Nightfire: Using the VIIRS Nighttime M-bands to Detect and Characterize Combustion Sources

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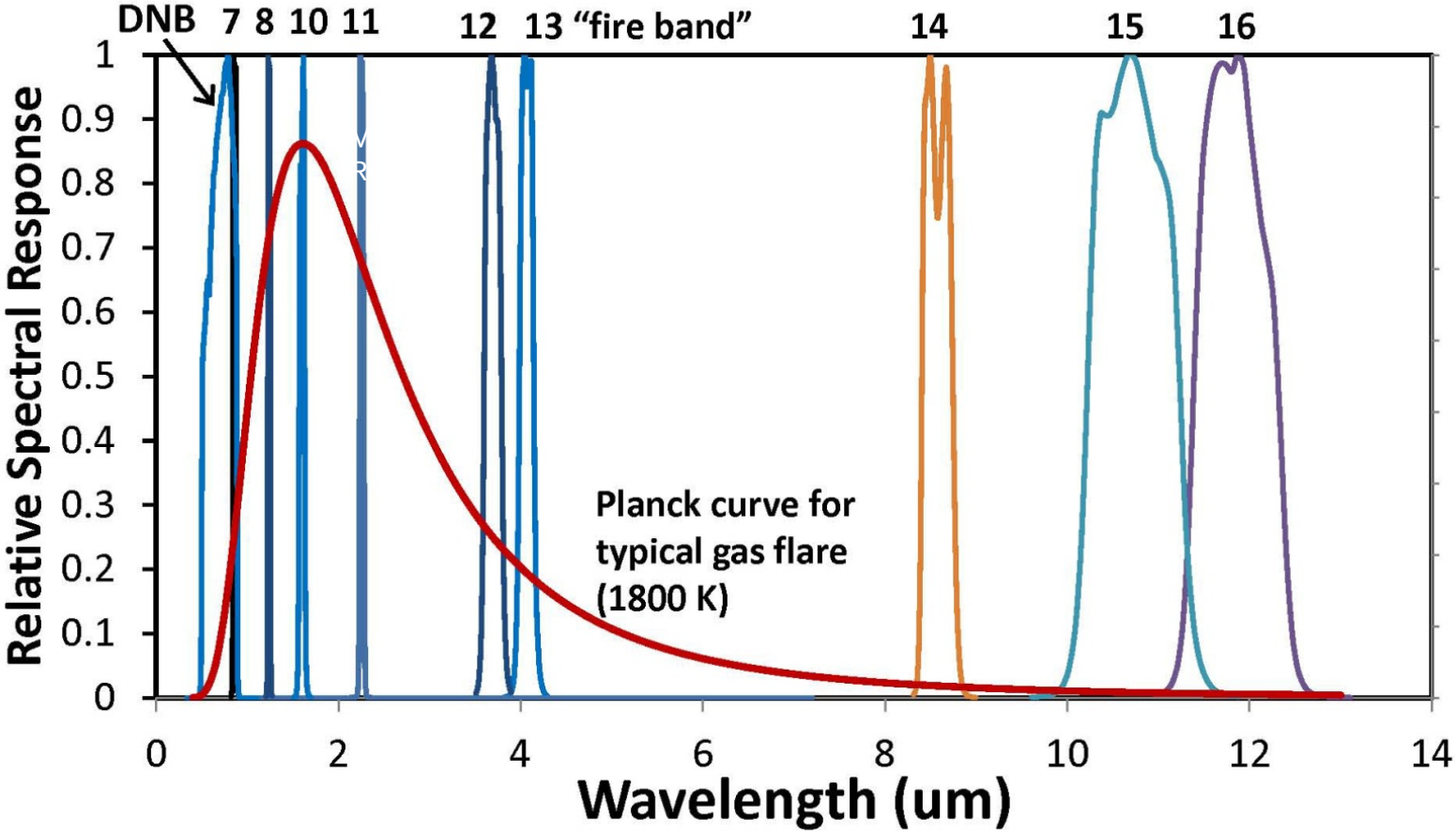
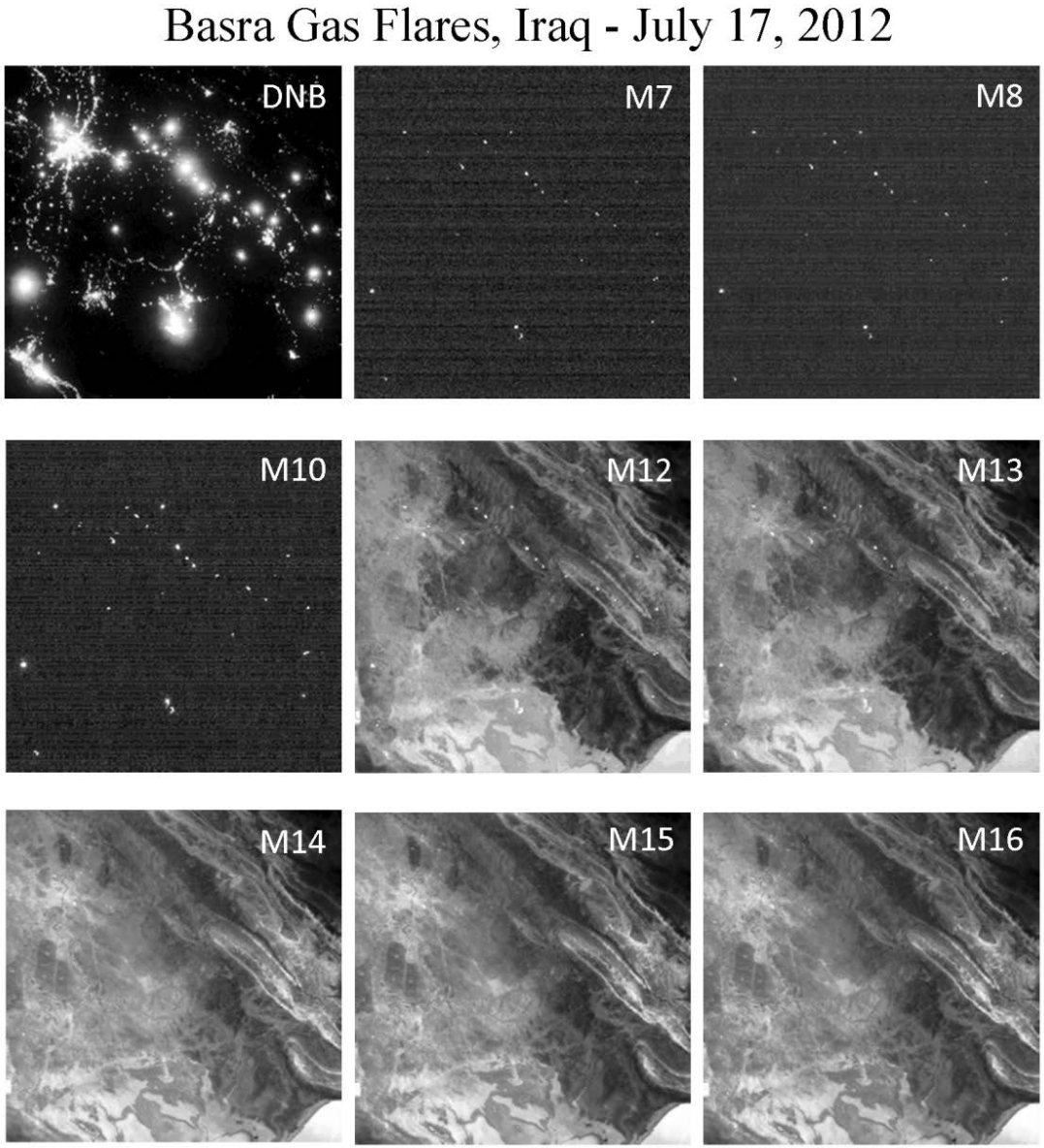
Gas Flaring

- A widely used practice to dispose of natural gas in oil production areas that lack infrastructure to make productive use of the gas.
- More common in remote locations and in impoverished countries.
- Reporting is poor since this is a waste disposal process.
- Satellite data sources have the potential for global systematic observation of flares and estimation of flared gas volume / CO_2 emissions.

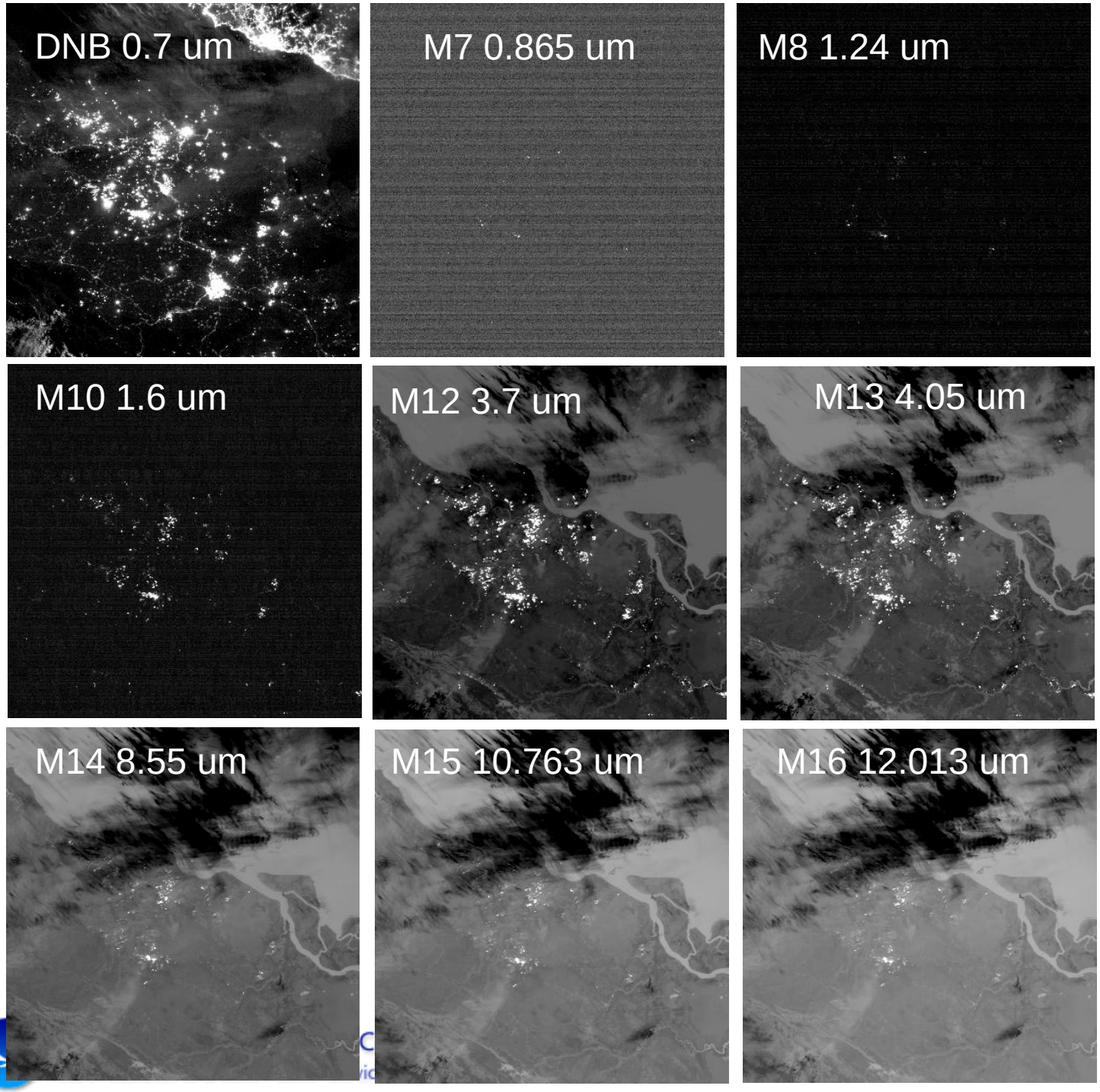
What makes nighttime VIIRS data so great for detection of combustion sources?



The M7,8,10 spectral bands are well placed to record the peak radiant emissions from flares. During daylight hours the signal is overwhelmed by sunlight. At night combustion sources stand out clearly against the background.



Gas flares are readily detected in the VIIRS M10 spectral band

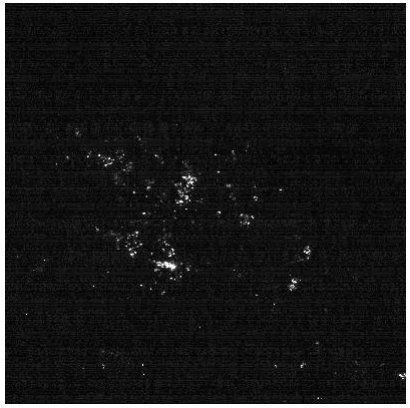


VIIIRS Nighttime Imagery

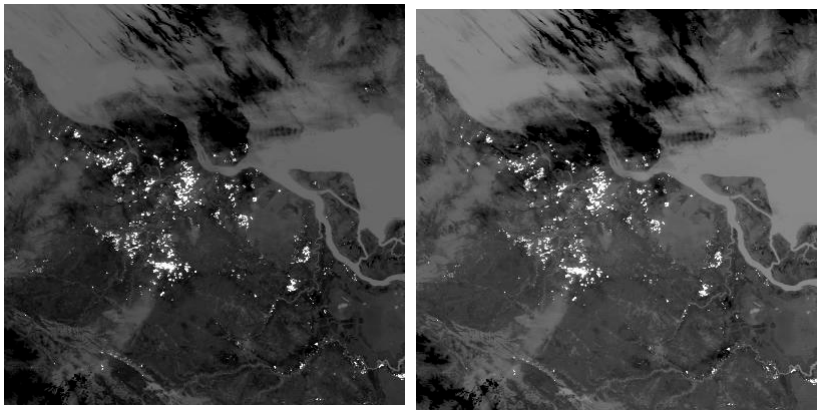
Riau Indonesia

June 19, 2013

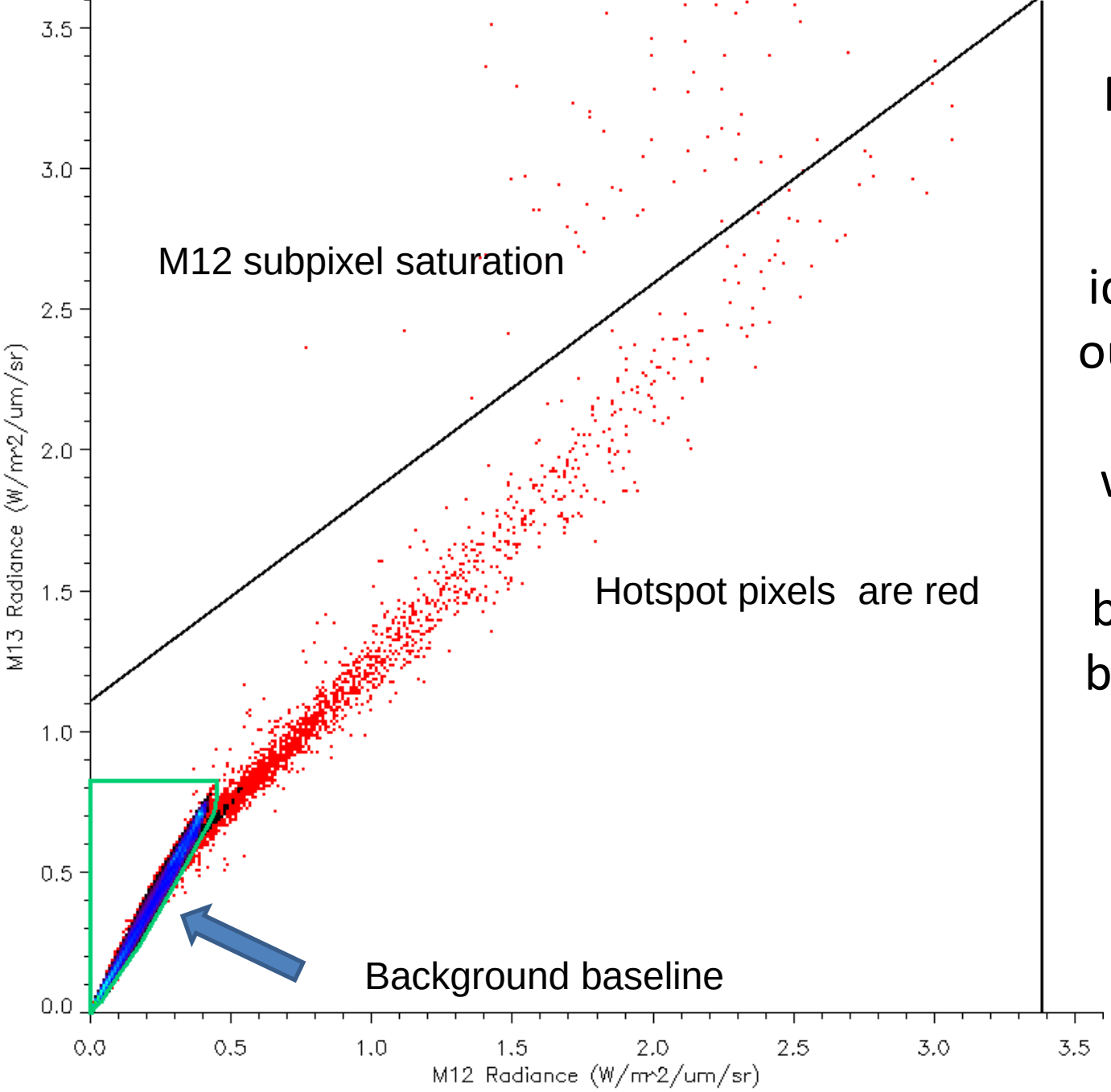
VIIRS Nightfire v2 has two independent hot pixel detection algorithms



High Temperature Detector
SWIR: M10 (1.6 um) detection threshold set based on background noise – mean plus four standard deviations. The detected pixels are then checked for detection in M7 & M8.



Low Temperature Detector
MWIR: M12-M13 (3.8 and 4 um) scattergram analysis identifies background. Hot pixels are the outliers.



M12 and M13 detection algorithm identifies pixels outside of scene background, which is in the form of a baseline. Local background not used.

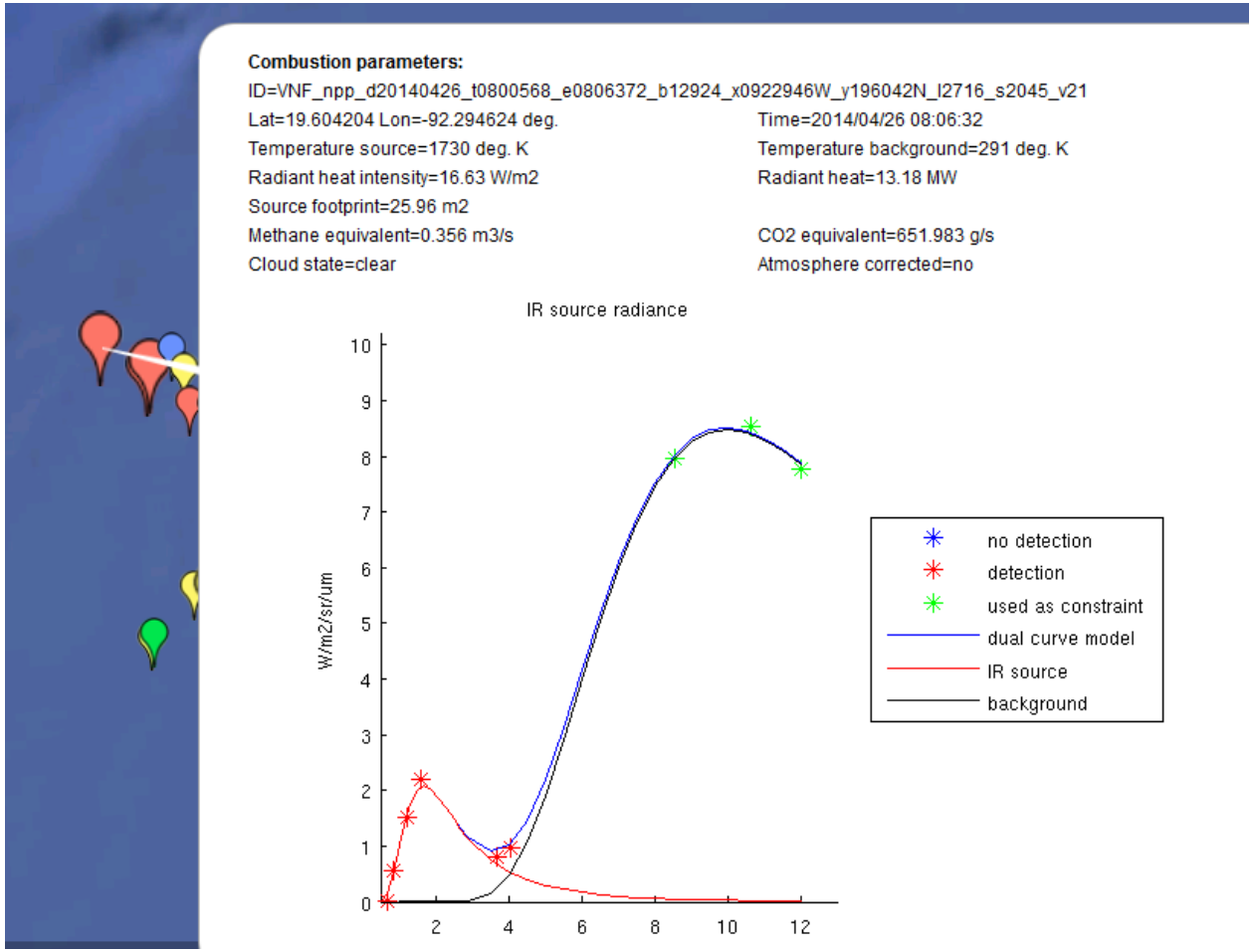
Planck Curve Fitting

- Planck curve fitting uses an iterative simplex algorithm.
- Pixels with M10 detection and no M12-M13 detection are fit with a single hot Planck curve.
- Pixels with M10 plus M12-M13 detection are fit with dual Planck curves (one hot and one background) spanning all nine bands. Observed radiances used as constraints.
- Single curve fitting with insufficient detections
  - Fitting for pixels without M16 detection use zero radiance in M16 as a hot source constraint.
  - Fitting for pixels without M10 detection use zero radiance in M10 as a hot source constraint.

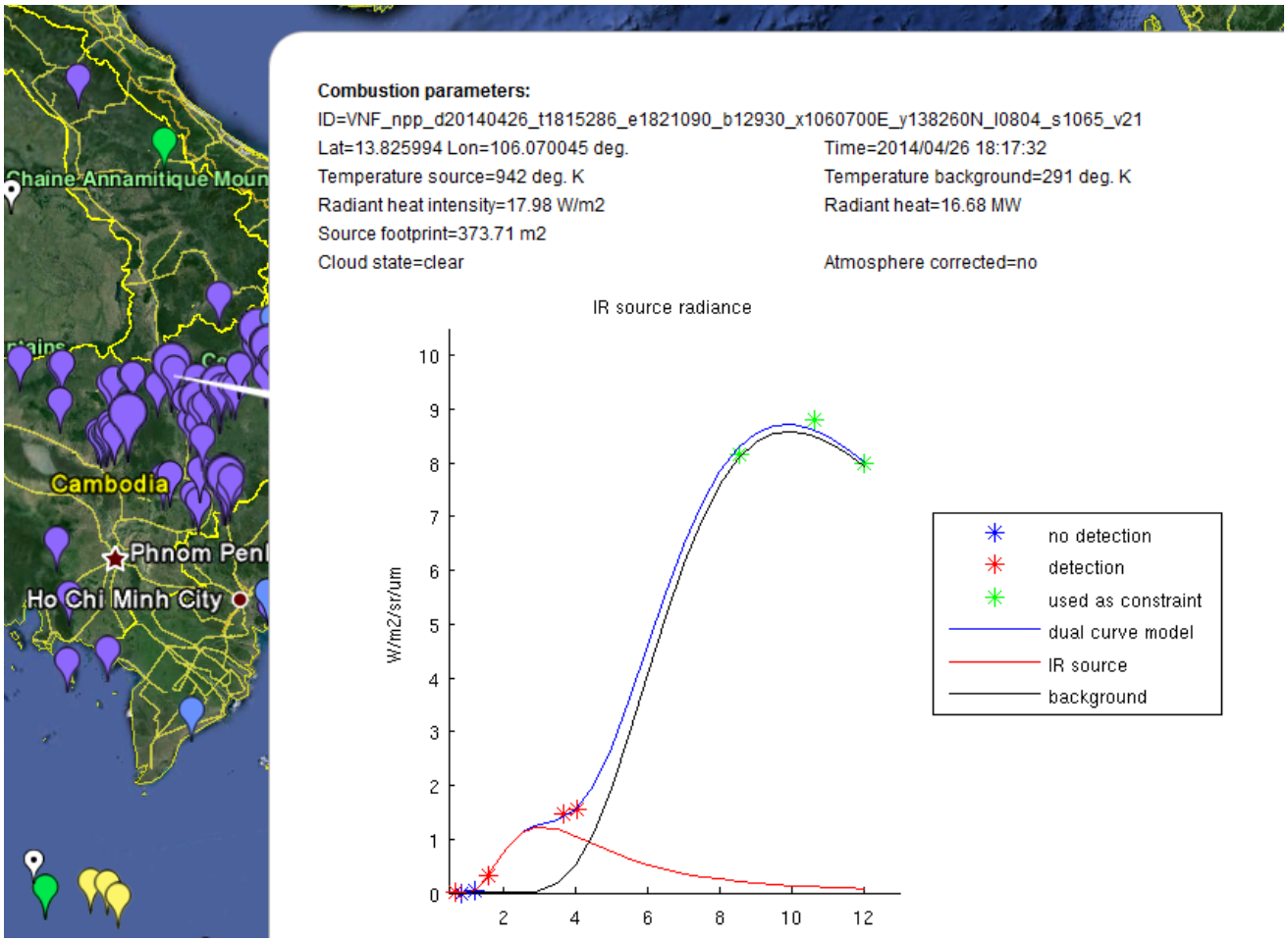
Planck Curve Calculations

- Peak radiance indicates temperature (K) using Wein's Displacement Law.
- Subpixel sources appear as graybodies. The ratio of the observed curve versus the full pixel 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 Detection

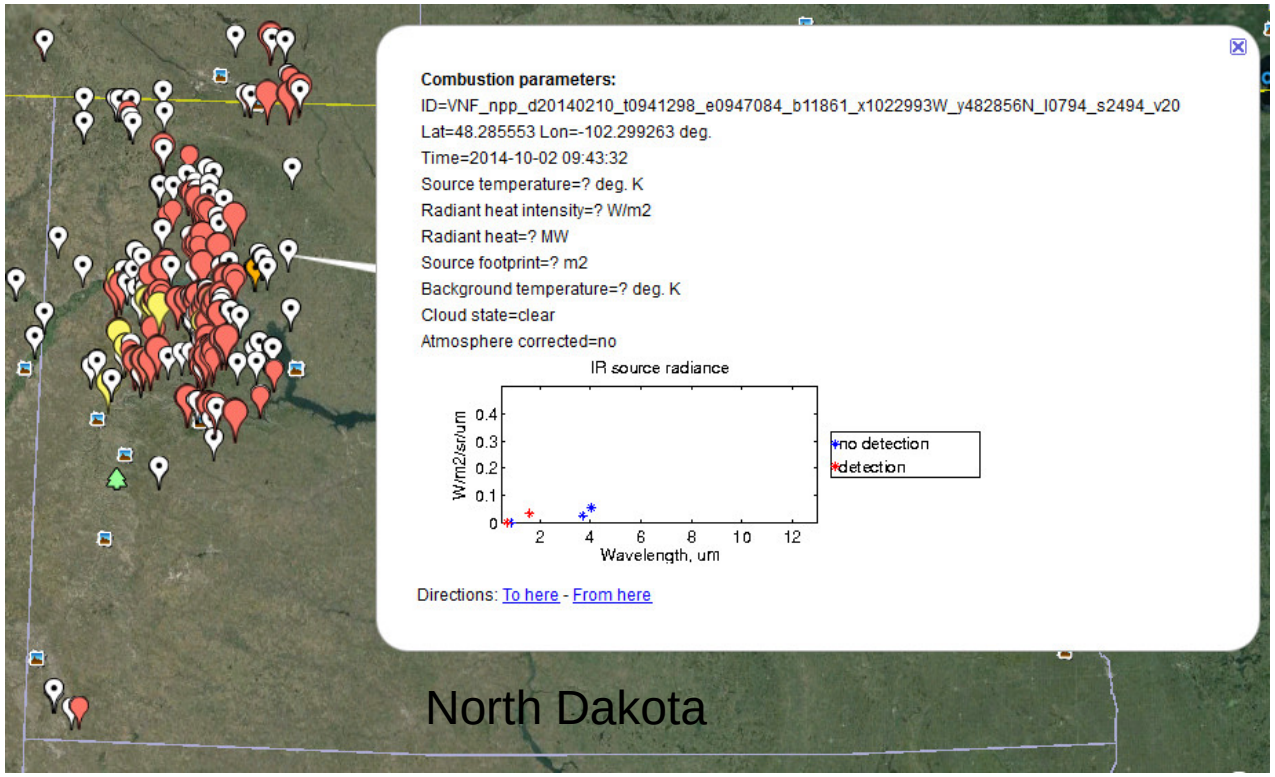


Typical Biomass Burning Detection



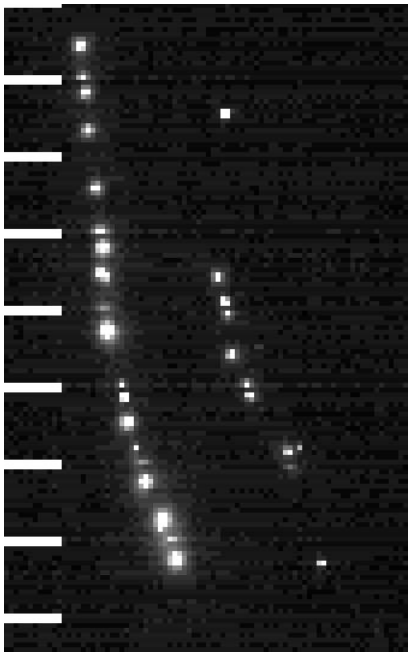
Lower temperature than gas flaring. Often these have larger source size than gas flares.

Weak Detections

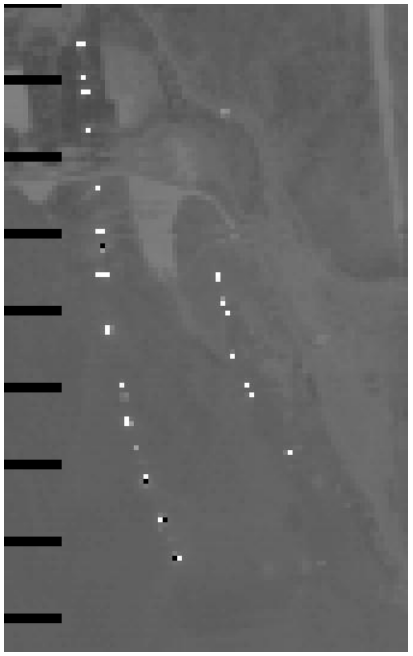


- Approximately 40% of all detections have M10 and DNB detection only.
- The Planck curve fitting fails.
- It is not possible to calculate temperature, radiative heat, and source footprint.

VIIRS Cloud Mask Algorithm Identifies Flares as Cloud

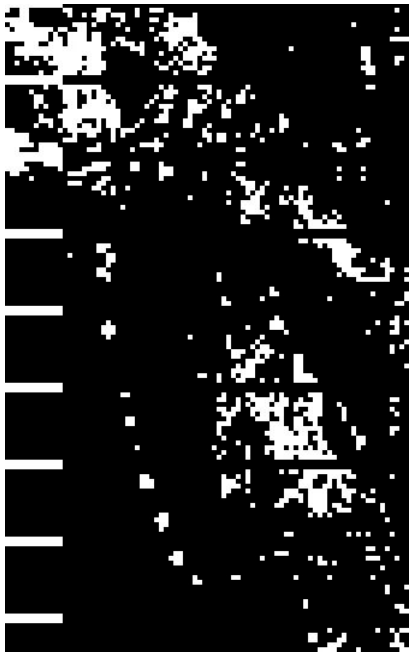


M10 Basra, Iraq



M13

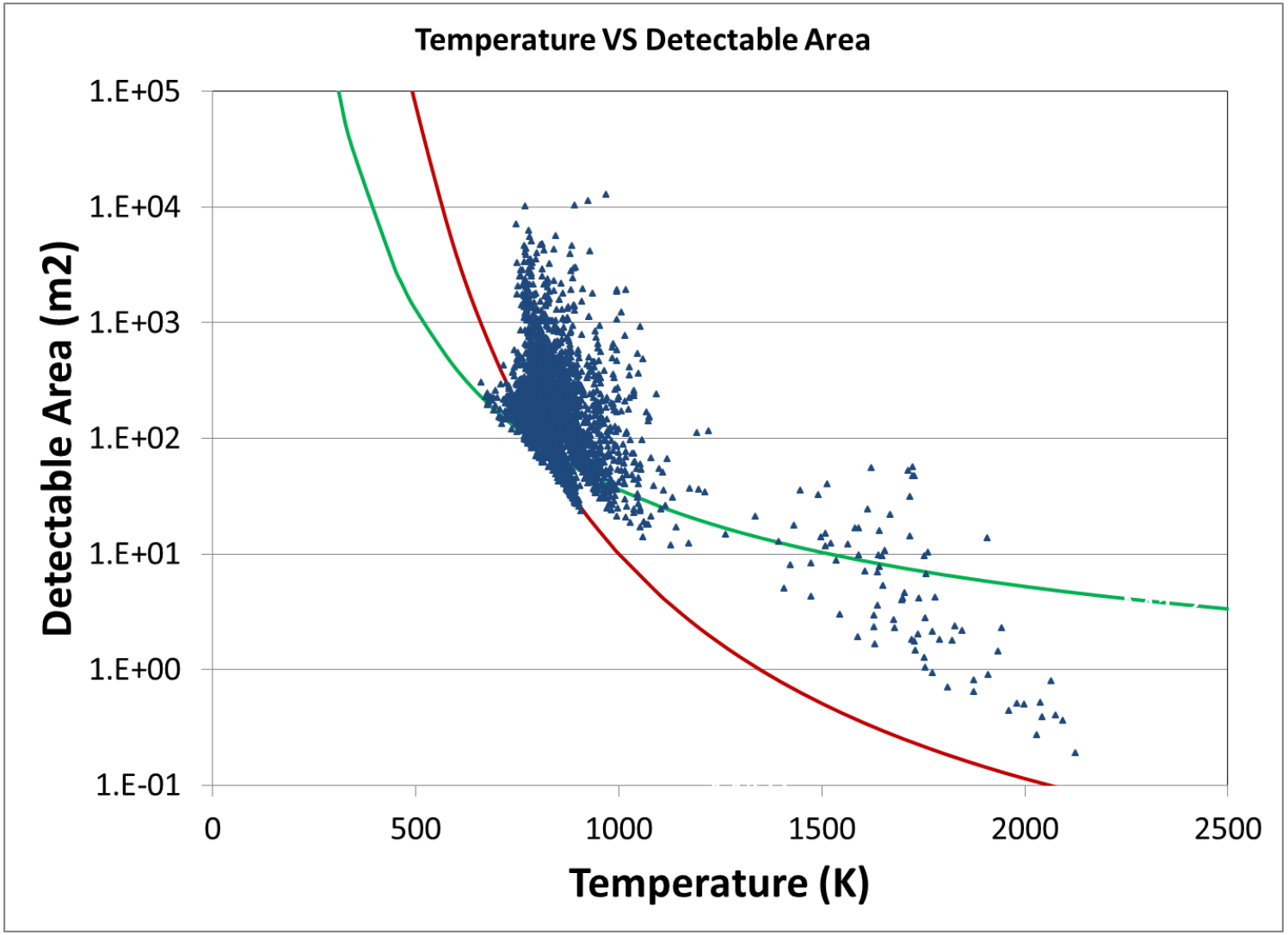
Cloud mask



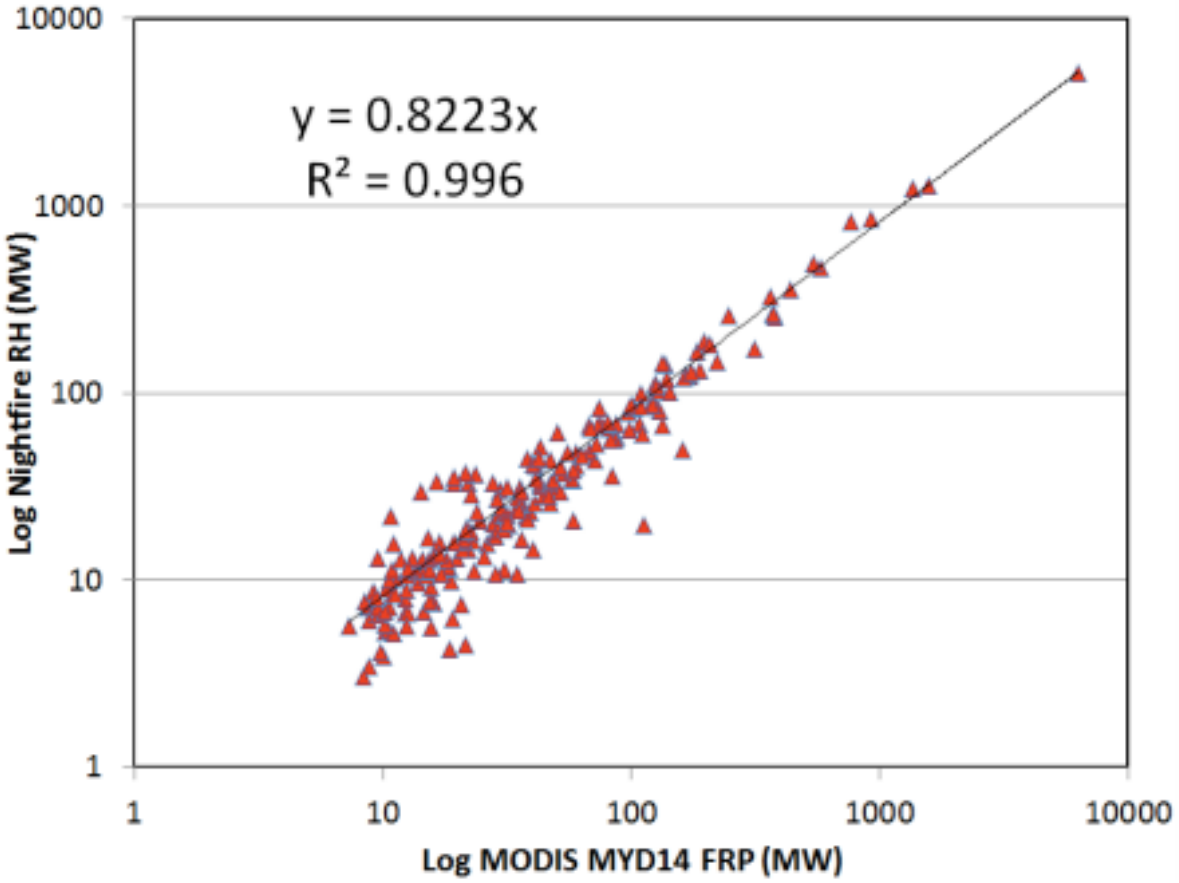
Cloud optical thickness

There is likely spectral confusion between clouds and gas flares.

Nightfire Detection Limits



Comparison with MODIS



Initial Flared Gas Volume Calibration Based on Monthly Reported Data