Can I identify a flare with a performance issue: Satellite monitoring – Thermal Imaging (VIIRS)

Summary

Heat emitted by flares can be monitored by satellites equipped with infrared sensors such as the Visible Infrared Imaging Radiometer Suite (VIIRS). The temperature and spectral range of the flare can be used to differentiate flaring from other heat signatures.

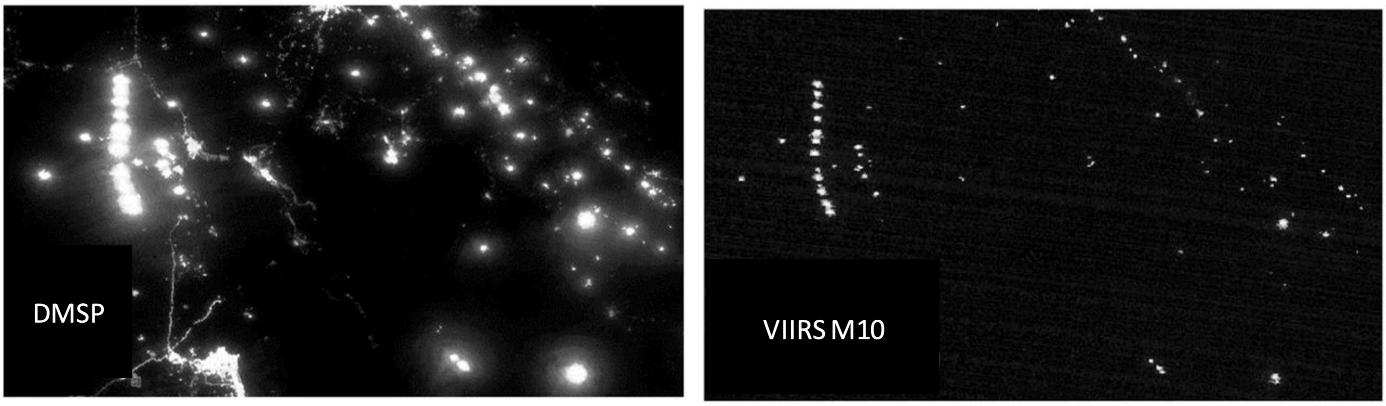
Measurements are conducted at night. Regular monitoring of heat data has been successfully used to estimate both volumes of total flaring and changes with time. It is not a direct measurement of methane emissions and cannot see cold sources – such as an unlit flare.

Environmental effects, such as cloud cover and wind can impact data quality.

Raw data is publicly available, with several organisations now providing data interpretation and alerts as services.

How it works

The Visible Imaging Radiometer Suite (VIIRS) instrument is aboard the joint NASA/NOAA Suomi National Polar-orbiting Partnership (Suomi NPP) and NOAA-20 satellite. It is a 22-band (spectral channels) imaging radiometer that collects visible and infrared imagery and is unique for collecting near and short?wave infrared data at night. VIIRS Nightfire (VNF) is the data product developed based on VIIRS imagery and specializes in gas flaring observation and estimation. VIIRS resolution is improved over earlier satellites and those used before 2012 such as NOAAs DMSP satellite.



A comparison of VIIRS data (right) to the lower resolution DMSP satellites in operation before 2012. Image courtesy of the World Bank.

VIIRS provides global coverage twice a day with 375~750 m resolution (depending on band)**.** During the night time, VIIRS continues to record data in near and short-wave infrared channels designed for daytime imaging. With sunlight eliminated, the hot pixels identified in these channels indicate combustion sources.

VNF calculates flare temperature, size, and radiant heat by Planck curve fitting and using physical laws. Location is also reported, and flared volume can be estimated.

Advantages

- ☑ High resolution -capable of picking up small flares (0.25~1 m2)
- ☑ Gas flaring can be distinguished from biomass burning and city lights
- ☑ Well recognized accuracy and efficiency in characterizing gas flares

- ✅ Detected locations, calculated temperatures, and estimated volumes provide guidance on potential locations for capturing and reusing methane
- ✅ VIIRS Day/Night Band also provides night-time imagery which can be used to quality control detections
- ✅ Data products are publicly available and are being continuously evolved/improved
- ✅ Vendors provide a range of data analysis and interpretation tools – including alerts for operated and non-operated facilities
- ✅ Widely used – allowing comparisons to be made between operators, regions or countries
- ✅ Nightly VNF data are available in CSV and KMZ format (viewable via Google Earth)

Limitations

- ❌ Uncertainties become larger when analysing multiple sub-pixel flares as well as intermittent flares
- ❌ Four-hour temporal latency
- ❌ Flared volumes are estimated (as opposed to being measured) based on calculated radiant heat
- ❌ Accuracies are impacted when cloud cover percentages are high
- ❌ Does not directly measure methane emissions – and is therefore blind to cold sources such as an unlit flare (which conversely has the highest greenhouse gas impact)
- ❌ To convert data to methane emissions, assumptions need to be made about combustion efficiency

Go Deeper

- World Bank: Overview on the use of satellite data
- VNF Nighfire
- Study of global flare volumes

- [Academic publication: Methods for Global Survey of Natural Gas Flaring]()
- [Academic publication: VIIRS Nightfire: Satellite Pyrometry at Night]()
- [Academic publication: Short Wavelength VIIRS Data]()
- [Vendor website: Flareintel]()

Case study

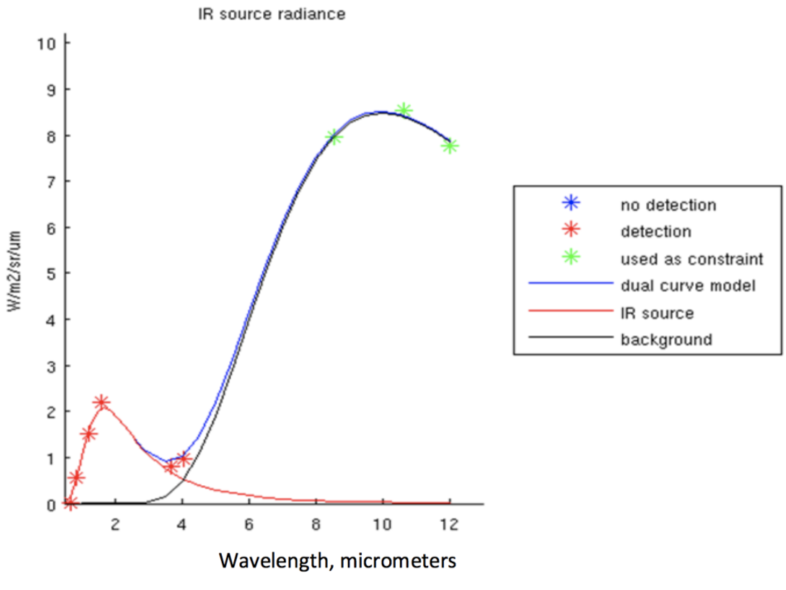
Estimation of flare gas volumes from satellite data

Reproduced from an original article written on behalf of the World Bank

Interpretation methodology to derive gas flare volumes from the VIIRS satellite data

Estimating flare radiant heat from the VIIRS satellite data

Responding to emissions at different wavelengths, the multiple VIIRS detectors enable Planck curves to be fitted to the detector responses. A Planck curve is a unique spectrum of emissions from a source of a given temperature; hotter sources emit at shorter wavelengths. Flares have maximum emissions at the shorter wavelengths detected by VIIRS. By fitting two Planck curves to the VIIRS detector responses (the red and green stars), one for a hot source (the flare) and one for a cooler source (the background), the emission spectrum from the flare can be defined.



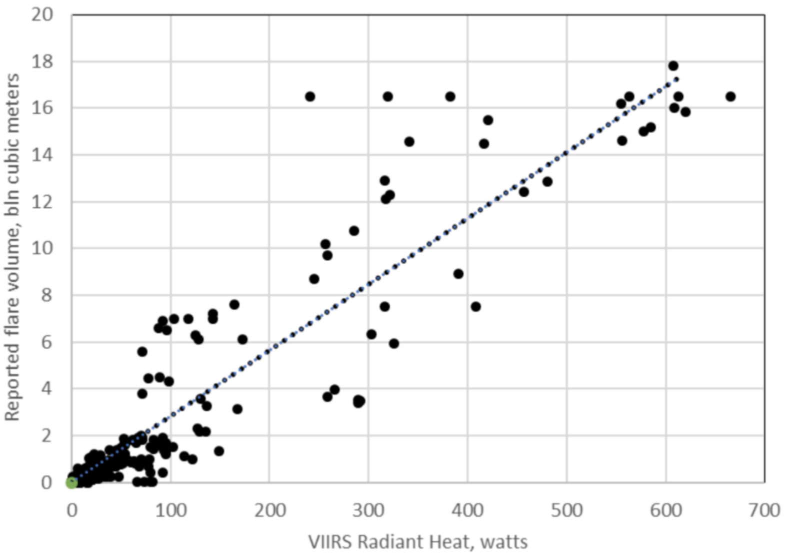
The “hot” Planck curve from the gas flare (the red curve in the example above) uniquely defines the flare’s temperature, in this case 1740 deg K; the black curve defines the very much lower temperature of the background. Using Stefan's Law, which relates the infrared flux per unit area (watts/m2) to the flare temperature, this temperature can be used to estimate the infrared flux per unit area being received from the flare. To estimate the total infrared emissions (watts) from the flare also requires an estimate of its effective emitting flare area. This area (m2) is proportional to the height of the observed flare Planck curve; the ratio of this height to the height of the Planck curve for a theoretical flare whose size completely fills the (known) detector area provides the estimate of the flare's emitting area. The total infrared emission (the radiant heat in watts) received at the VIIRS detectors from the flare is then estimated as the product of the infrared flux per unit area (watts/m2) and the flare emitting area (m2). These estimations of the radiant heat are made automatically for each of the ~10,000 flares detected annually by VIIRS.

Estimating flare volumes from satellite radiant heat estimates

The infrared emissions received by the VIIRS detectors from a flare have been affected by a number of factors as they travel from the flare, through the atmosphere, to the satellite detectors. While at the wavelengths of interest the effect of the atmosphere is small and effectively constant over the entire globe, the combination of factors affecting the received emissions is too complex for theoretical correction. The infrared estimates must therefore be calibrated using reported data.

There are limited reported flare volume measurements made on-site available in the public domain. However, Cedigaz, an organization that provides consultancy services to the oil and gas industry, uniquely collects flare volume data from the majority of countries and has made this data available for calibration of the satellite data. It should be noted that the data collected by Cedigaz comes from a variety sources of variable reliability, ranging from "official" data reported by governments to "guesstimates" made by "informed" individuals. Cedigaz therefore does not guarantee the accuracy of the data it provides.

To make the current calibration, the total VIIRS estimates of infrared emissions from flares in each country has been correlated with the country-level data collected by Cedigaz for 2013-2017, assuming a linear relationship between VIIRS emission estimates and flare volume.



Correlation between Cedigaz reported flare volumes and VIIRS radiant heat estimates

The correlation coefficient of the correlation is 0.85, and from the least-squares regression:

Satellite flare volume estimate = 0.0281 x VIIRS radiant heat

Using the regression relationship obtained between VIIRS emission estimates and reported flare volume data, an estimate of flare volumes can be made for each of the ~10,000 flares for any time period. In this way, both global gas flaring estimates and estimates for individual countries have been made annually for each year from 2012 to 2018.

In 2018, tests at John Zinc's flare testing facility in Oklahoma were commenced to validate and/or modify this calibration. At these tests, simultaneous on-site measurements and satellite estimates of flare volumes are being made so that a direct relationship between the two can be established. The gas volumes flared in these tests have been up to the equivalent of 2 bcm/year, so the range of data being acquired in the tests covers the full range of flare volumes encountered at flaring sites around the world. The correlation between this initial comparison of satellite data and the measured flare volumes differs only slightly from that between the satellite and the Cedigaz data.

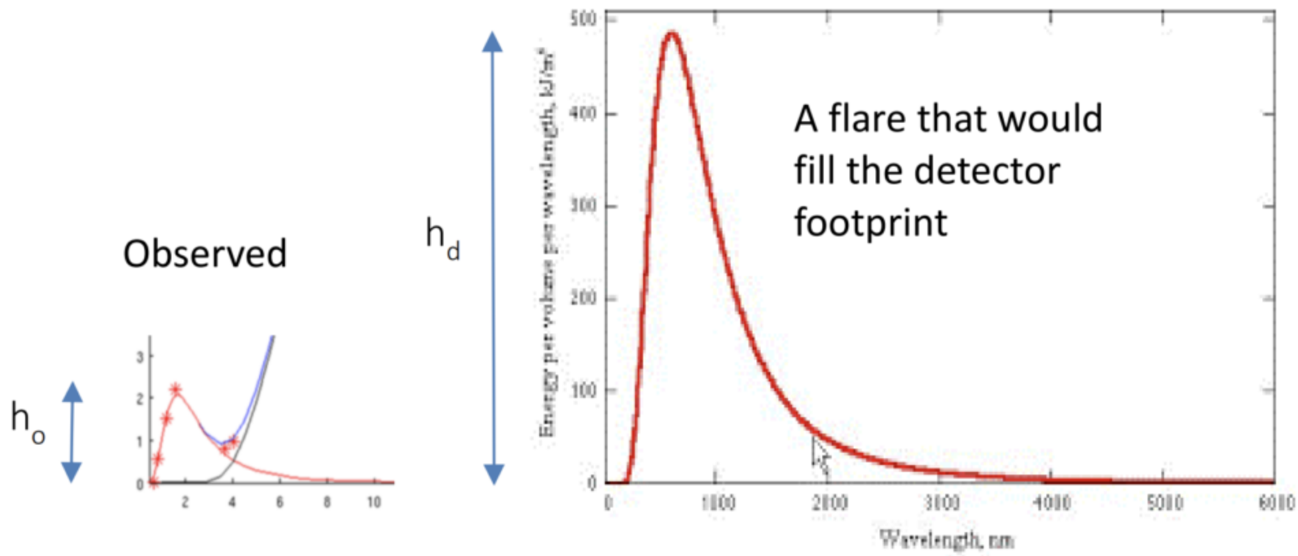
In 2020 these tests will be continued to confirm the linearity of the relationship between radiant heat and flare volume, and to investigate any impact, for example of. variations in gas composition, on this relationship.

Relationships used to estimate flare volumes from VIIRS data

1. The flare Temperature is calculated using Wein's Displacement Law: T = b/?max where T is the temperature (deg K), ?max is the wavelength at the flare Planck curve's peak, and b is Wien's displacement constant.

2. The flare Radiant Heat per Unit Area is calculated from the temperature estimate using the Stephan-Boltzmann equation: J = ??T 4 where J is the Radiant Heat per Unit Area (watts/m2), ? is the flare emissivity (assumed constant) and ? is the Stefan-Boltzmann constant.

3. The flare Surface Area (m2) is estimated from the ratio of the height (h) of the observed flare Planck curve and the height of the curve that would result from a flare that fills the entire area of detector footprint, times the area of the detector footprint:



Flare surface area = ho / hd x detector footprint area

Can I identify a flare with a performance issue?

[Can I identify a flare with a performance issue: Satellite monitoring – Wide area methane emissions monitoring]

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