Estimation of CO_2 emissions from gas flares using data collected by the SNPP VIIRS

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May 21, 2013

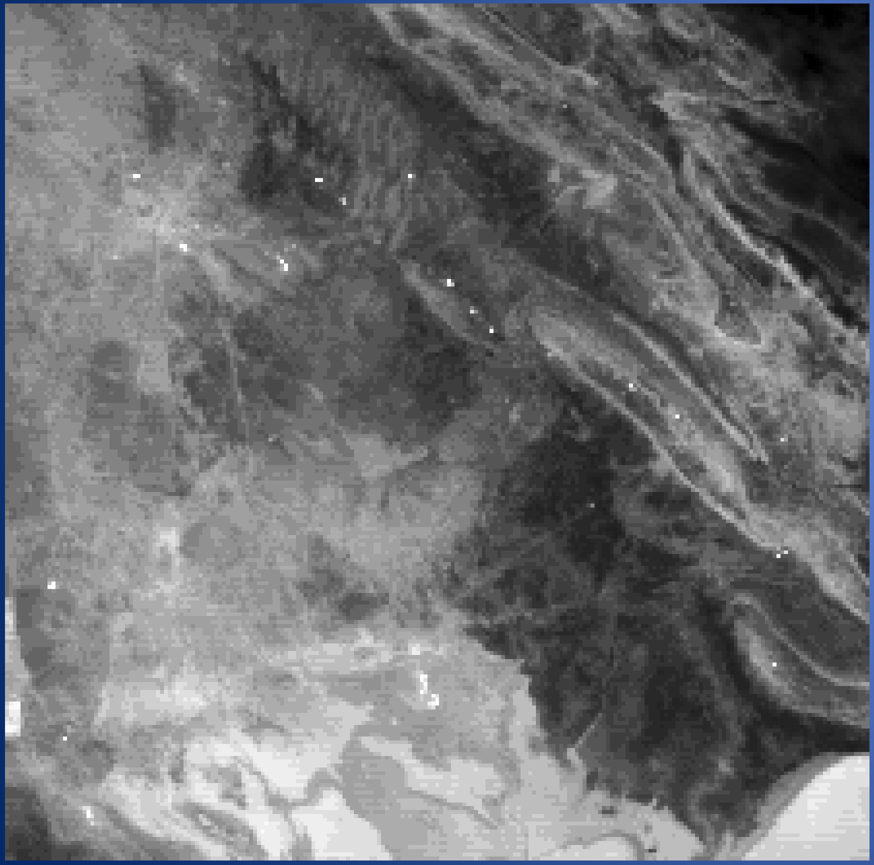
Why study gas flares with satellites?

- Flares are carbon emission point sources that are typically not included in emission databases.
- Reporting on locations and magnitudes of flares is scant since it is waste disposal process.
- Satellite sensors are the only plausible means for global detection and monitoring of flares

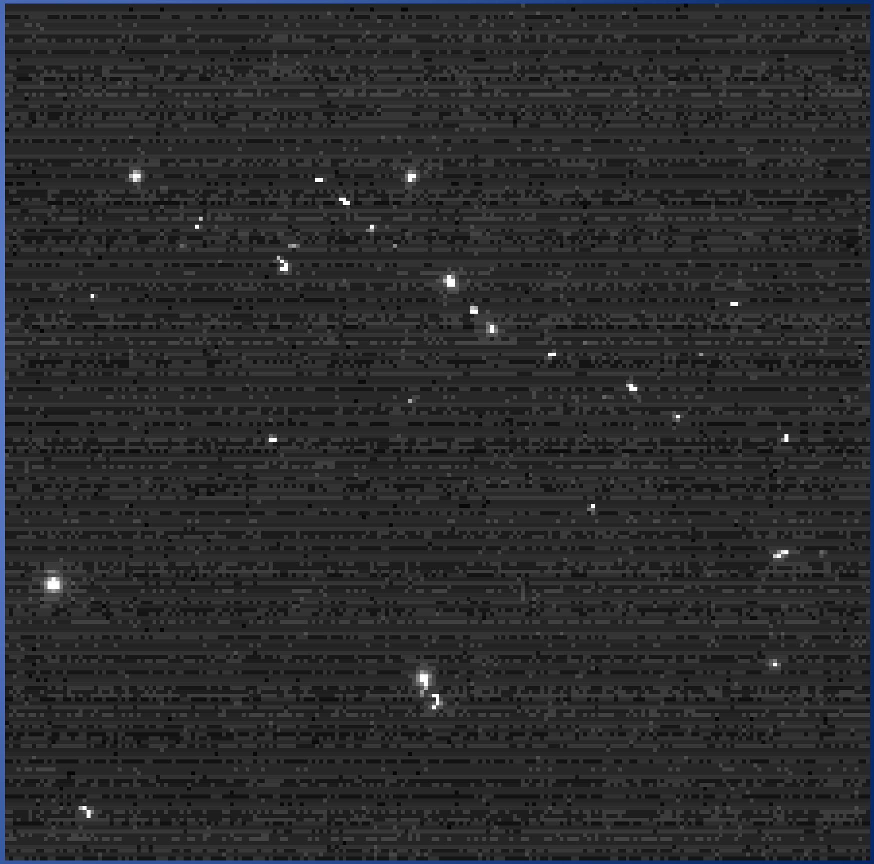
What makes VIIRS data so great?

At night the VIIRS collects data in three daytime imaging bands: M7, M8, and M10.
The nighttime M10 data have a remarkable ability to detect combustion sources!

M13 "Fire Band"

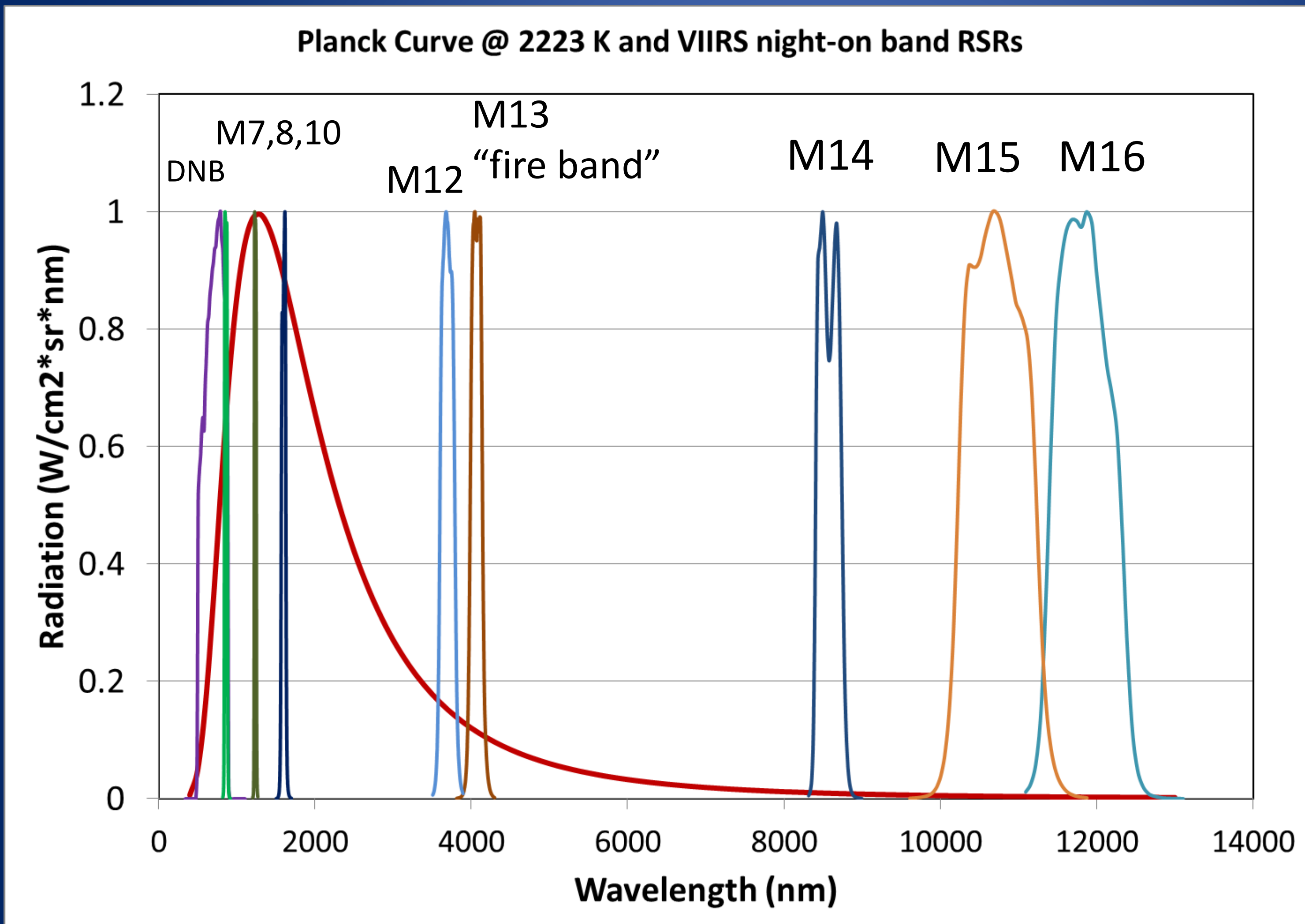


M10



Detection of Combustion Sources Basra, Iraq Region at Night
July 17, 2012

VIIRS collects visible, NIR and SWIR at nights

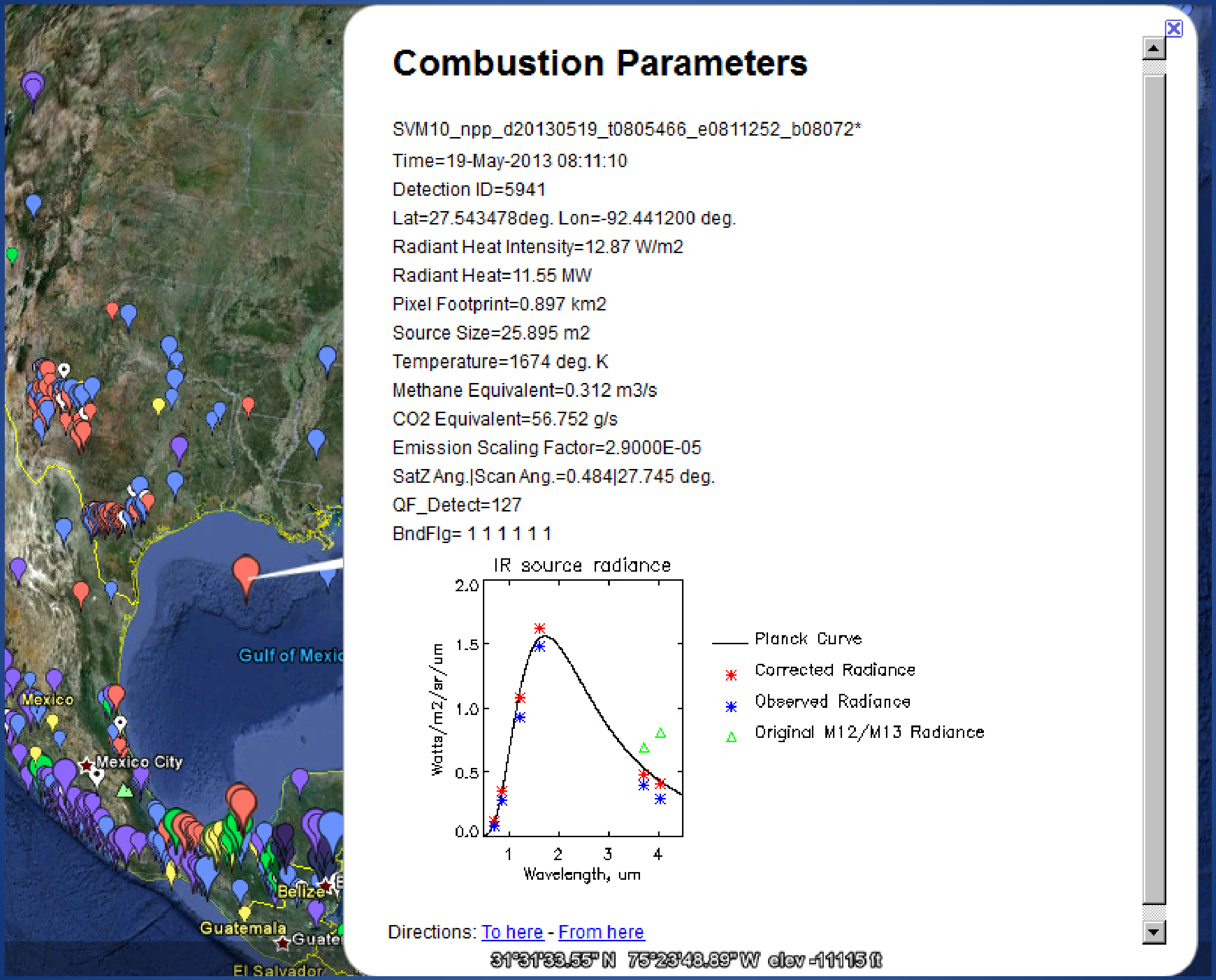


VIIRS is unique in recording NIR and SWIR channels at night. Combustion sources stand out clearly against the noise background – with no detection of lights. Methane burns (in air) at 2223 K.

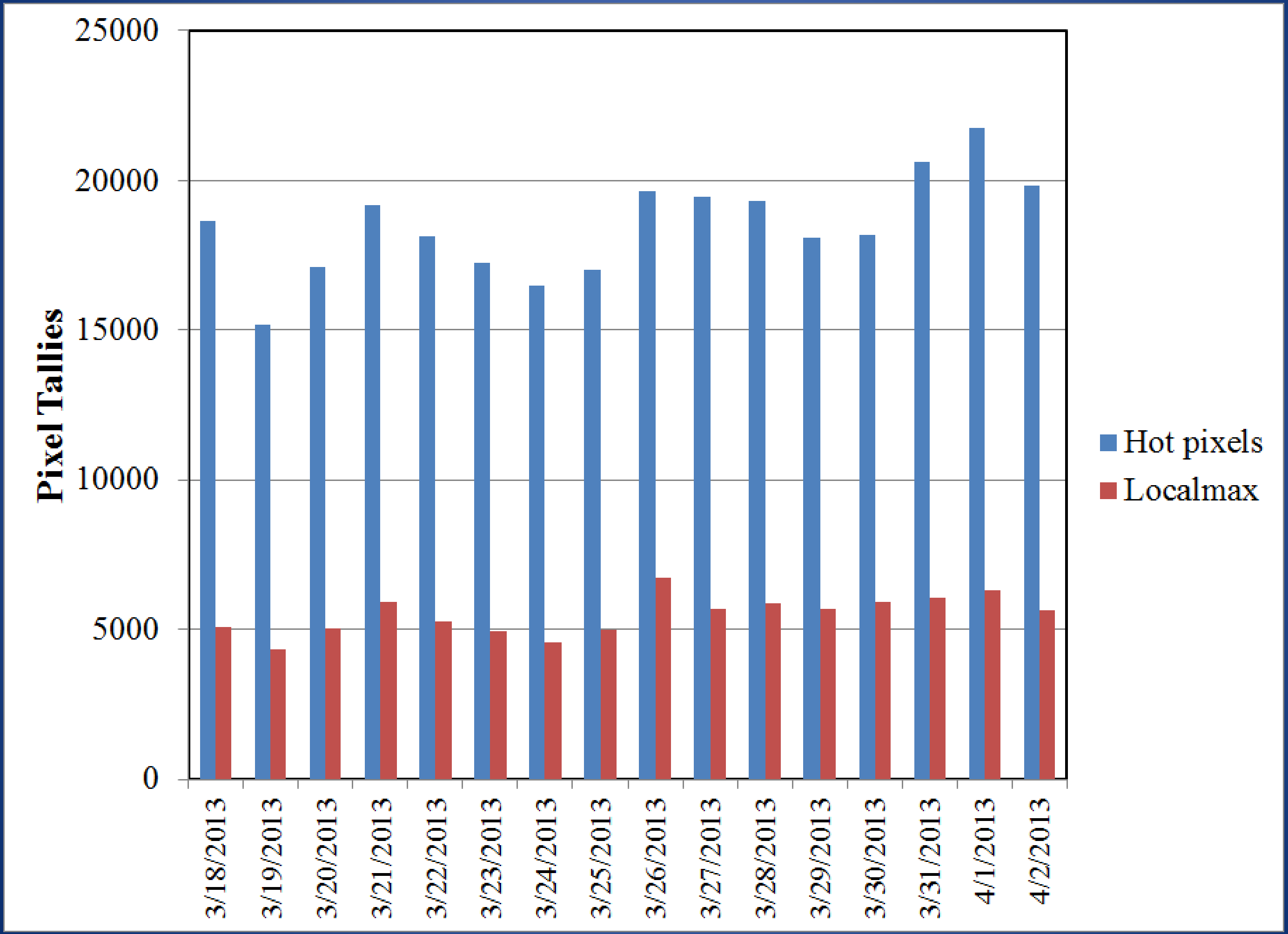
VIIRS Nightfire

- Funded FY12-15 by the JPSS Proving Grounds Program.
- Development started in April 2012.
- Runs on VIIRS data as they arrive at NGDC for archive.
- Detection of hot pixels in M10. Noise is filtered by requiring detection in at least one additional band.
- Atmospheric correction being implemented.
- Planck curve fitting of blackbody emission yields temperature (K) and emission scaling factor.
- Stefen-Boltzmann Law used to calculate radiant heat intensity.
- Combined with pixel ground footprint the source size and radiant heat are calculated.
- Radiant heat is used to calculate methane combustion rate with CO_2 emissions.
- Output on 24 hour increments available at: http://www.ngdc.noaa.gov/eog/viirs/download_viirs_fire.html
- KMZ output for local maxima.
  CSV has data on all hot pixels.

VIIRS Nightfire kmz for September 1, 2012



Detection Tallies



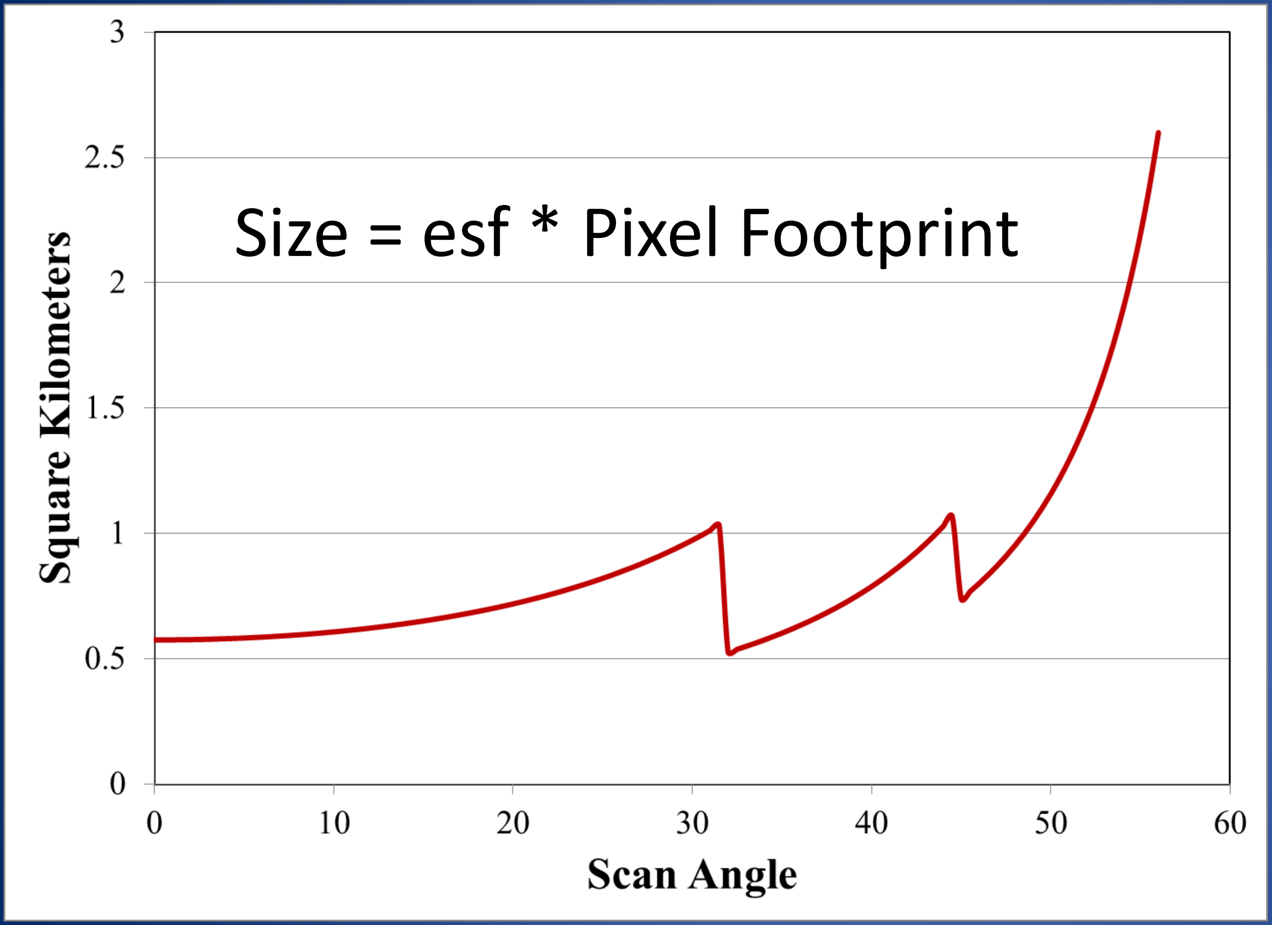
Planck Curve Fitting

$$B_\lambda(T) = \frac{2hc^2}{\lambda^5}\frac{1}{e^{\frac{hc}{\lambda \kappa_B T}} - 1}$$

Where B is the spectral radiance of the surface of the black body, T is its absolute temperature, λ is its wavelength, k_B is the Boltzmann constant, h is the Planck constant, and c is the speed of light.

Curve is fit using a Simplex Optimization algorithm to get the best match to the observed radiances with two variables – temperature and emission scaling factor.

Estimating Source Size



Hot objects appear as gray-bodies because they occupy a small fraction of the pixel. The esf is multiplied by the pixel footprint size (on the ground) to estimate the size of the hot source in square meters.

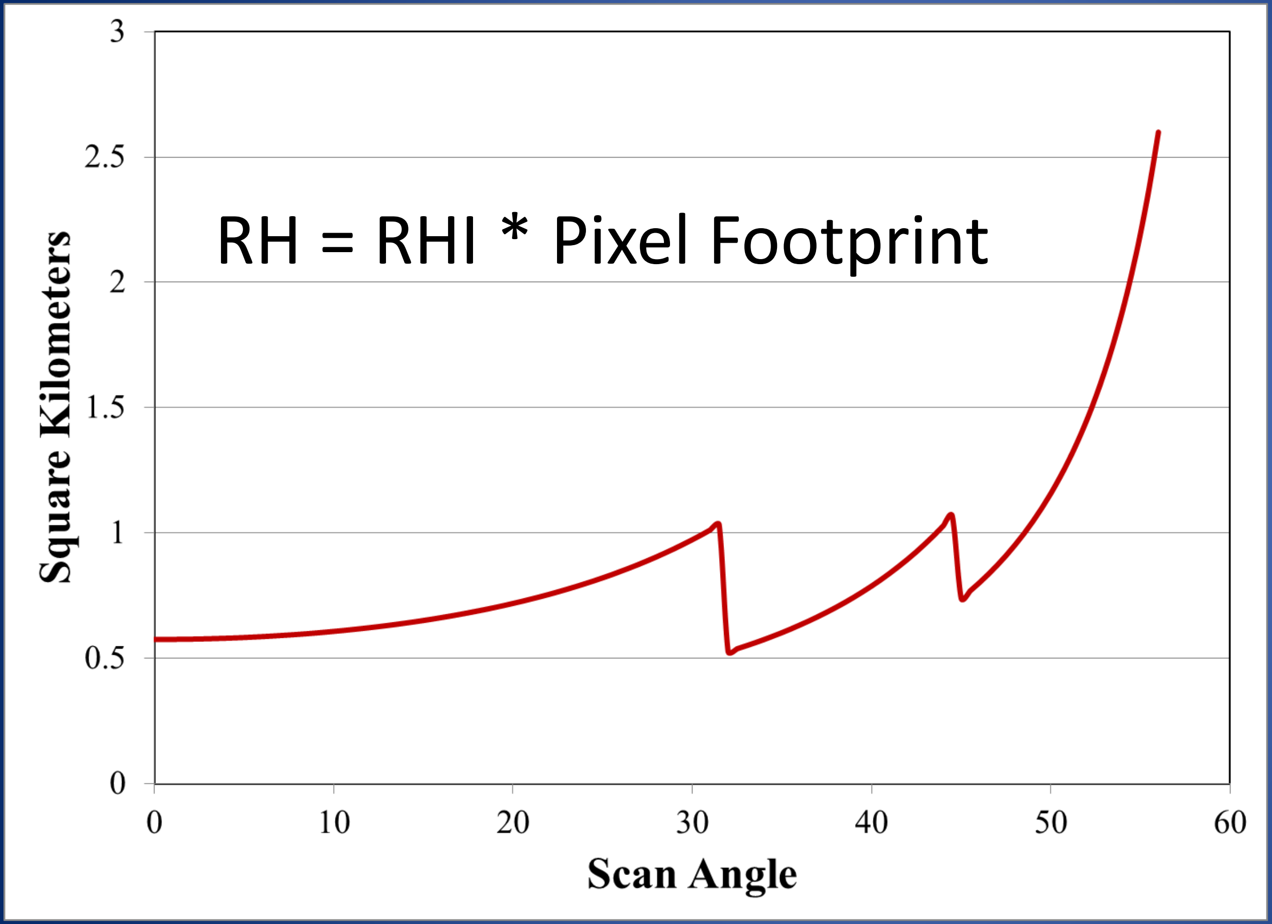
Estimating Radiant Heat Intensity (W/m2/sec)

$$j^* = \varepsilon\sigma T^4$$

Radiant heat intensity is calculated through application of the Stephan-Bolzmann Law.

Where σ is the the Stefan–Boltzmann constant.
E is the emissivity of the grey body (esf)
T is degrees K
J* is Watts/m^2/sec

Estimating Radiant Heat



Radiant heat intensity ($W/m^2/sec$) is multiplied by the footprint area to calculate radiant heat (W/sec).

Estimating Methane Consumption

$$V_{CH_4} = RH/HHV_{CH_4} \;\; (m^3/sec)$$

RH = Radiant heat (W/sec)

HHV_{CH4} = Higher Heating Value of methane (W/m^3)

Estimating CO_2 Emissions

- $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

Combustion of 1 m^3 CH_4 emits 1 m^3 of CO_2

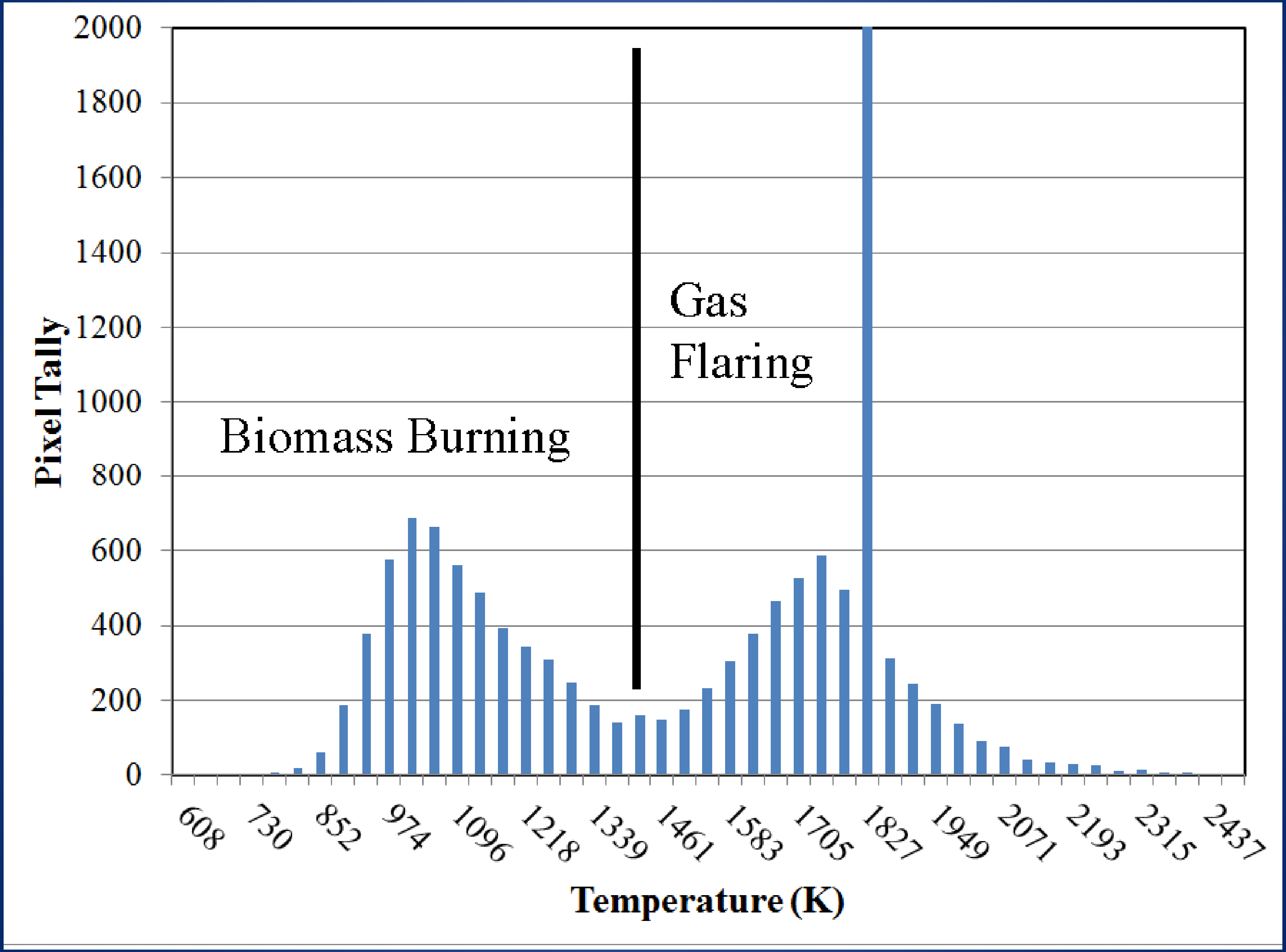
- @20C, 1 atm, 1 m^3 contains 41.62 moles of molecules = 1831.35 g of CO_2

- $W_{CO_2} = 1831.35 * V_{CH_4}$

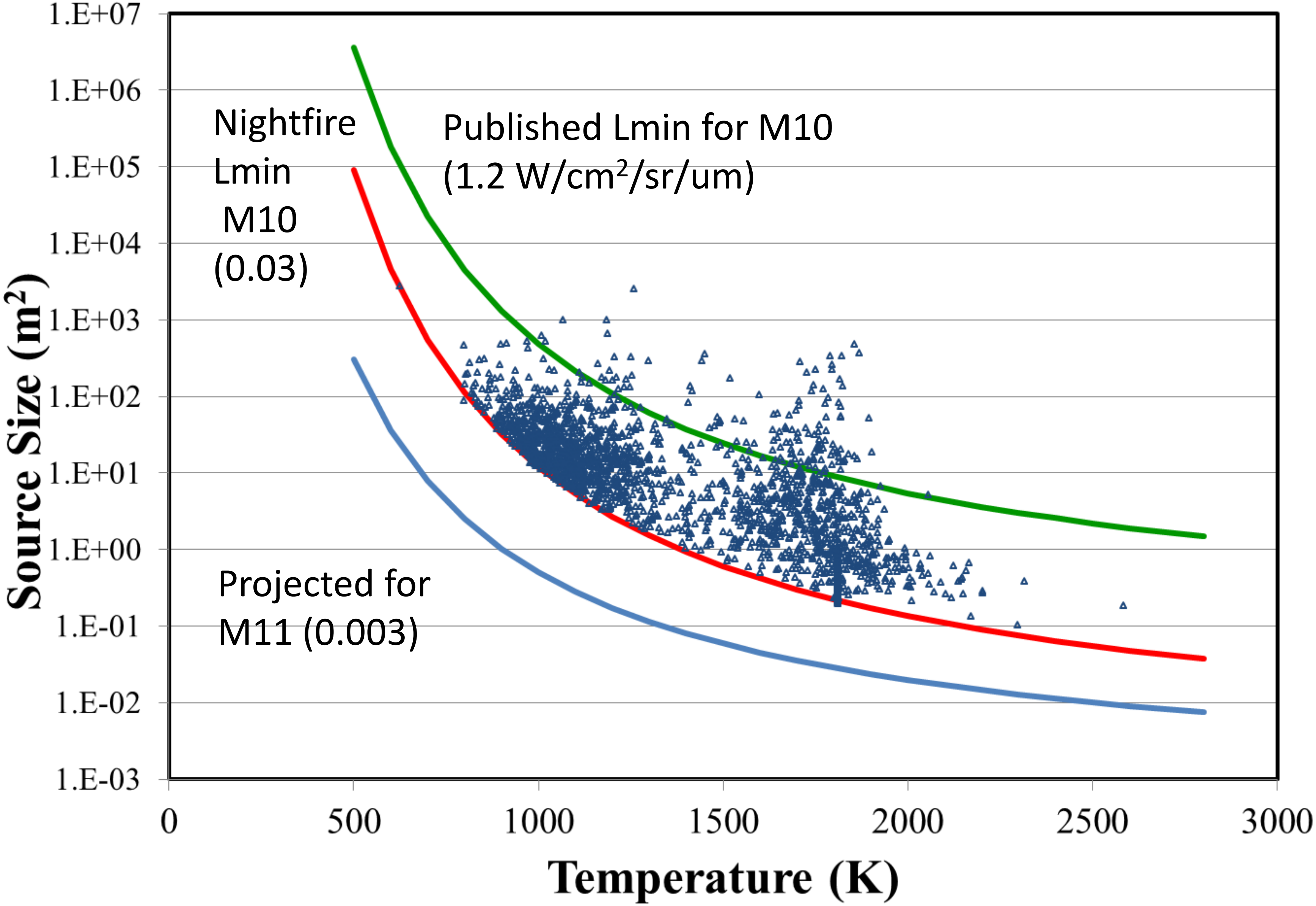
  W_{CO2} = CO_2 weight (g/sec)

  V_{CH4} = Methane volume (m^3/sec)

Bimodal Temperature Distribution



Nightfire Detection Limits



Summary

- NGDC provides open access to nightly global combustion source detection data from VIIRS.
- The nighttime VIS, NIR and SWIR data make it possible to model combustion source blackbody emission spectra, yielding estimates of temperature, radiant output, methane combustion and CO_2 emissions.
- NGDC will be developing calibrations for improved estimation of flared gas volumes and CO2 emissions.
- NGDC is developing monthly and annual summary data sets, which will rank gas flares based on their CO_2 emissions.
- While the Nightfire focus is on gas flares, the system also detects other combustion sources, such as biomass burning, industrial sites and volcanoes.
- The Nightfire database could be used to identify flare locations where the natural gas could be harvested for other purposes.