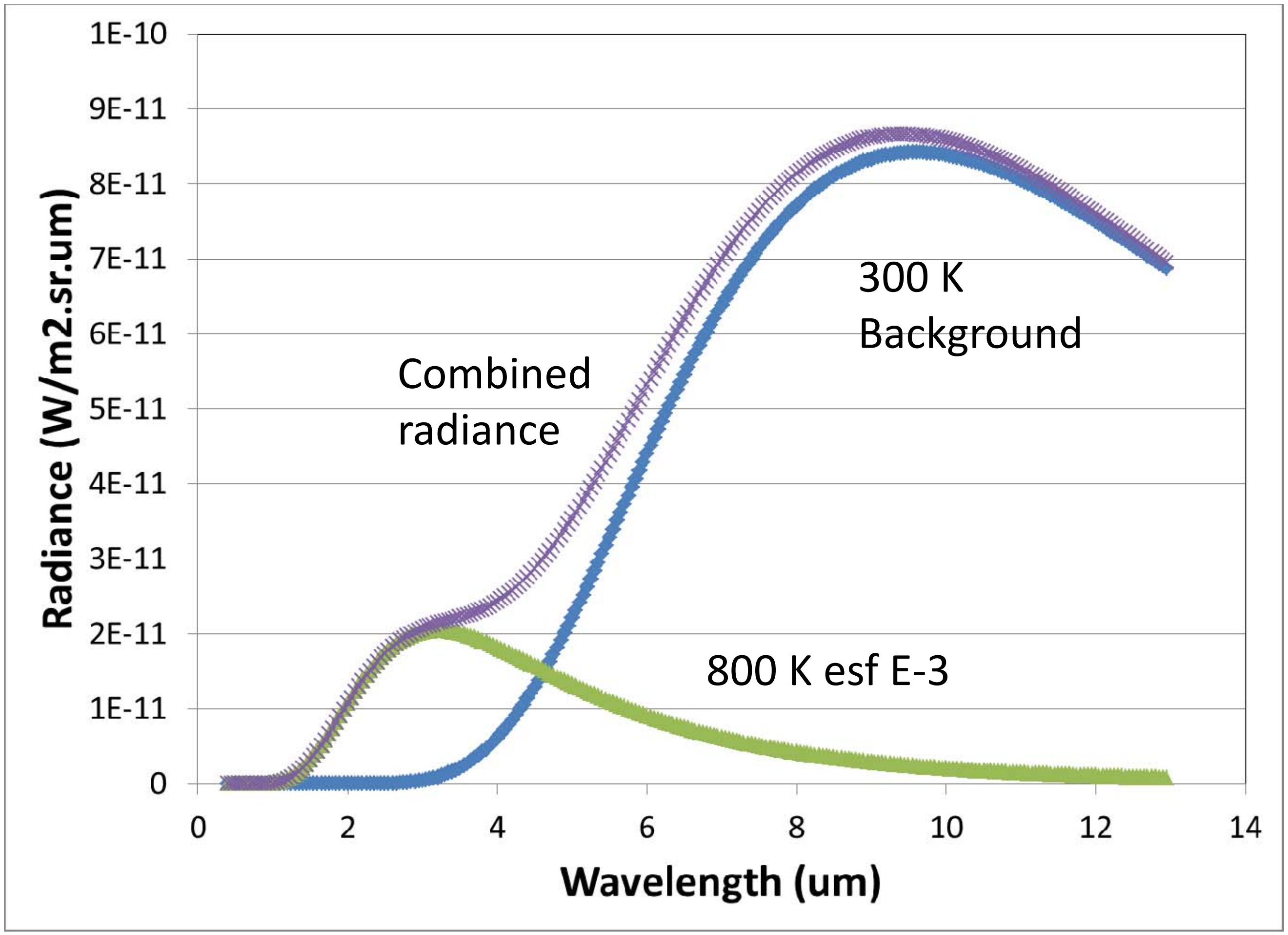


Wein’s law provides the temperature. The emission scaling factor (ESF) is the ratio of the observed peak radiance to the full pixel peak radiance for an object at that temperature.

Subpixel fire at 900 K (flaming phase) filling 1/1000 (E-3) of the pixel footprint

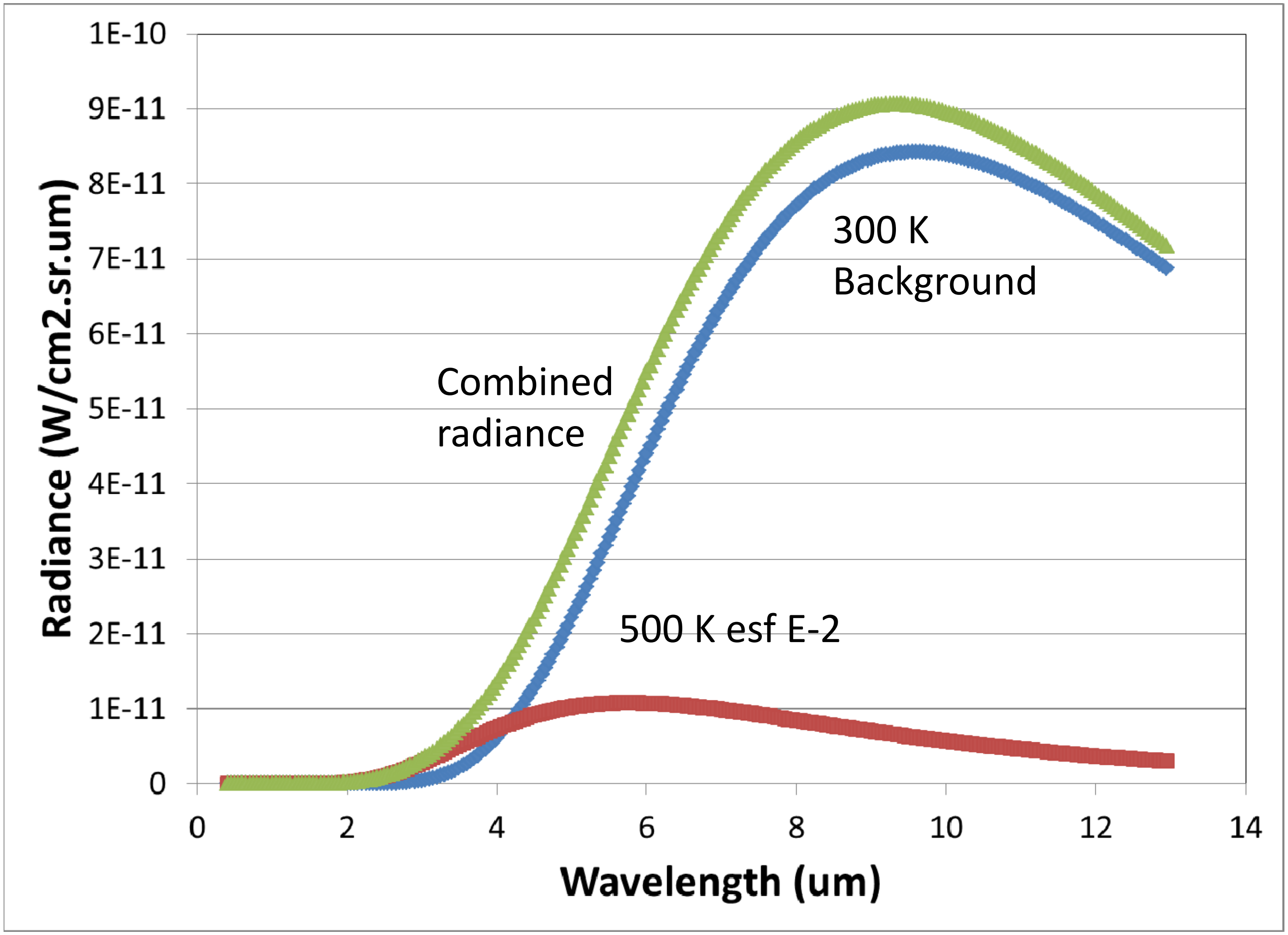


Subpixel fire at 800 K filling 1/1000 (E-3) of the pixel footprint



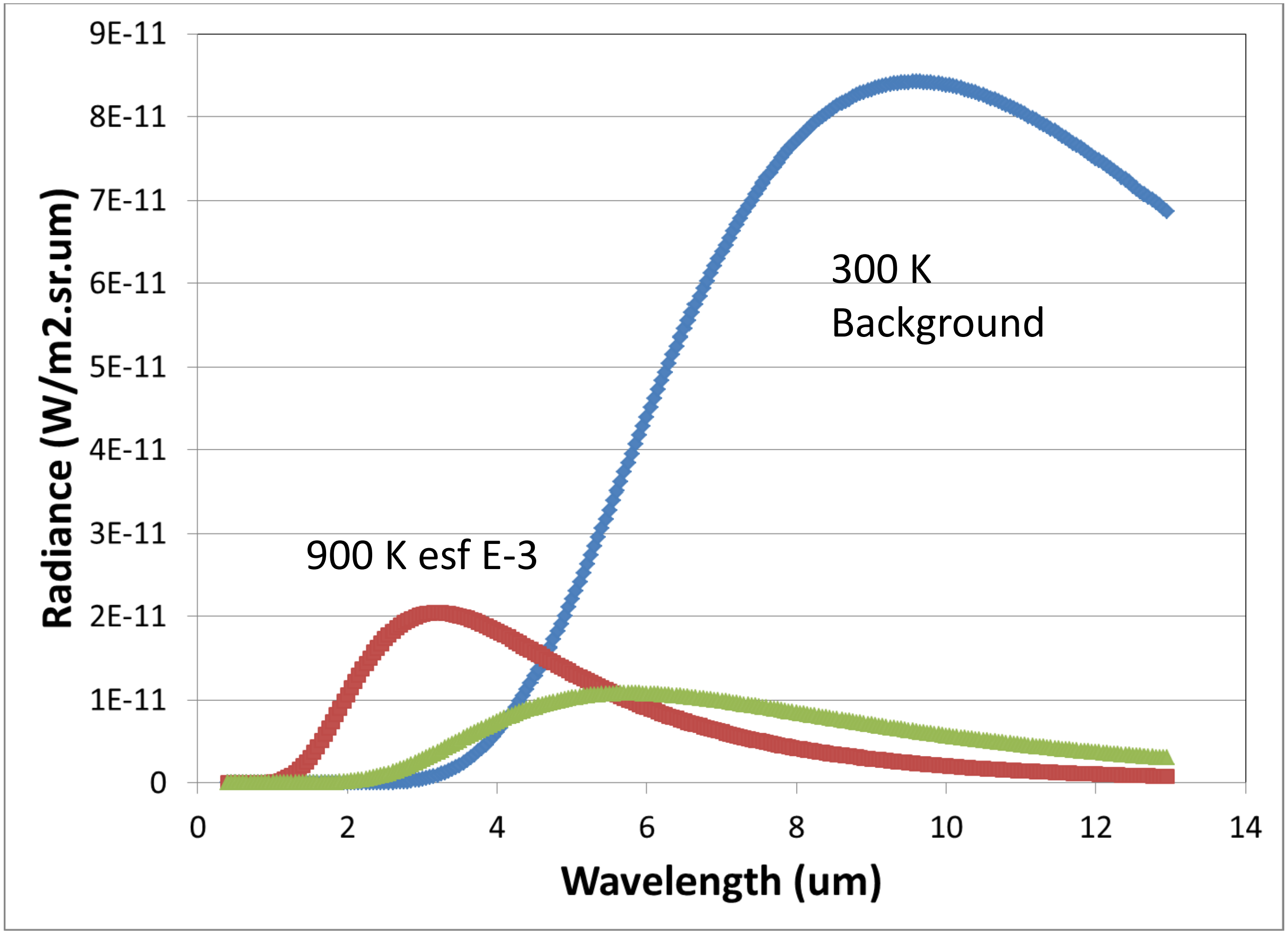
Detect hot spot pixels based on anomalous radiance in SWIR and MWIR

Subpixel smoldering at 500 K filling 1% (E-2) of the pixel footprint

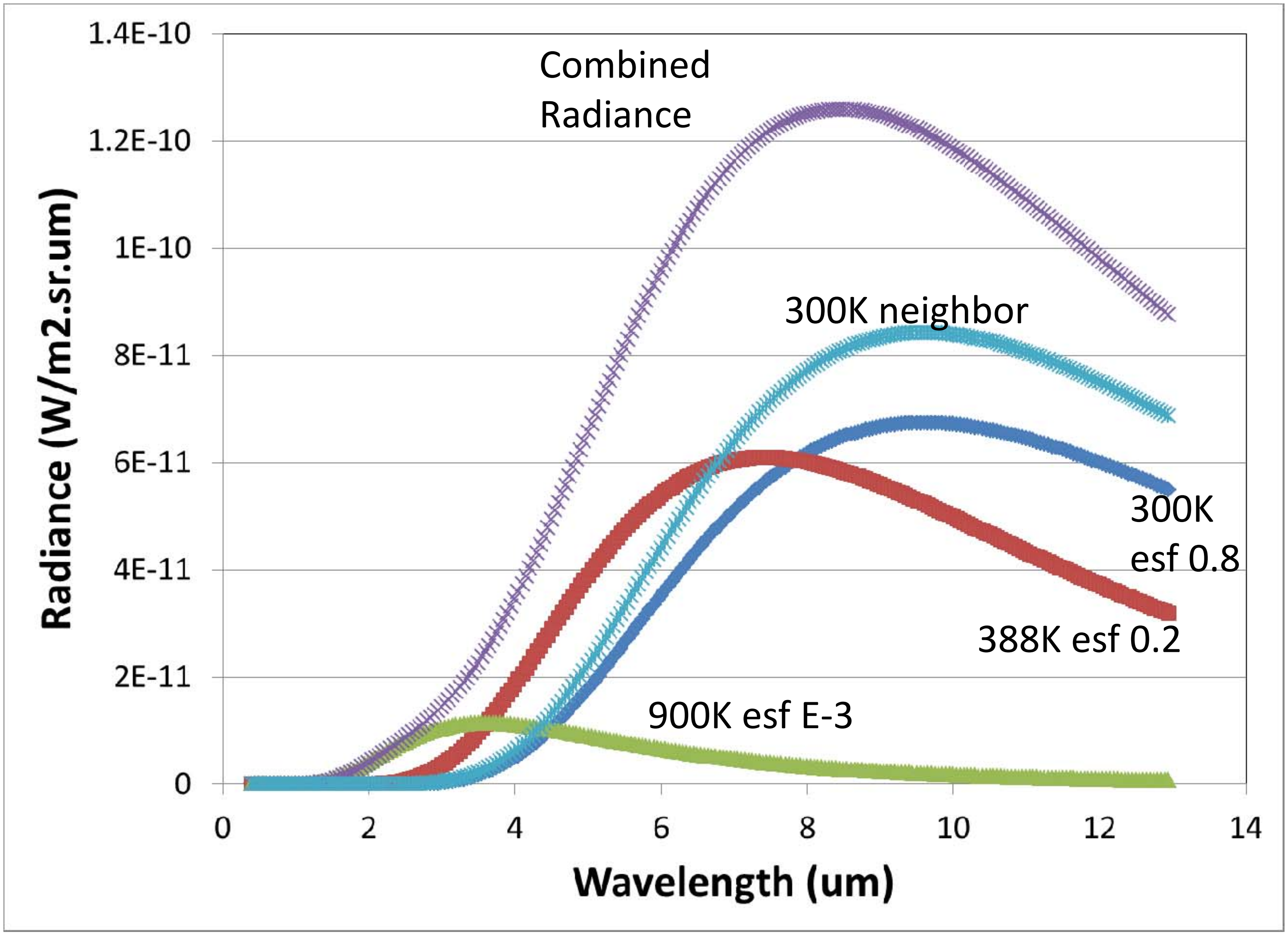


Difficult to detect smoldering in km scale pixel footprints

Subpixel fire at 900 K filling 1/1000 (E-3) plus smoldering at 500K filling 1% of the pixel footprint



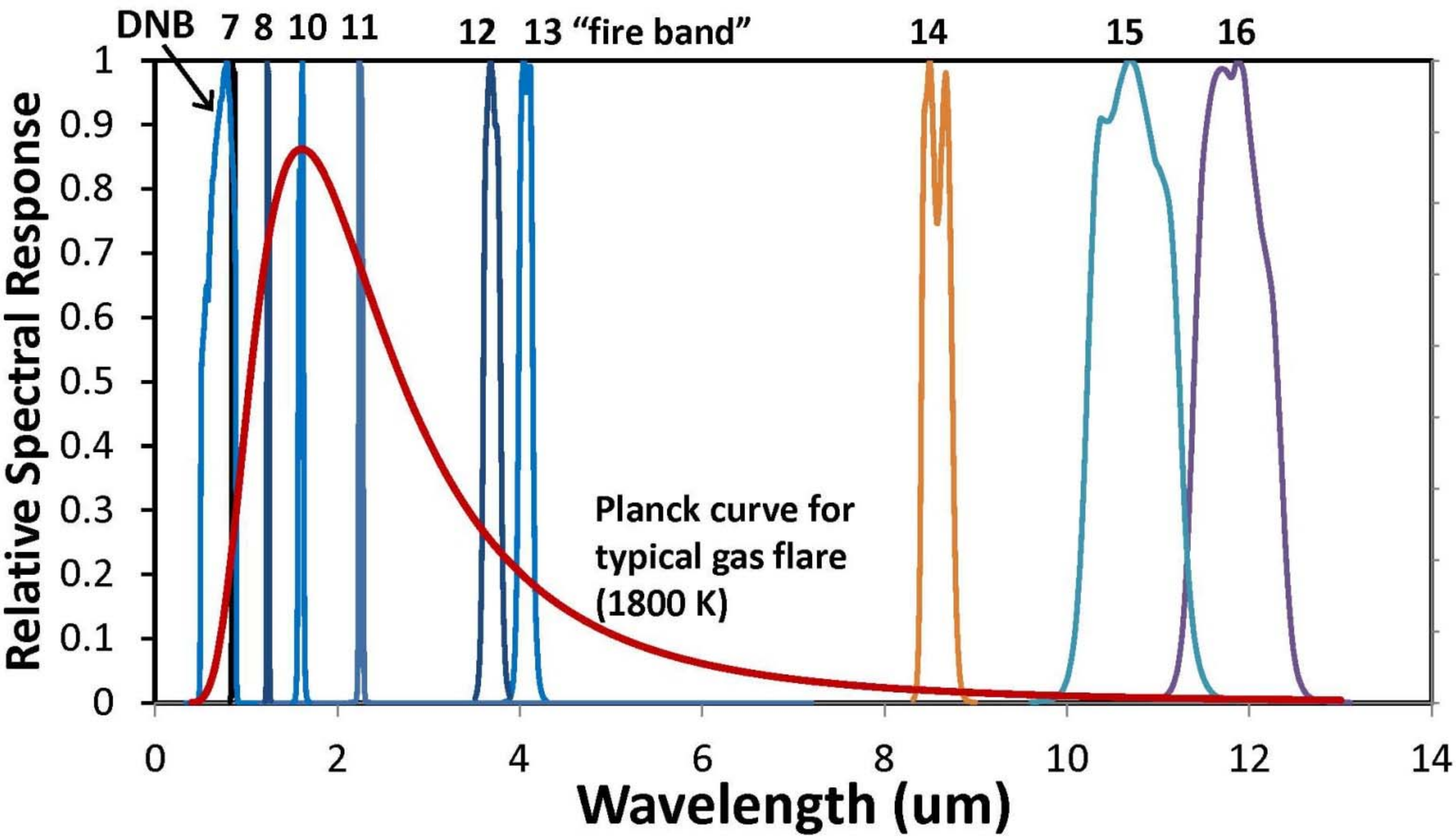
Subpixel fire at 900 K filling 1/1000 (E-3) plus smoldering at 388K filling 20% of the pixel footprint



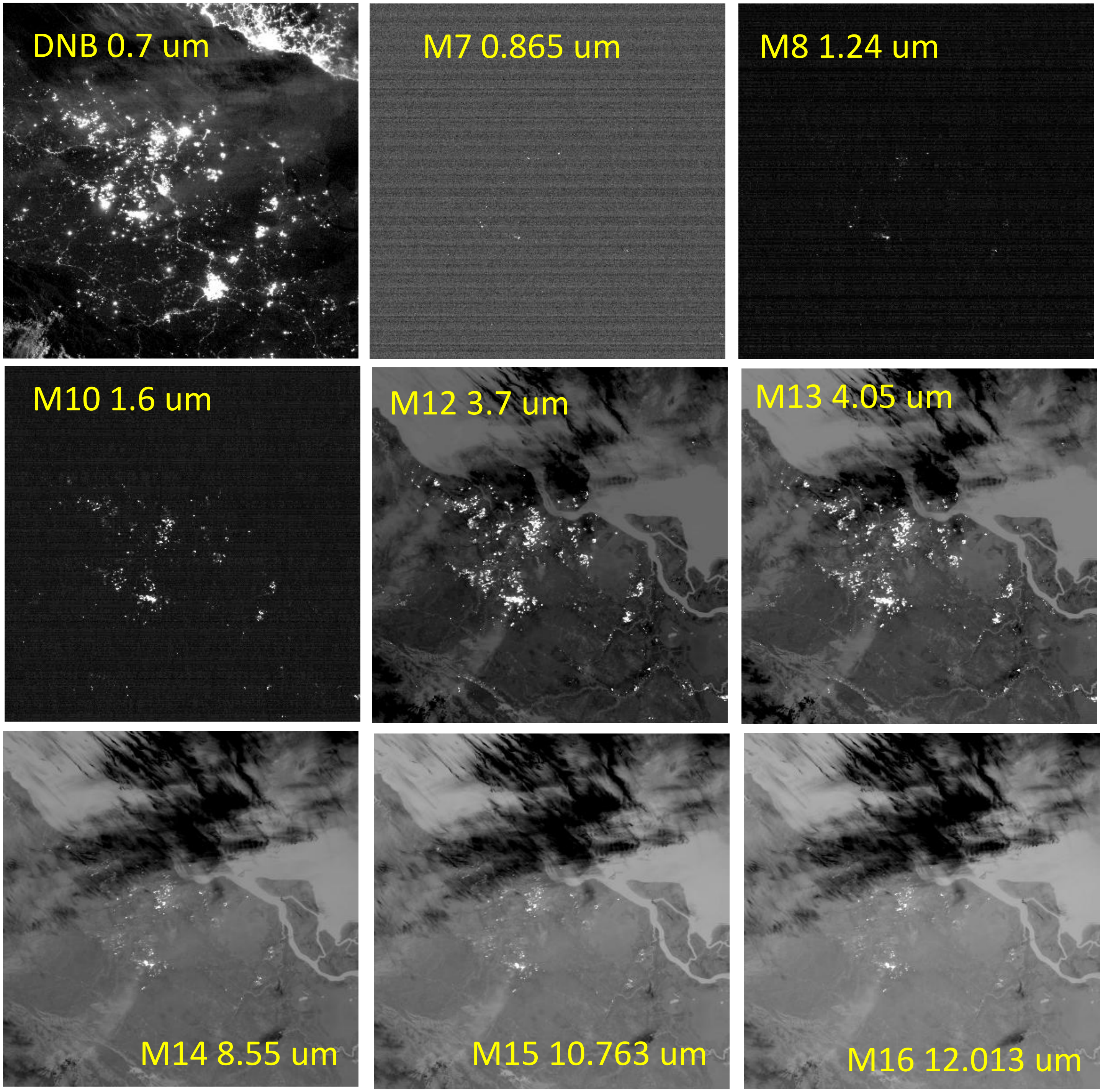
VIIRS

- The Visible Infrared Imaging Radiometer Suite (VIIRS) is the primary imaging sensor flown on the NASA/NOAA Suomi National Polar Partnership satellite.
- Launched on October 28, 2011, VIIRS began to collect usable data in late-February 2012.
- 22 spectral channels, most with 750 meter pixels at nadir.
- 3000 km swath. Overpasses at ~01:30 and 13:30 daily.
- VIIRS is unique for collecting near and short-wave infrared data at night.

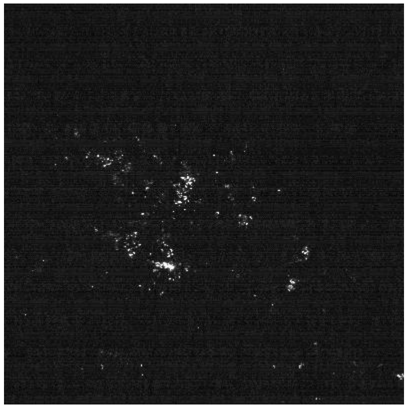
VIIRS Nighttime Bands
Note – B11 nighttime collection is pending



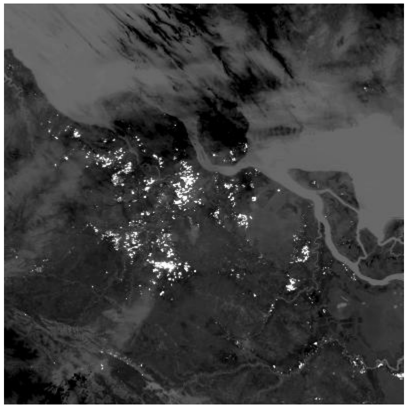
VIIIRS Nighttime Data Riau June 19, 2013

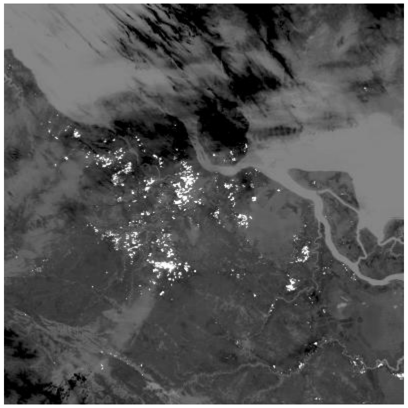


VIIRS Nightfire has three hot pixel detection algorithm types

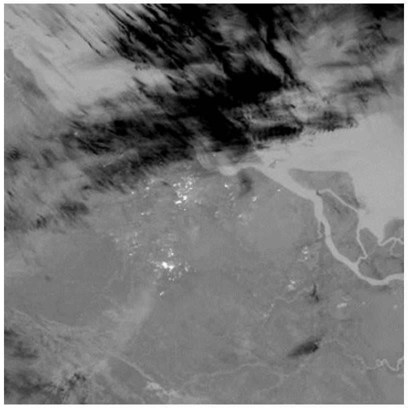


1. NIR & SWIR: Detection threshold set based on background noise – mean plus four standard deviations. The detected pixels are then checked for detection in M7 & M8.



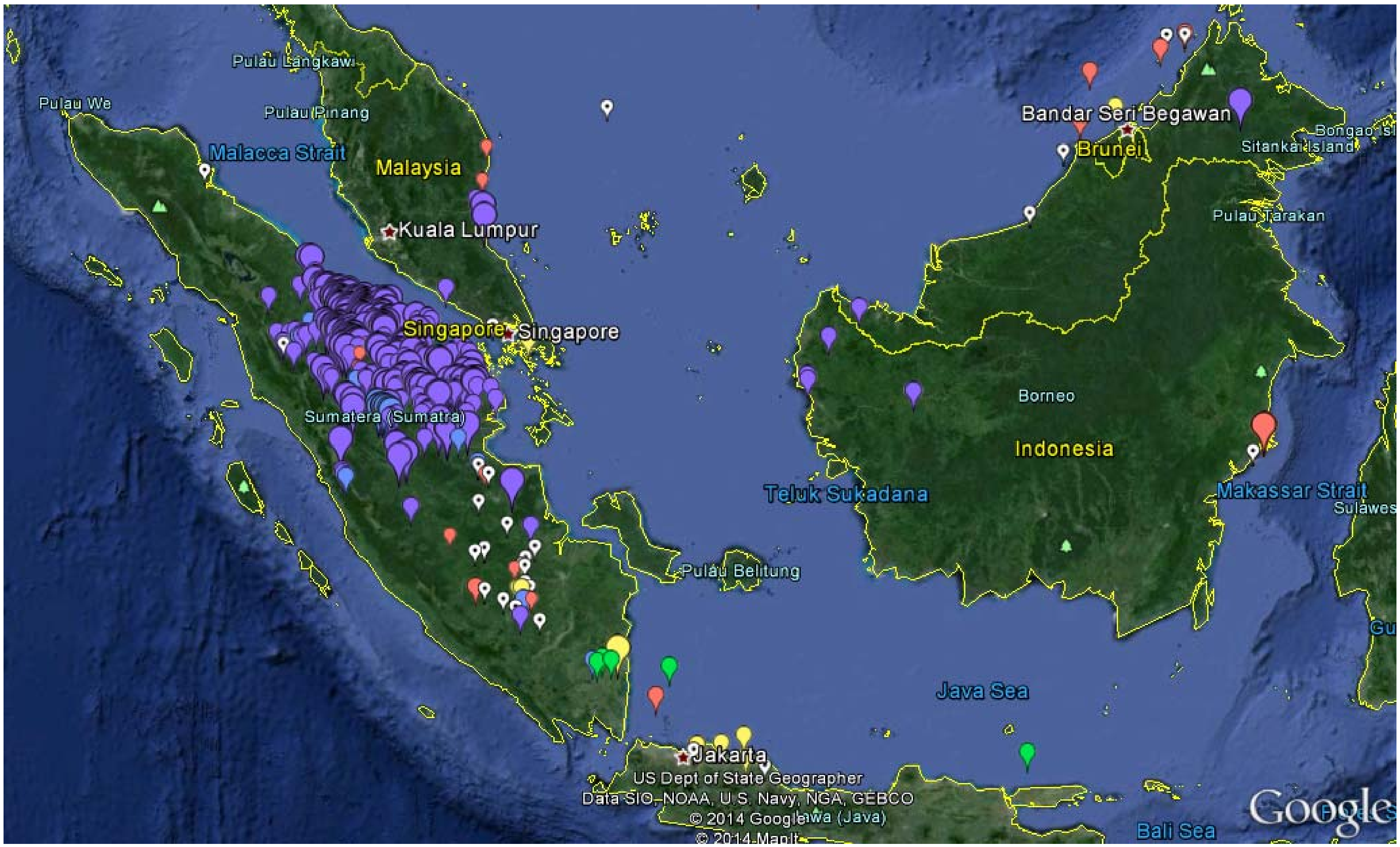


2. MWIR: M12-M13 (3.8 and 4 um) scattergram analysis identifies background. Hot pixels are the outliers. M12 sub-pixel saturation detected by M13/M12 ratio.



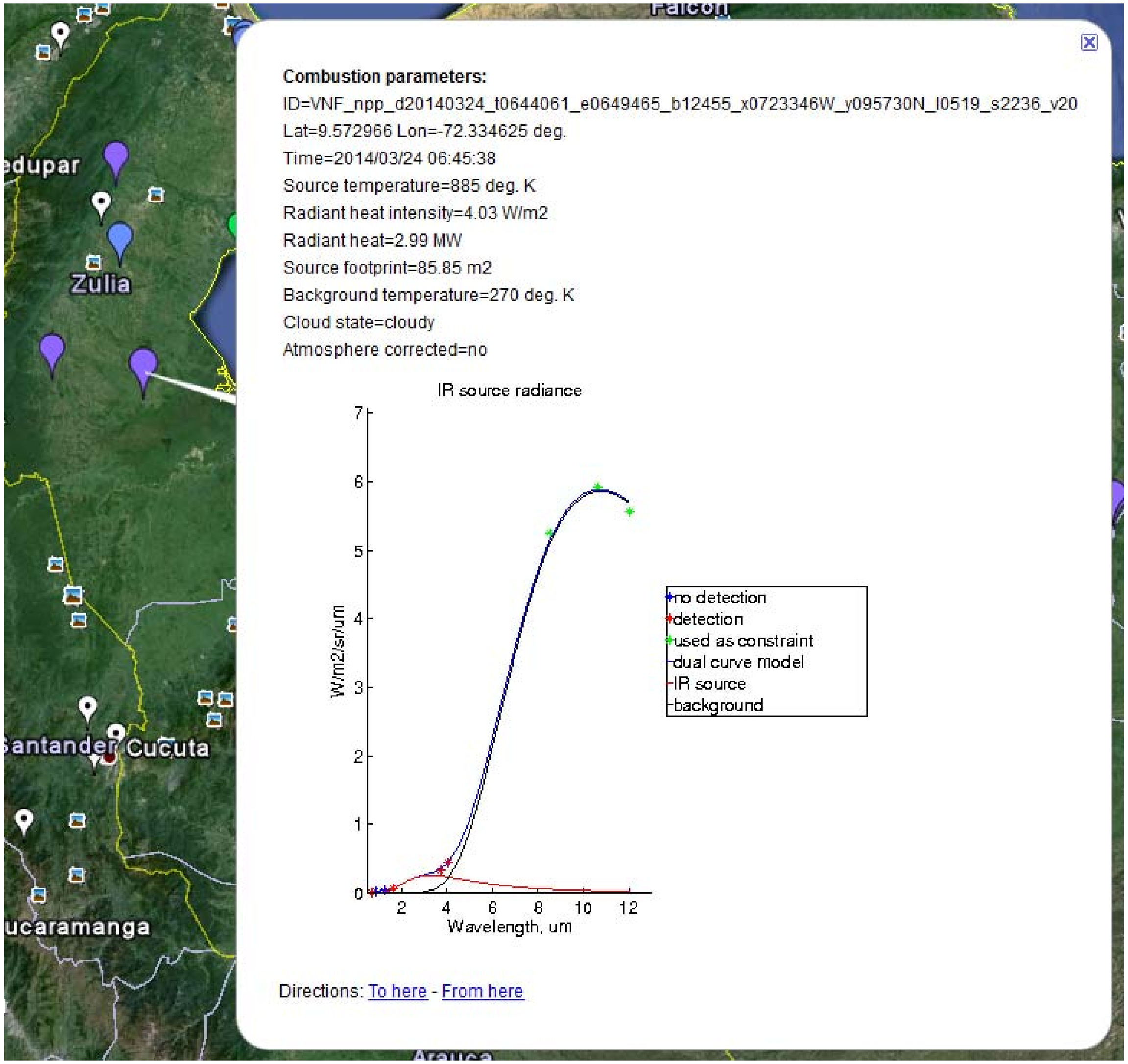
3. LWIR algorithm sets detection threshold as the maximum M16 radiance found for the M12/M13 background pixel set.

VIIRS Nightfire hot pixel detections for June 19, 2013



Detections are color coded based on temperature. Hot gas flares are red, yellow, or green. Fires are purple or blue. White markers have insufficient signal for Planck curve fitting.

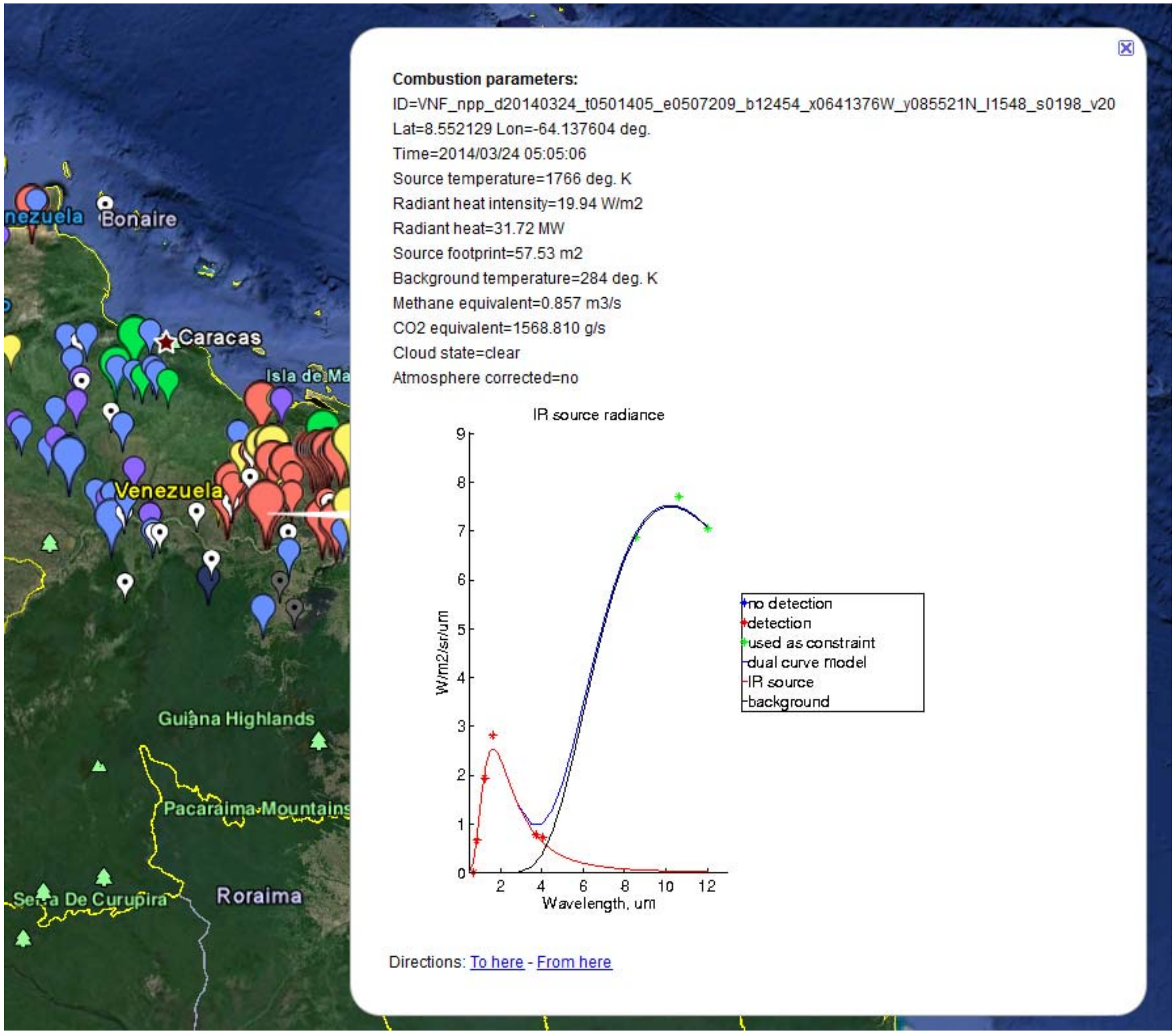
Typical biomass burning
Temperature in the 700-1000 K range



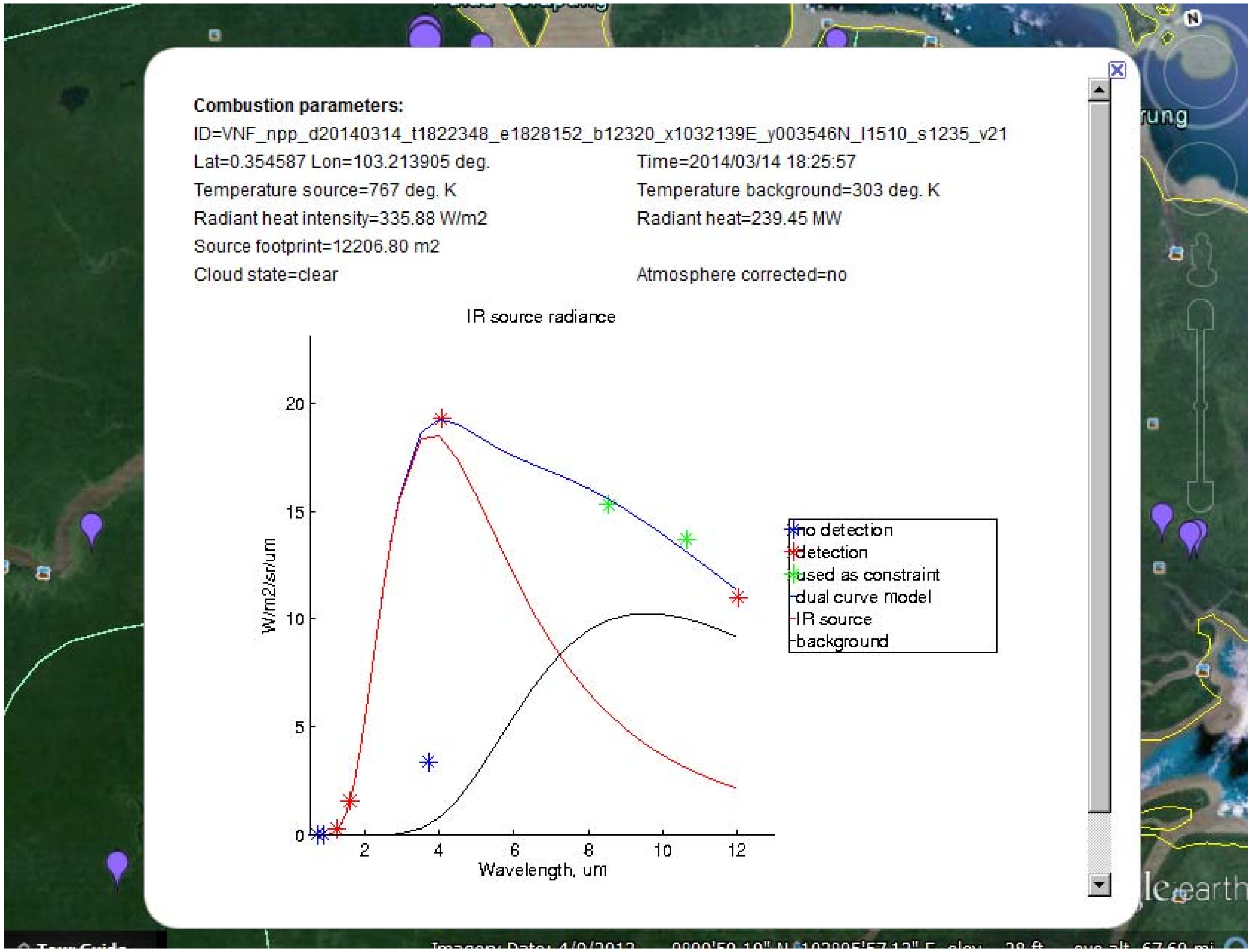
Planck Curve Calculations

- Peak radiance indicates temperature (K) using Wein's Displacement Law.
- Subpixel sources appear as graybodies. The ratio of the observed curve versus the full field of view curve for that temperature is traditionally referred to as emissivity. We call it emission scaling factor (ESF) to distinguish it from full field of view graybodies. Source area is calculated by multiplying ESF by the size of the pixel footprint.
- Radiant heat (aka heat release) is calculated in MWs using the Stefan-Boltzmann Law.

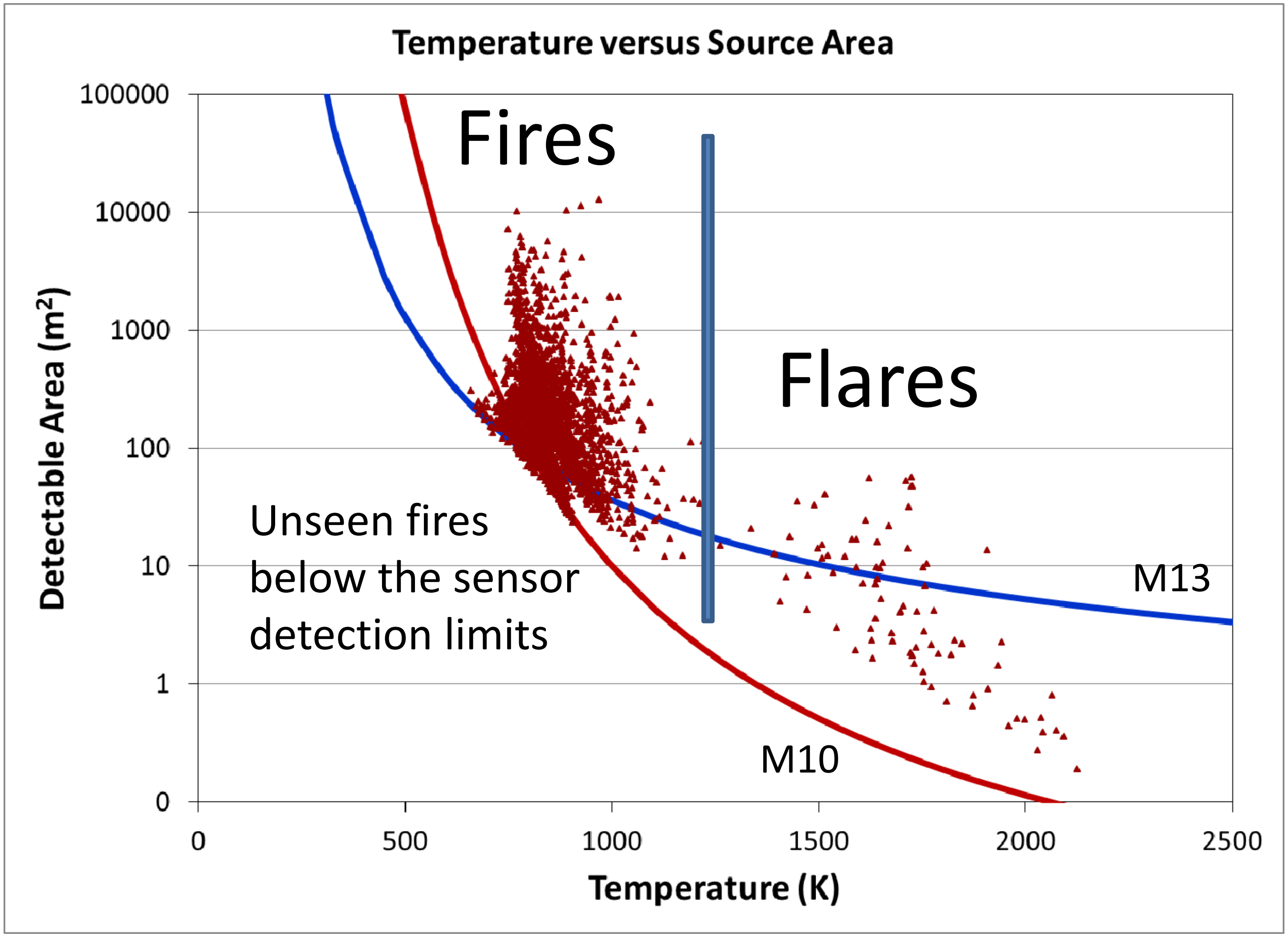
Typical gas flare
Temperature near 1800 K



Band M12 subpixel saturation is ignored in Planck curve fitting



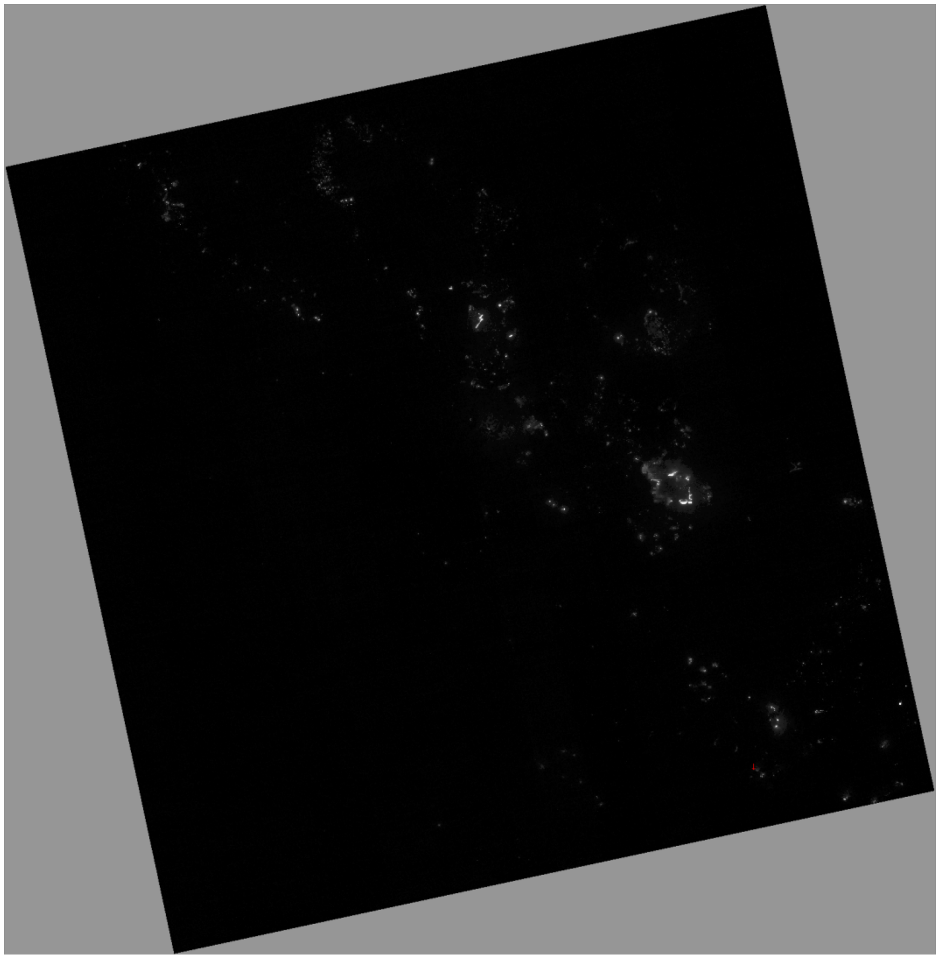
VNF detection limits versus observed data Sumatra June 19, 2013



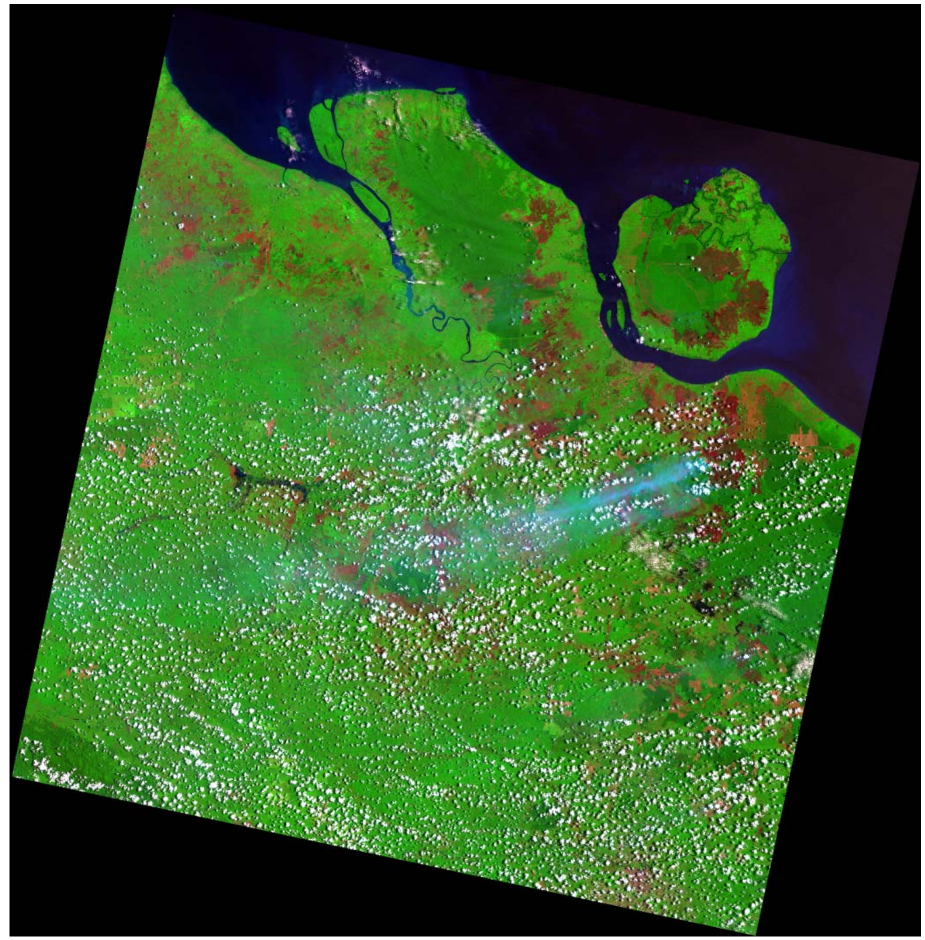
Landsat 8

Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) Launched February 11, 2013	Bands	Wavelength (micrometers)	Resolution (meters)
	Band 1 - Coastal aerosol	0.43 - 0.45	30
	Band 2 - Blue	0.45 - 0.51	30
	Band 3 - Green	0.53 - 0.59	30
	Band 4 - Red	0.64 - 0.67	30
	Band 5 - Near Infrared (NIR)	0.85 - 0.88	30
	Band 6 - SWIR 1	1.57 - 1.65	30
	Band 7 - SWIR 2	2.11 - 2.29	30
	Band 8 - Panchromatic	0.50 - 0.68	15
	Band 9 - Cirrus	1.36 - 1.38	30
	Band 10 - Thermal Infrared (TIRS) 1	10.60 - 11.19	100
	Band 11 - Thermal Infrared (TIRS) 2	11.50 - 12.51	100

Night and Day Landsat 8



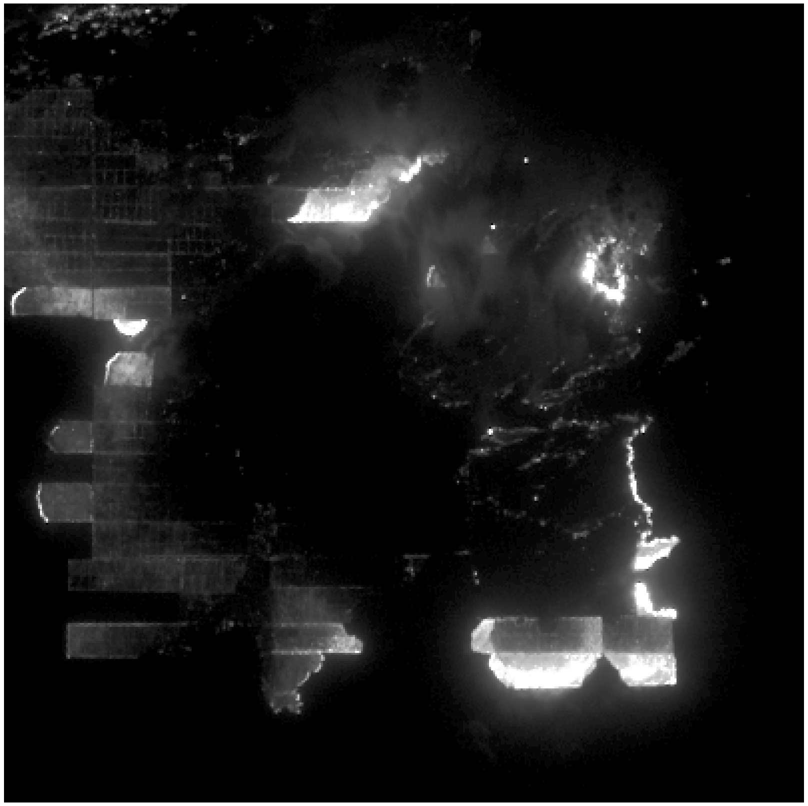
Nighttime Band 7 (2.2 um)
March 28, 2014



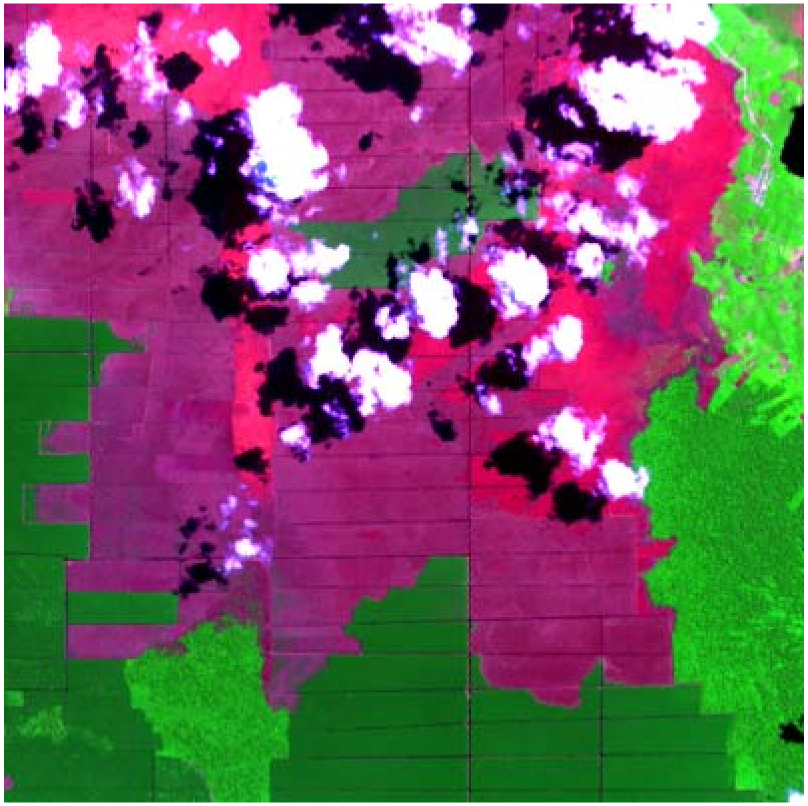
Daytime Band 7,5,4 RGB
March 24, 2014

Full Resolution
Night vs Day

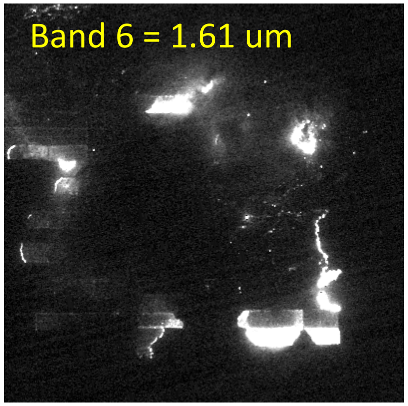
March 28, 2014

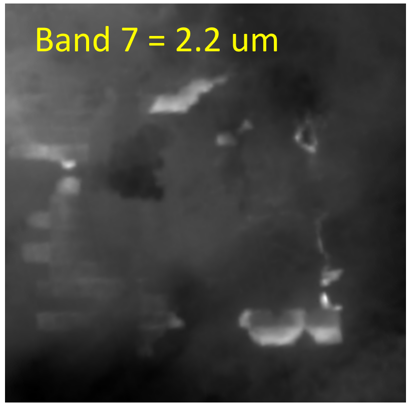


April 4, 2014

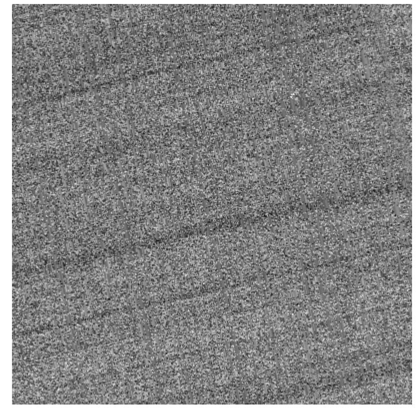


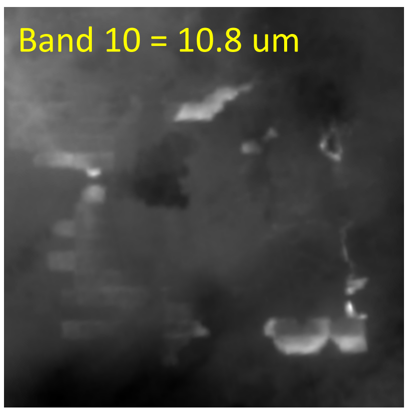
Nighttime Landsat has fire detection in four spectral bands

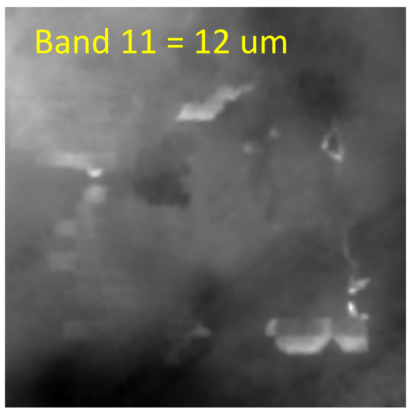




The strongest signal is in band 7.





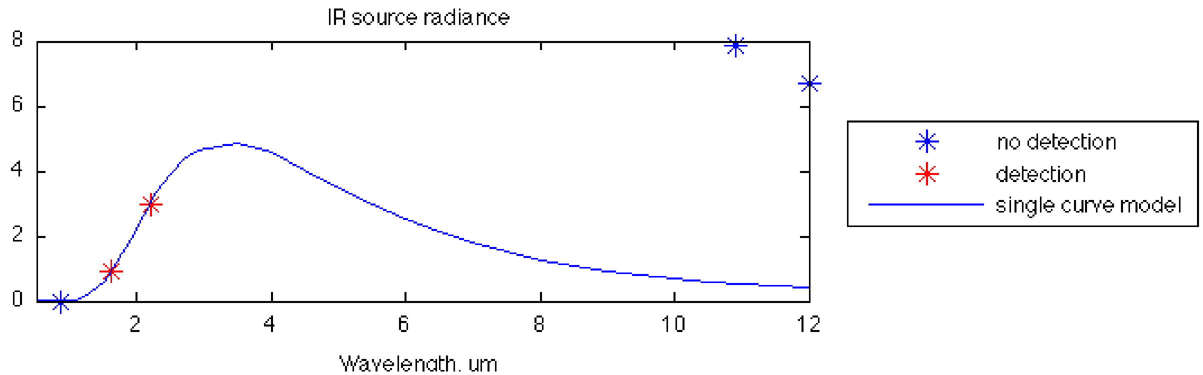


No signal detected in bands 1,2,3,4 & 9.
Rare pixel detects in bands 5 & 8.

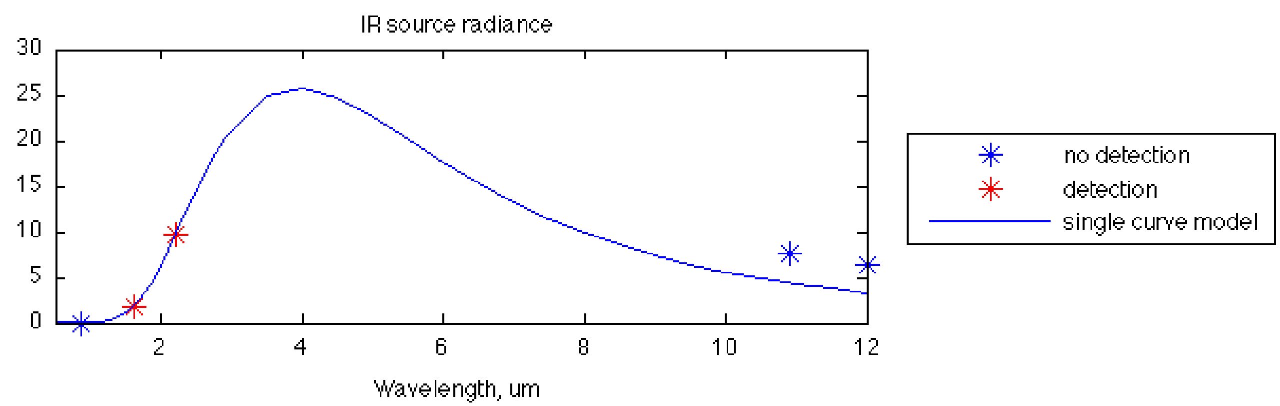
Are the LWIR hot pixels sites of peat fire?

Planck curve modeling with bands 6 & 7

Source ID=x1008477E_y018062N_l1752_s1347_v01
Lat=1.806159 Lon=100.847726 deg.
Source temperature=868 deg. K
Radiant intensity=78.26 W/cm2
Radiant heat=70.43 KW
Source footprint=2.19 m2

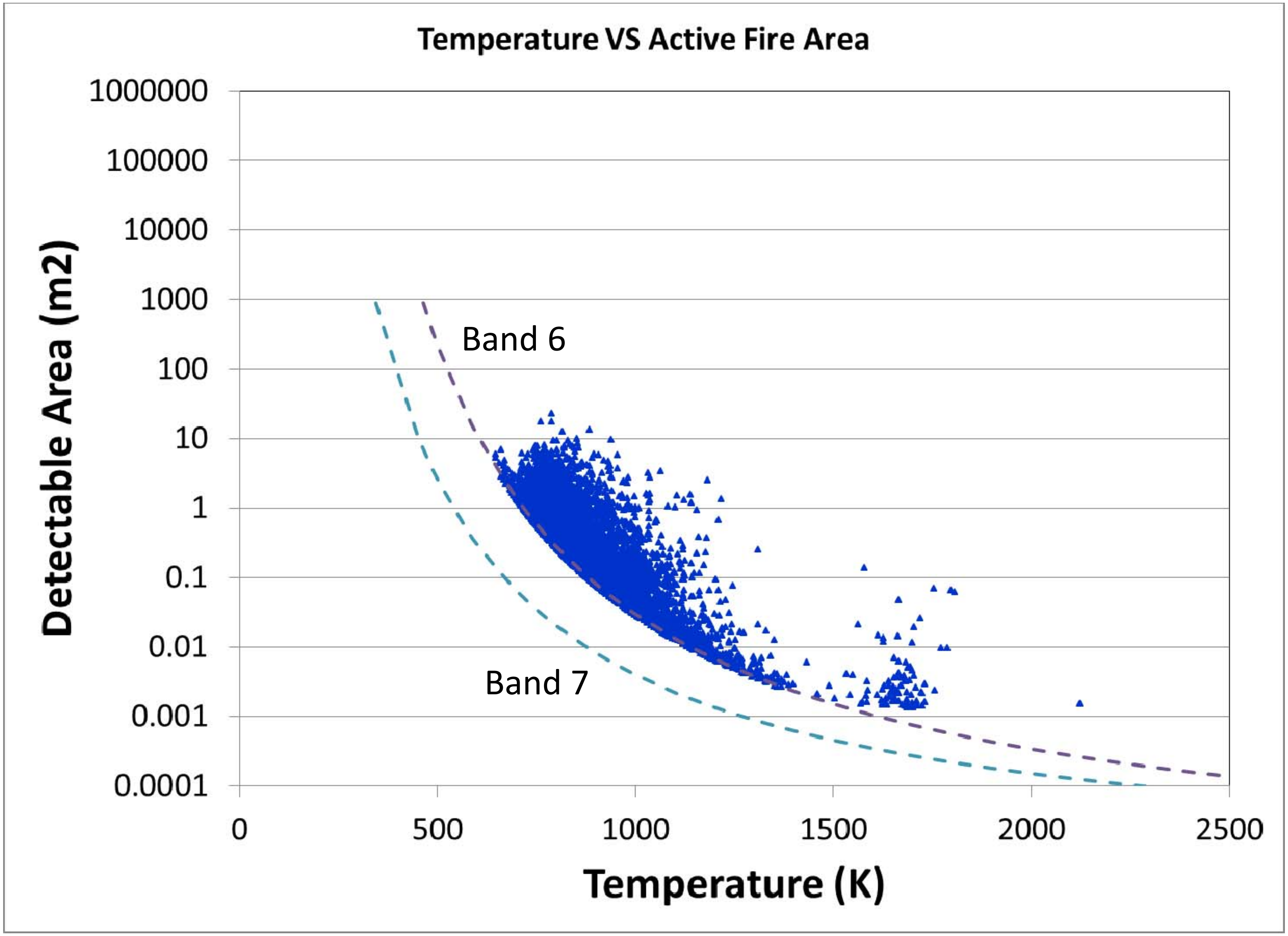


Source ID=x1016628E_y014497N_l3764_s5223_v01
Lat=1.449700 Lon=101.662836 deg.
Source temperature=742 deg. K
Radiant intensity=480.80 W/cm2
Radiant heat=432.72 KW
Source footprint=25.19 m2

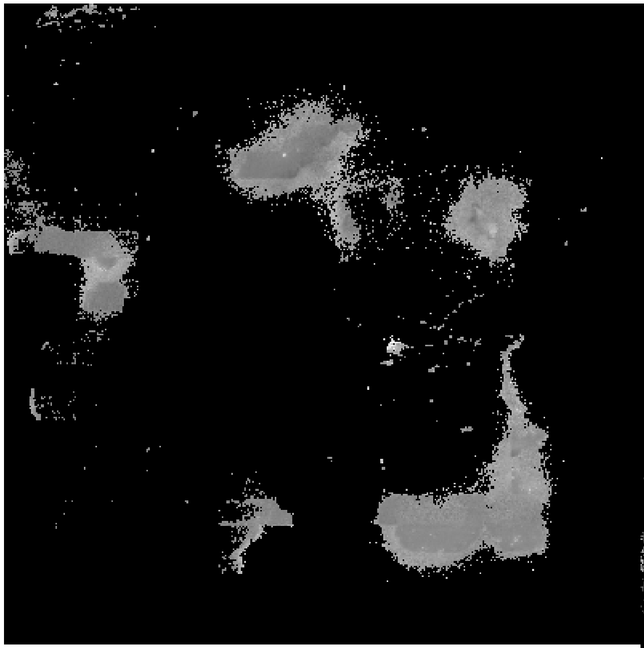


Planck curves were modeled with bands 6 & 7. From these we calculated temperature, source size, radiant heat and hot source radiance in band 10.

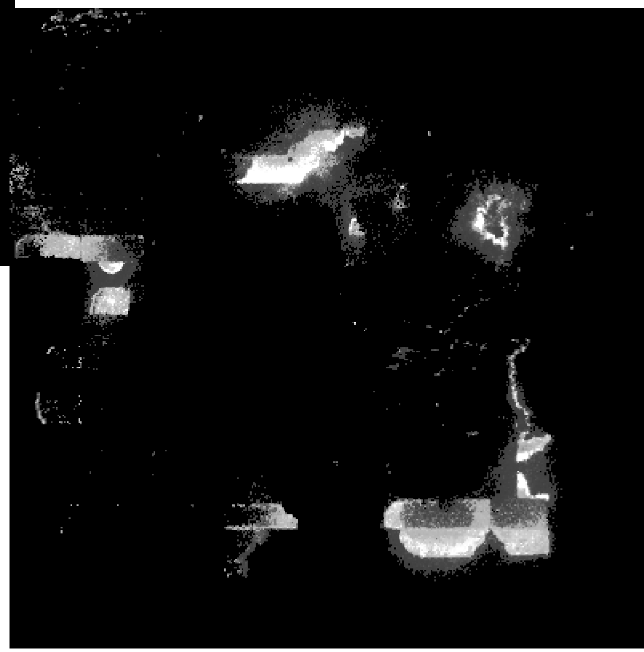
Nighttime Landsat Fire Detection Limits



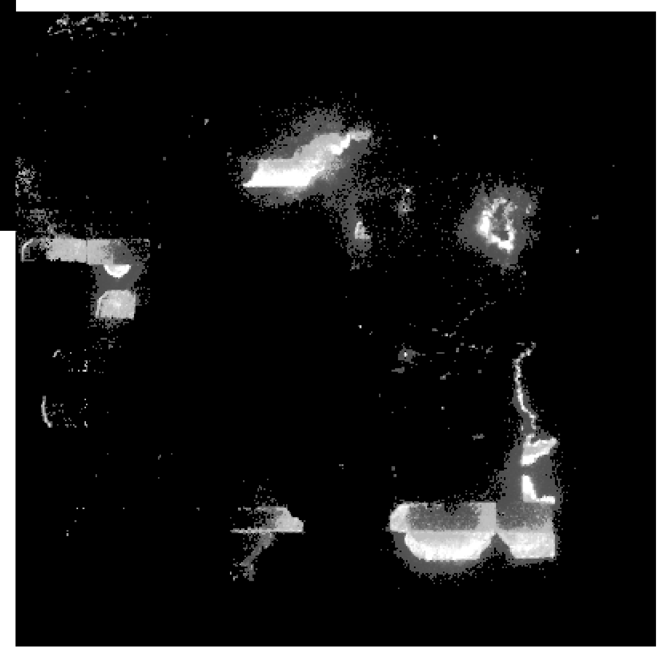
L8 Night Combustion Parameters



Temperature (K)
Little variation
Most pixels are in the 700-900 K range

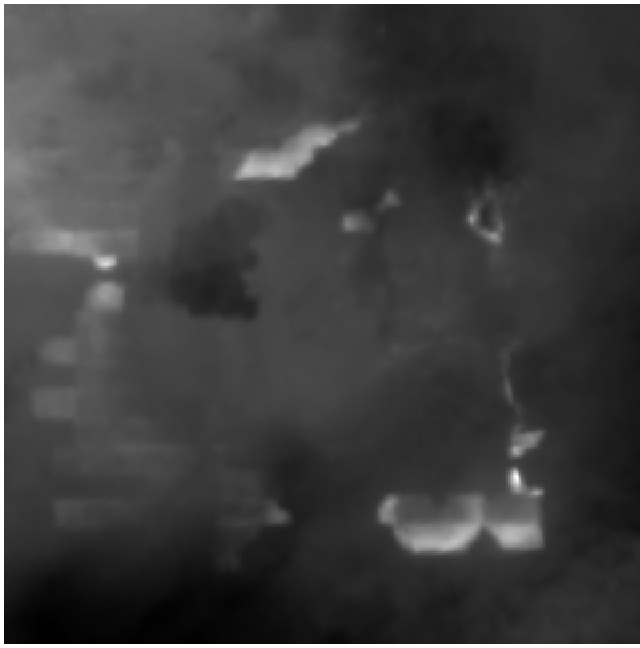


Area of Active Fire (m^2)

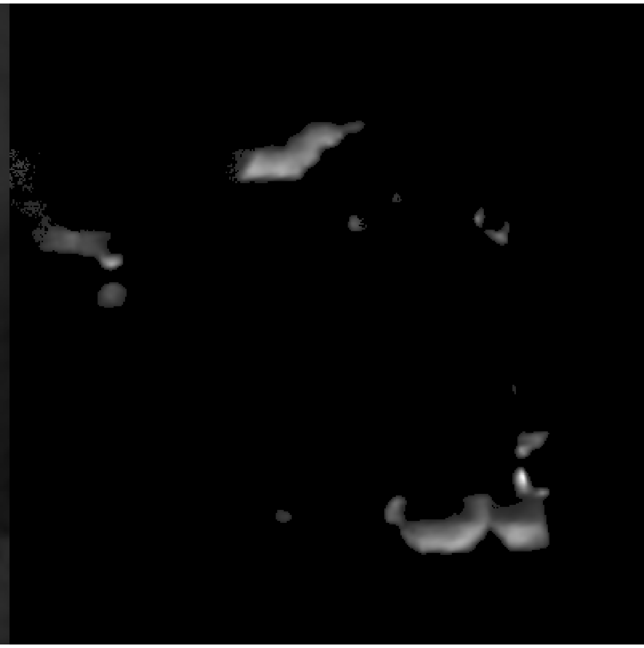


Radiant Heat (KW)

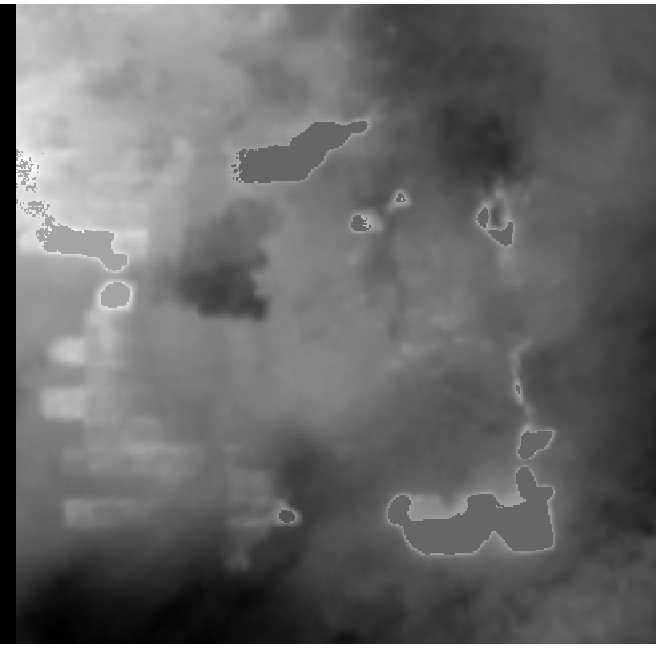
Is there residual LWIR emission indicating the detection of smoldering? No.



Band 10



Band 10 hotpixels

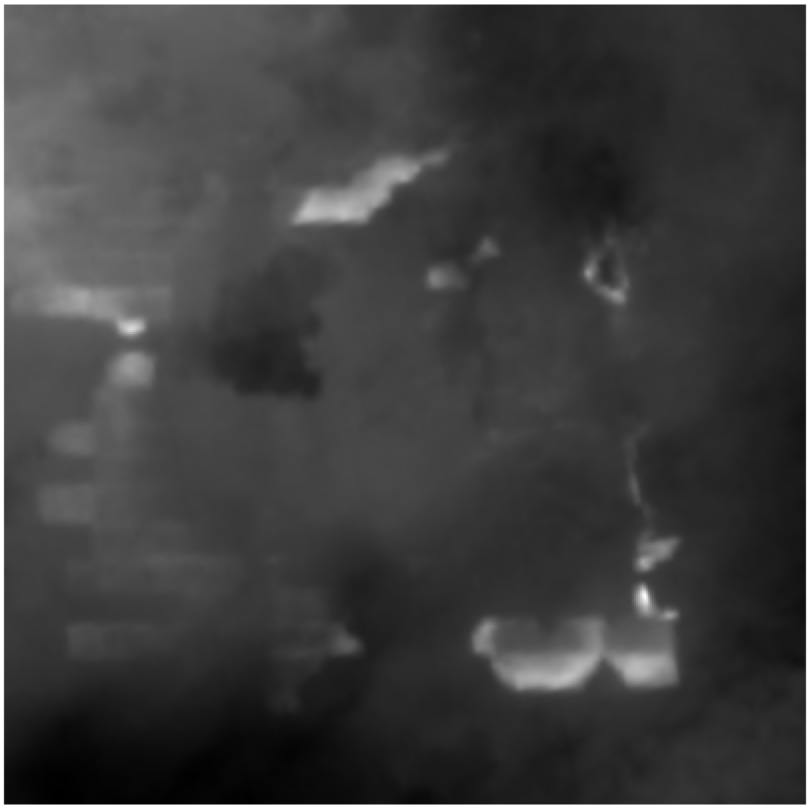


Band 10 minus radiance
modeled from B6 & B7
Planck curve

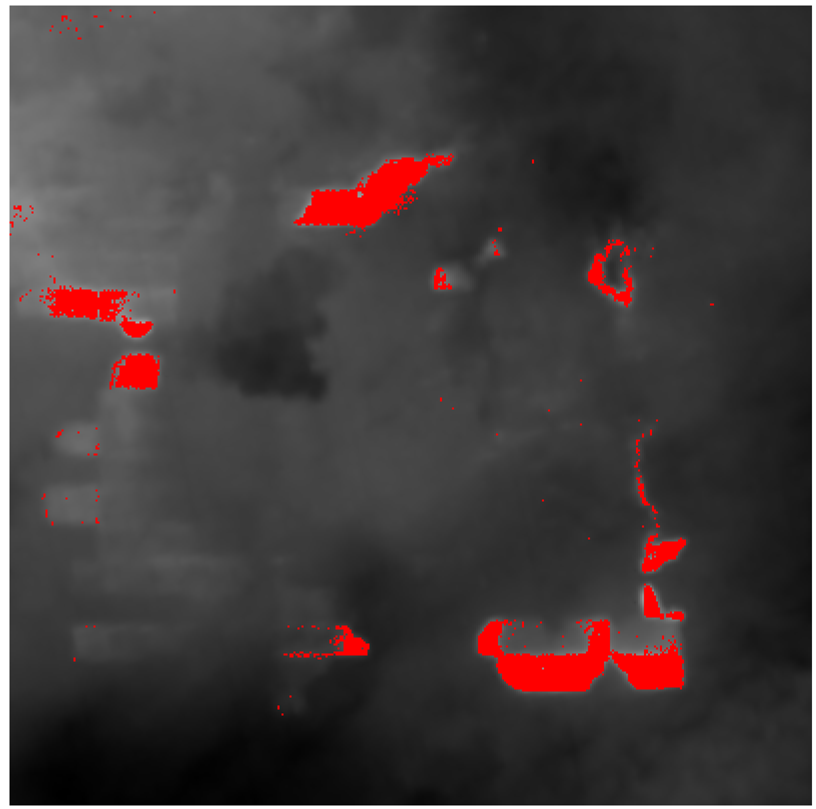
Hypothesis: The LWIR detections found in nighttime Landsat are expressions of smoldering phase peat fires

- Take the B6 & B7 Planck curve as a representation of flaming phase burning
- Estimate flaming phase radiance in LWIR with Planck curve
- Subtract the flaming phase LWIR radiance from the observed LWIR radiance
- A positive residual LWIR radiance indicates a second hot source at lower temperature = peat fire
- If there is no positive residual, the LWIR anomalies are attributable to flaming phase burning

Active fire area of LWIR anomalies is generally great than 1m^2



Band 10



Active fire area g.e. 1 m^2 as red

Summary on Nighttime Landsat

- Nighttime Landsat short-wave infrared (SWIR) data readily detects flaming phase peatland fires down to meter sizes.
- The SWIR data are amenable to Planck curve modeling to estimate temperature, source size and radiant heat.
- LWIR anomalies are found in areas with daytime Landsat spectral signatures associated with peat fires.
- Subtracting the flaming phase LWIR radiance, no residual was found, smoldering could not be detected.
- LWIR hot pixels are associated with active fire areas of more than $1m^2$.
- Nighttime Landsat collections are being continued in the coming months when more burning is anticipated.
- Field validation is planned.

Reference

- Elvidge, C.D.; Zhizhin, M.; Hsu, F.-C.; Baugh, K.E. VIIRS Nightfire: Satellite Pyrometry at Night. Remote Sens. 2013, 5, 4423-4449. doi:10.3390/rs5094423