MONITORING AND ESTIMATION OF GAS FLARING PHYSICAL PARAMETERS BY VIIRS NtL REMOTE SENSING DATA, CASE OF ALGERIA

Agence Spatiale Algérienne, Centre des Techniques Spatiales, Arzew, Algérie
{fbenharrats, abouhlala, fbenhalouche, skaroui}@cts.asal.dz

Outline

- Introduction
- Used data & Study area
- Considered Method
- Obtained Results
- Conclusion

Introduction

Operational production flaring
(Downstream)

Natural gas transported by pipeline to liquefaction plants

At instrument failures or during maintenance
(Emergency procedure)

Continuous production flaring
(Upstream)

Natural gas produced by oil wells
(Associated gas)

No economical gas valorization route for a satellite field

Introduction

Introduction

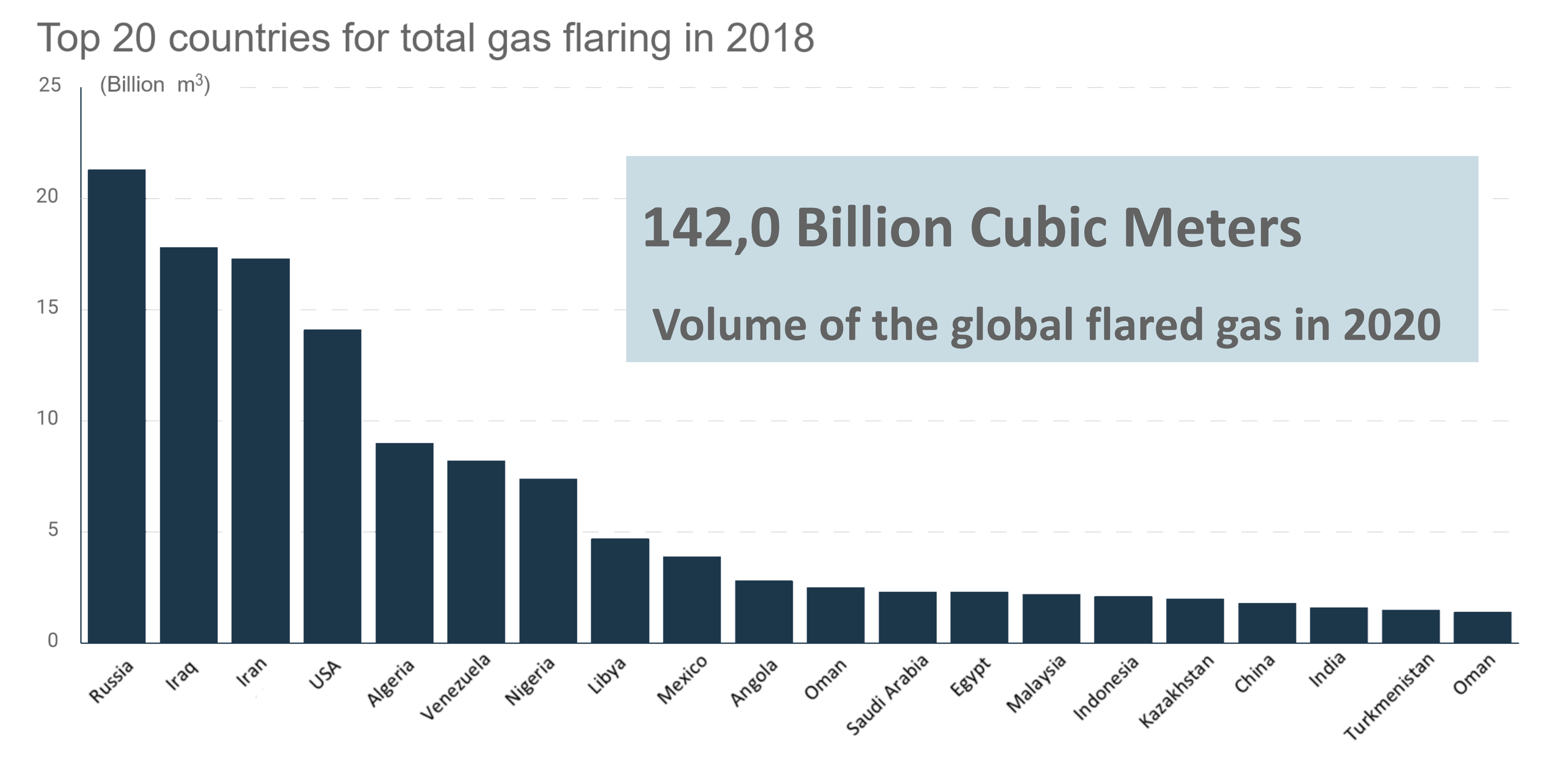
Launched in **2015**, the **Zero Routine Flaring** (ZRF) initiative commits governments and oil companies, to end routine flaring no later than **2030**.

The World Bank Group

Seeking a world **free of routine gas flaring** and venting.

GGFR Partnership Charter

Introduction



Source : NOAA, GGFR - 2020

Gas Flaring Estimation From VIIRS NtL Remote Sensing Data

Used Data & Study Area

Considered Method

Obtained Results

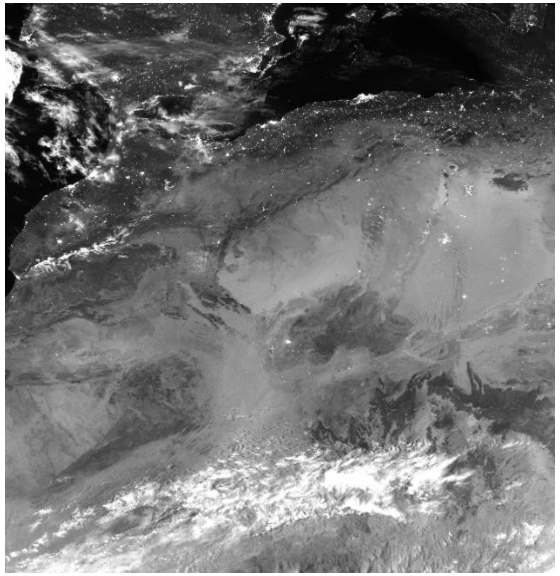
VIIRS (VIsible/Infrared Imager Radiometer Suite)

Multispectral Sensor

On board the polar-orbiting Suomi National Polar-orbiting Partnership (Suomi NPP) and NOAA-20 weather satellite.

Collect data in 22 different spectral bands of the electromagnetic spectrum.

SDR (Sensor Data Records) preprocessing level or Level-1B.



Band Designation	Spectral Range	Bandpass (μm)	Band Center (μm)
DNB	Panchromatic	0.5–0.9	0.7
M7	Near infrared	0.843–0.881	0.862
M8	Near infrared	1.225–1.252	1.2385
M10	Short-wave IR	1.571–1.631	1.601
M12	Mid-wave IR	3.598–3.791	3.6945
M13	Mid-wave IR	3.987–4.145	4.066
M14	Long-wave IR	8.407–8.748	8.5775
M15	Long-wave IR	10.234–11.248	10.741
M16	Long-wave IR	11.405–12.322	11.865

Gas Flaring Estimation From VIIRS NtL Remote Sensing Data

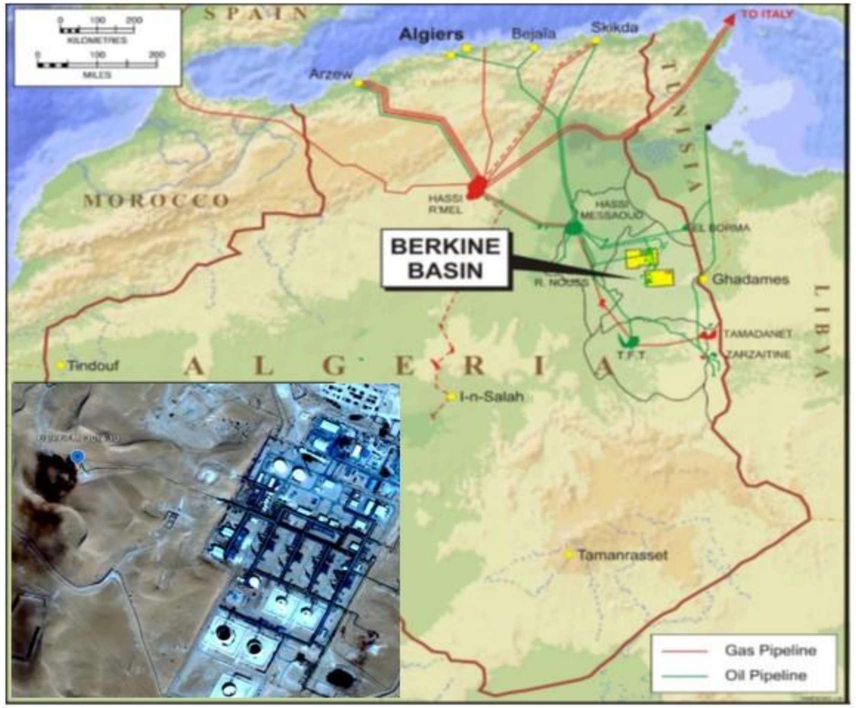
Used Data & Study Area

Considered Method

Obtained Results

Study area

Oil installation equipped with a flare burning the not-exploited associated gases.



Data covers the southern region of Algeria and the considered flare FIT-M8-101A-1U (Berkine basin, Hassi Messaoud, Algeria).

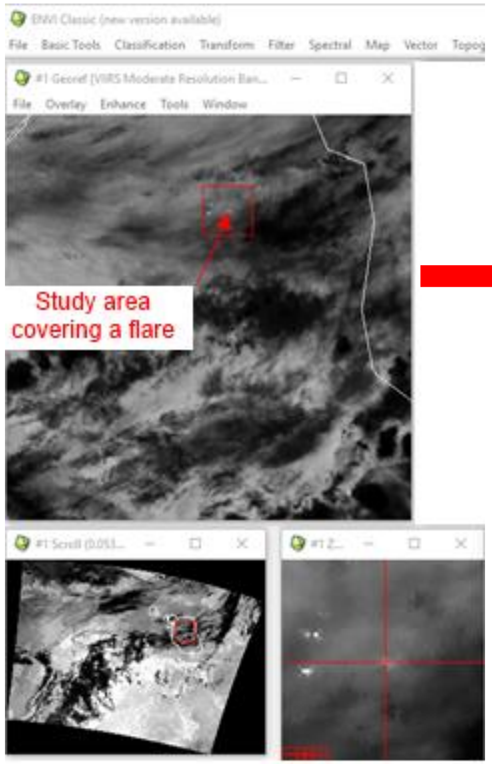
Gas Flaring Estimation From VIIRS NtL Remote Sensing Data

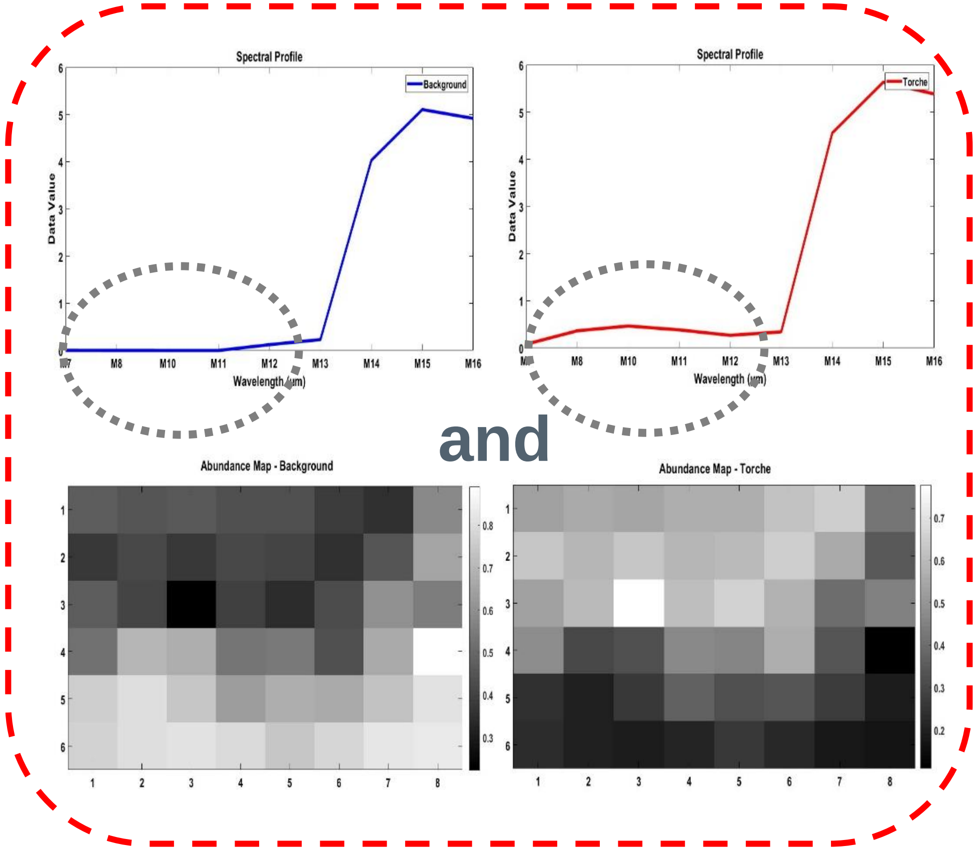
Used Data & Study Area

Considered Method

Obtained Results

Flare detection

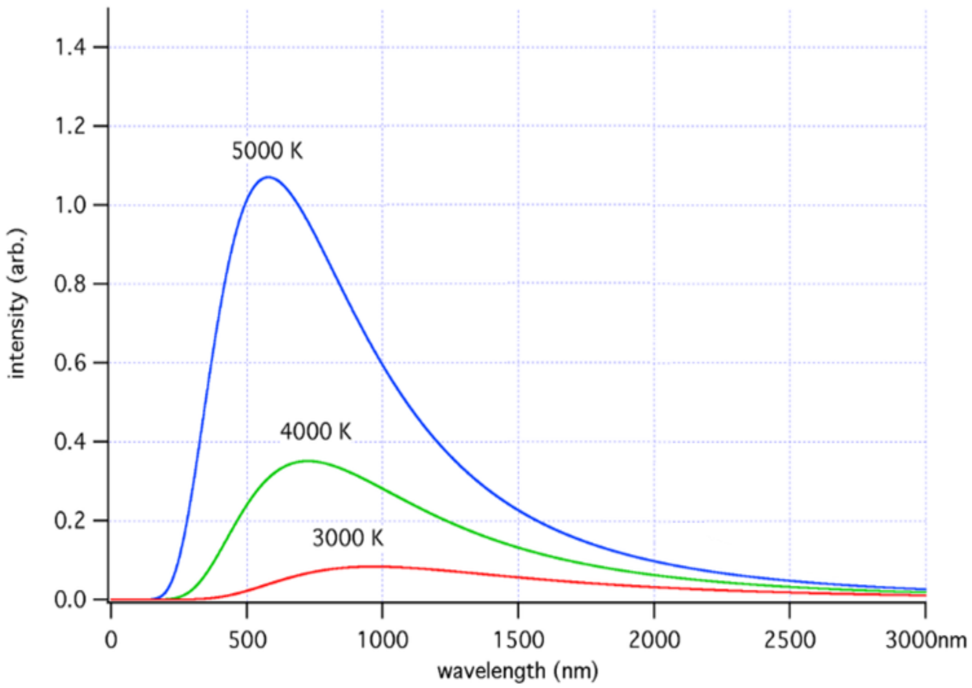




Gas Flaring Estimation From VIIRS NtL Remote Sensing Data

Planck's law

Describes the electromagnetic radiation emitted by a black body in thermal equilibrium at a definite temperature :



$$L_\lambda = \frac{2hc_\lambda^2}{\lambda^5} \frac{1}{\exp\left(\frac{hc_\lambda}{k\lambda T}\right) - 1}$$

Where :

c : speed of light in the void (3×10^8 m.s^{-1})

h : Planck constant (6,625 10^{-34} J.s)

k : Boltzmann constant (1,38 10^{-23} J.K^{-1})

T : Black-body temperature in Kelvin

Gas Flaring Estimation From VIIRS NtL Remote Sensing Data

Used Data & Study Area

Considered Method

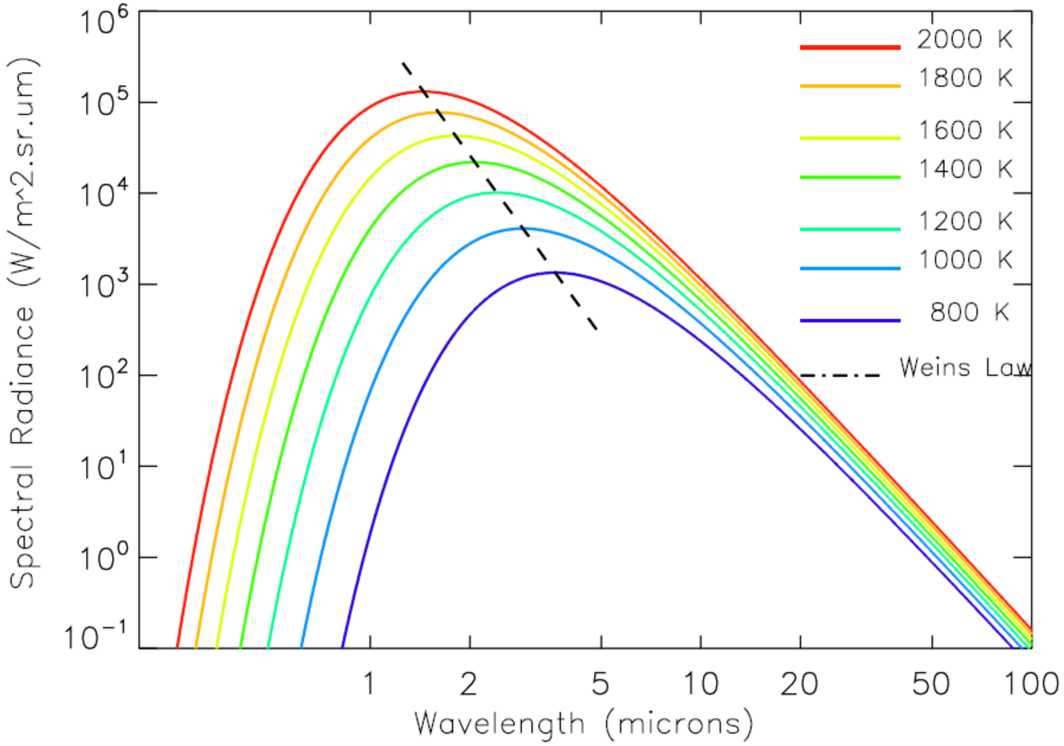
Obtained Results

Wien's displacement law

Used to derive the temperature for a corresponding wavelength of peak emission :

$$\lambda_{max} = \frac{hC}{4.9651 \times kT}$$

$$T = \frac{2.898 \times 10^{-3}}{\lambda_{max}}$$



Gas Flaring Estimation From VIIRS NtL Remote Sensing Data

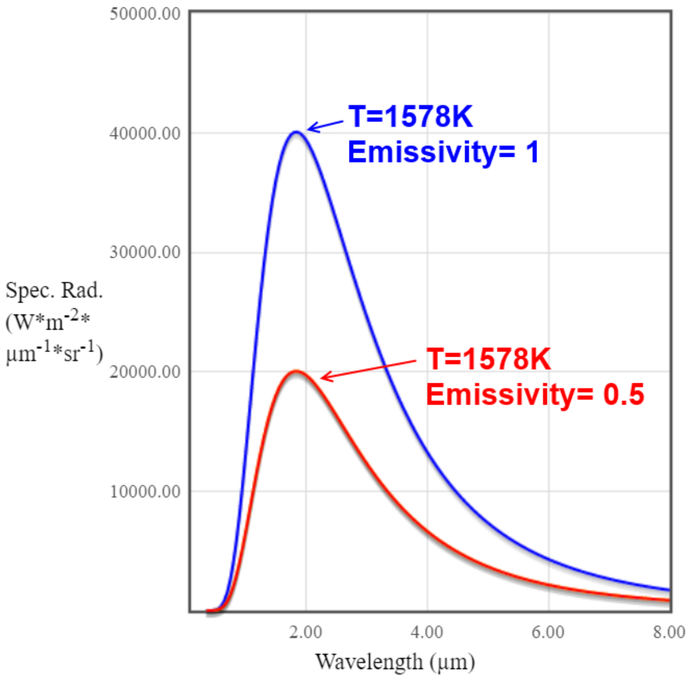
Used Data & Study Area

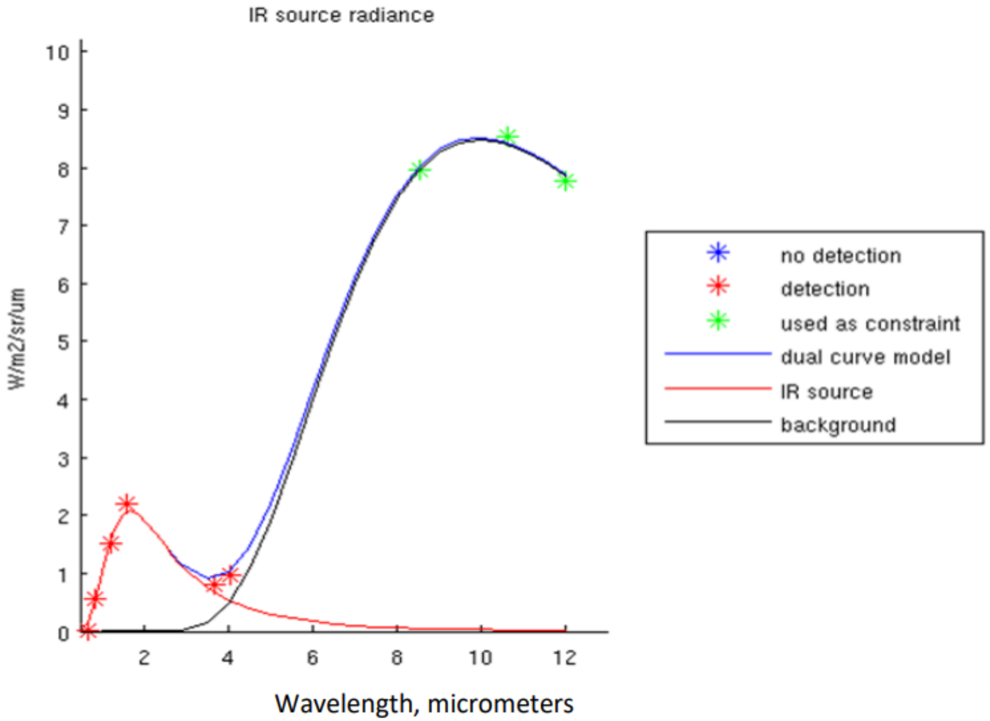
Considered Method

Obtained Results

Planck curve fitting

The fitting outputs are estimates of a temperature and an emissivity value of the hot source present in a given pixel.

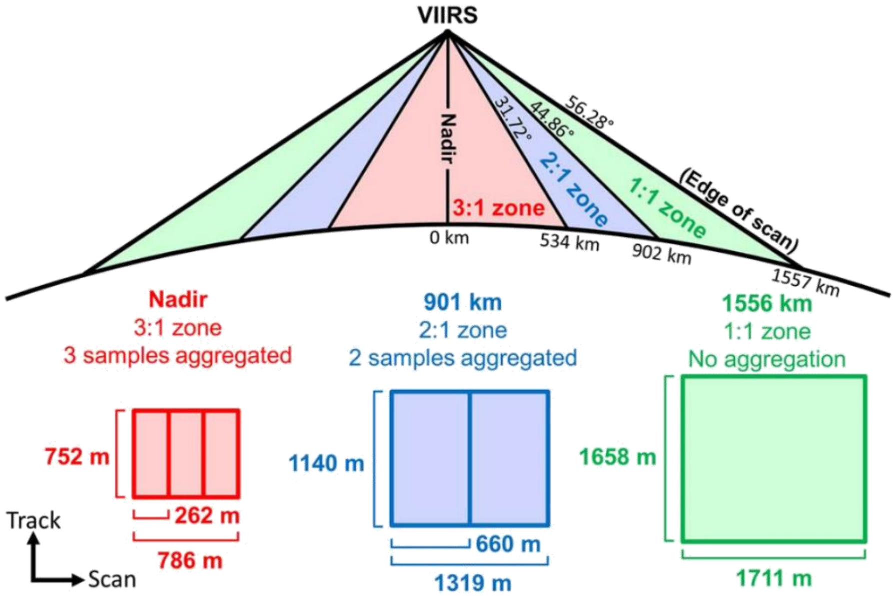




Gas Flaring Estimation From VIIRS NtL Remote Sensing Data

Source area estimation (S)

Determine the size of the pixel footprint (A) :



$$S = \varepsilon\, A$$

Along scan pixel size « ΔS »

$$\Delta S = R_e\ S_s \left(\frac{\cos\theta}{\sqrt{\left((R_e/r)^2 - \sin^2\theta\right)}} - 1 \right) \frac{1}{x}$$

Along track pixel size « ΔT »

$$\Delta T = r.S_t.\left(\cos\theta - \sqrt{\left((R_e/r)^2 - \sin^2\theta\right)} \right)$$

Gas Flaring Estimation From VIIRS NtL Remote Sensing Data

Used Data & Study Area

Considered Method

Obtained Results

Radiant Heat estimation

Applying the Stefan-Boltzmann's law :

$$RH = \sigma\, T^4\, S$$

Where :

σ : Stefan-Boltzmann constant (5,67 10^{-8} $J.K^{-4}.m^{-2}.s^{-1}$)

T : Black-body temperature in Kelvin

Gas Flaring Estimation From VIIRS NtL Remote Sensing Data

Used Data & Study Area

Considered Method

Obtained Results

Estimated parameters

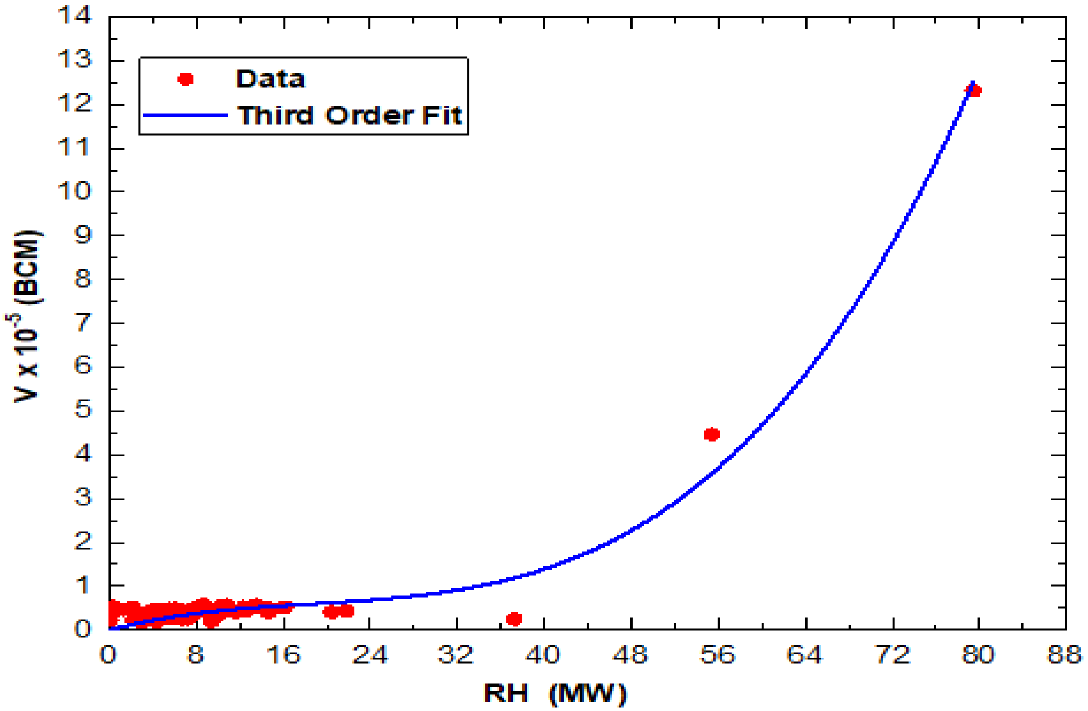
Planck curve fit estimated parameters :

	Proposed Approach
T (Kelvin)	1668.7
ε	1.3970×10^{-5}
A (m^2)	1 417 838.3112
S (m^2)	13.3084
RH (MW)	5.8509

Gas Flaring Estimation From VIIRS NtL Remote Sensing Data

- Used Data & Study Area
- Considered Method
- **Obtained Results**

Volume estimation



The established intercepting zero “third-order” polynomial regression model, using all dates of the two months of October and November 2021, by means of the proposed approach and the provided “hourly” in-situ flaring gas volumes.

Gas Flaring Estimation From VIIRS NtL Remote Sensing Data

Used Data & Study Area

Considered Method

Obtained Results

Obtained results by means of the established intercepting zero "third-order" polynomial regression model using the two months of October and November 2021:

Hourly regression coefficients $\boldsymbol{\alpha_h}$	$\boldsymbol{\alpha_{h_1}}$	6.5982×10^{-7}
	$\boldsymbol{\alpha_{h_2}}$	- 2.7400×10^{-8}
	$\boldsymbol{\alpha_{h_3}}$	4.8962×10^{-10}
Daily regression coefficients $\boldsymbol{\alpha_d = 24 \times \alpha_h}$	$\boldsymbol{\alpha_{d_1}}$	1.5835×10^{-5}
	$\boldsymbol{\alpha_{d_2}}$	-6.5760×10^{-7}
	$\boldsymbol{\alpha_{d_3}}$	1.1751×10^{-8}
Annual regression coefficients $\boldsymbol{\alpha_a = 24 \times 365.25 \times \alpha_h}$	$\boldsymbol{\alpha_{a_1}}$	5.7838×10^{-3}
	$\boldsymbol{\alpha_{a_2}}$	-2.4020×10^{-4}
	$\boldsymbol{\alpha_{a_3}}$	4.2920×10^{-6}
Determination coefficient $\boldsymbol{R^2}$	0.9763	
Hourly $\boldsymbol{RMSE_{\text{Volume}}}$ (October and November 2021) in BCM	2.6614×10^{-6}	
Daily $\boldsymbol{RMSE_{\text{Volume}}}$ (October and November 2021) in BCM	3.2309×10^{-4}	
Daily $\boldsymbol{RMSE_{\text{Volume}}}$ (considered 156 dates of 2020) in BCM	5.2423×10^{-5}	

Gas Flaring Estimation From VIIRS NtL Remote Sensing Data

Used Data & Study Area

Considered Method

Obtained Results

Estimated annual 2021 flared gas volumes (in BCM×10^{-3}) for the considered FIT-M8-101A-1U flare :

Method	Proposed Approach	Cedigaz
Estimated volume	33.0743	255.3538
Measured volume	67.6293	
|Estimation error|	**34.5550**	187.7245

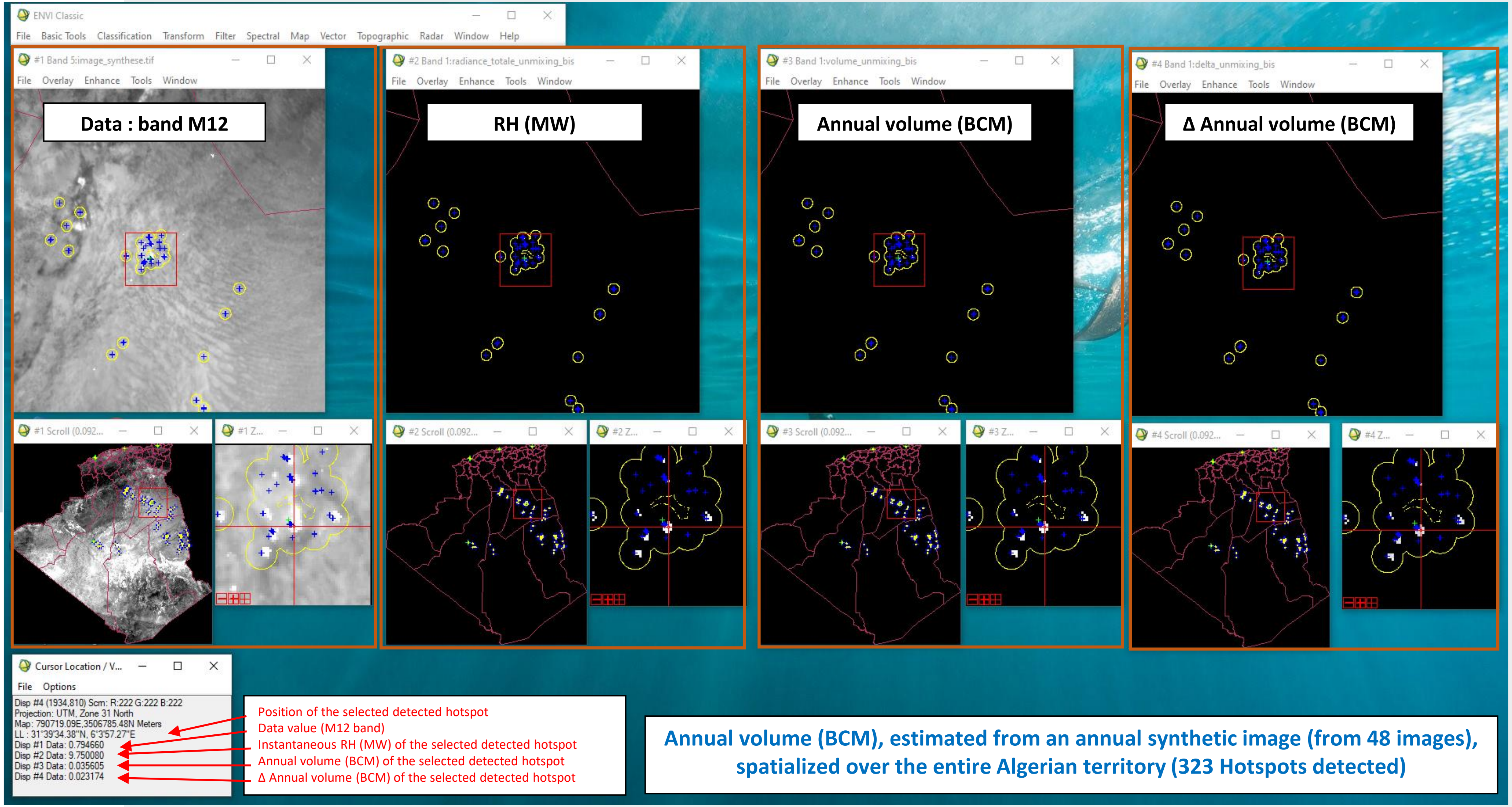
Gas Flaring Estimation From VIIRS NtL Remote Sensing Data

Proposed Approach

$Estimated\ volume\ V \approx 2\ BCM$

Cedigaz

$Estimated\ volume\ V \approx 11\ BCM$



Conclusion

- In this work, the parameters of a flare, located in a southern region of Algeria, are estimated, by means of, publicly available, NtL VIIRS remote sensing data, using a new proposed approach.
- This designed approach consists, principally, in deriving, from considered remote sensing data, pure flare flame spectrum and its abundance fraction that are, then, employed by physical law equations, in order to estimate flare physical parameters.
- These investigations were carried out by considering the provided daily and hourly in-situ flaring gas volume measurements, in order to estimate flared gas volumes during 2020- and 2021-year periods.
- The obtained results show the overall superiority of the designed approach, in terms of flared gas volume estimations, as compared with estimations achieved by using the Cedigaz regression coefficient.

Thank you for your attention