

Gas flare detection with Sentinel-3, including night-time acquisition in S1-S4



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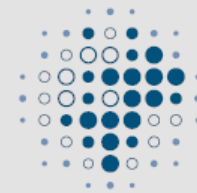


Gefördert durch:



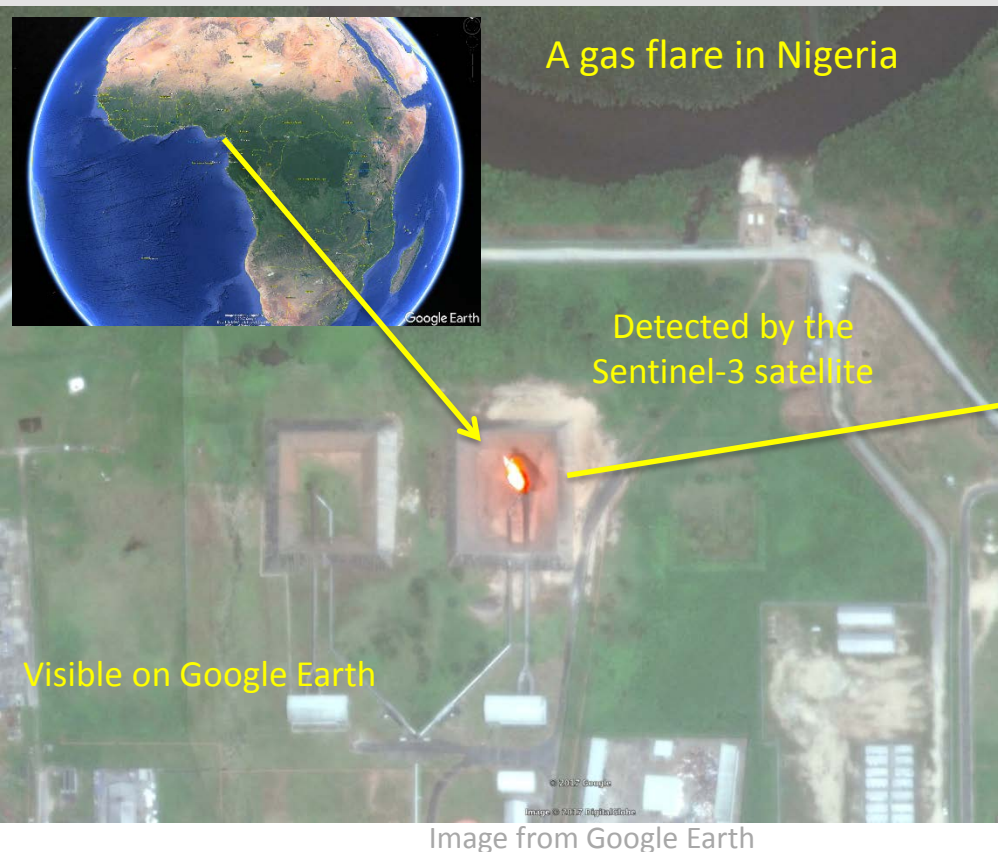
Bundesministerium
für Wirtschaft
und Energie

aufgrund eines Beschlusses
des Deutschen Bundestages

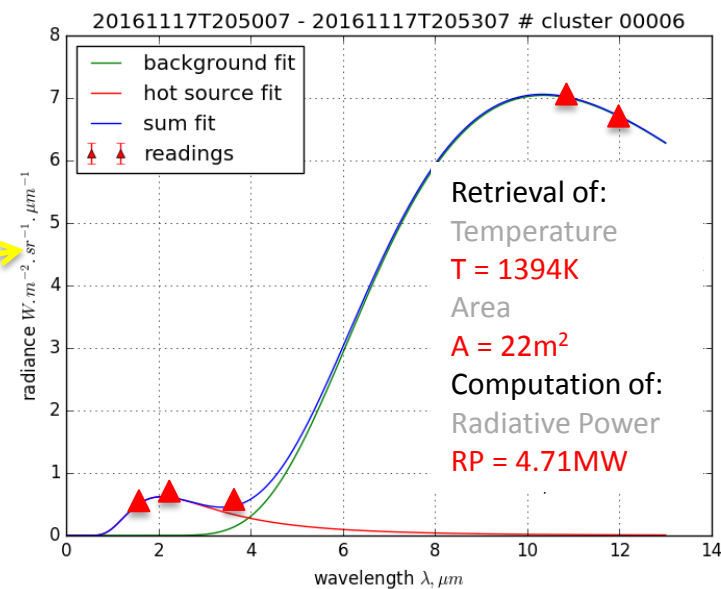


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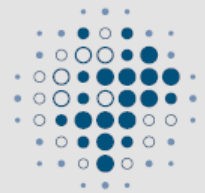
Detection and characterisation



Fit the sum of 2 Planck curves (Background and Hot Source) to satellite infrared readings:



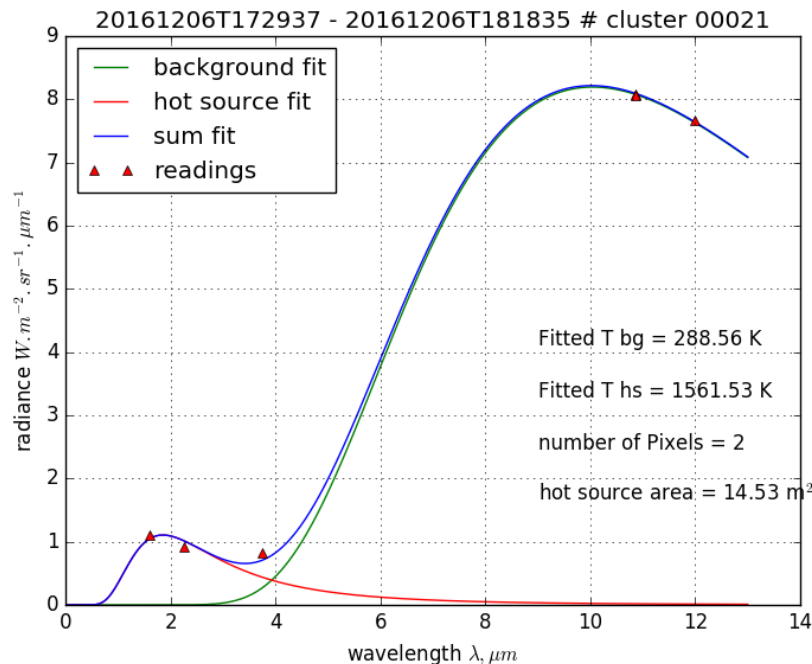
At night, the satellite registers the radiance in 5 channels



Dual Planck Curve fitting

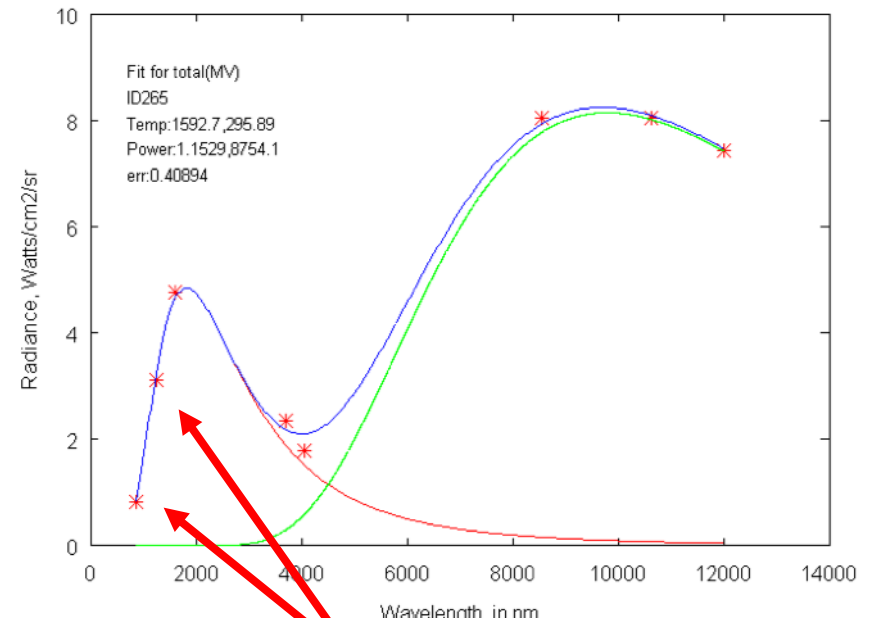
Input options

- SLSTR S5-S9
- SLSTR S1-S9
- VIIRS M7, M9-M12, M15, M16

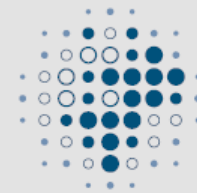


Provenance

VIIRS Nightfire [Elvidge et al. 2013]



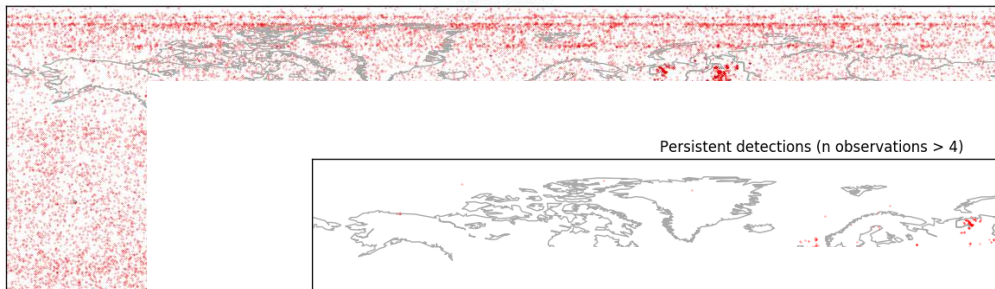
- strong hot source temperature constraint in NIR range



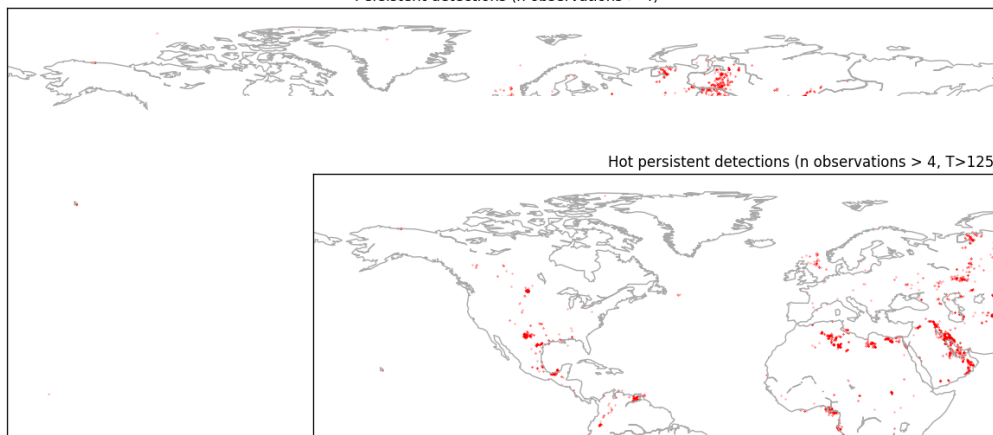
Global results – Detection of gas flares

Sentinel-3: global daily coverage, operational until 2040.

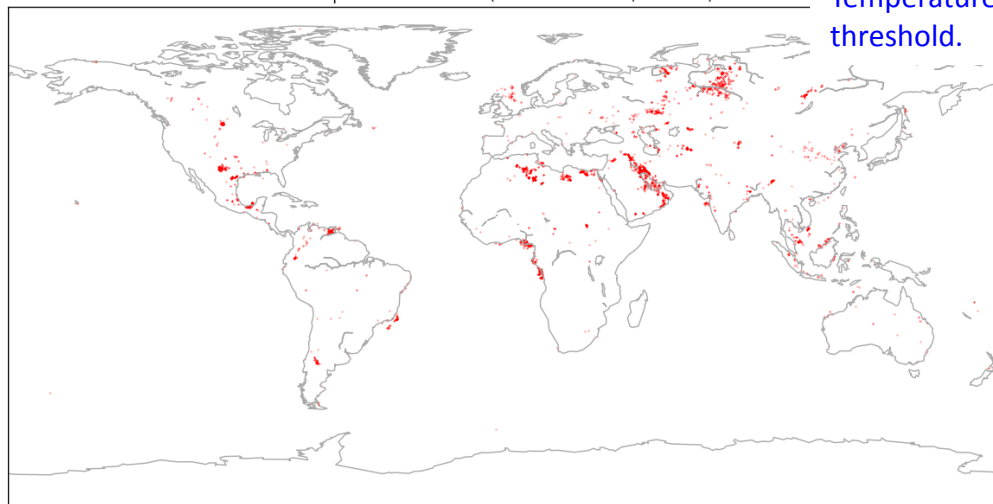
All detections



Persistent detections (n observations > 4)



Hot persistent detections (n observations > 4, $T > 1250K$)



Applying a lower
Temperature
threshold.

Gas Flares are expected to burn (semi-)continuously. Only consider locations with at least 4: still detect some vegetation fires and industrial sites.

4634 flaring sites detected globally
(2017, 150 days)

Top 50% in 5 countries:

Russia: 778

United States: 461

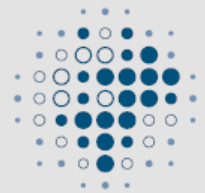
Iran: 361

Algeria: 267

Iraq: 260

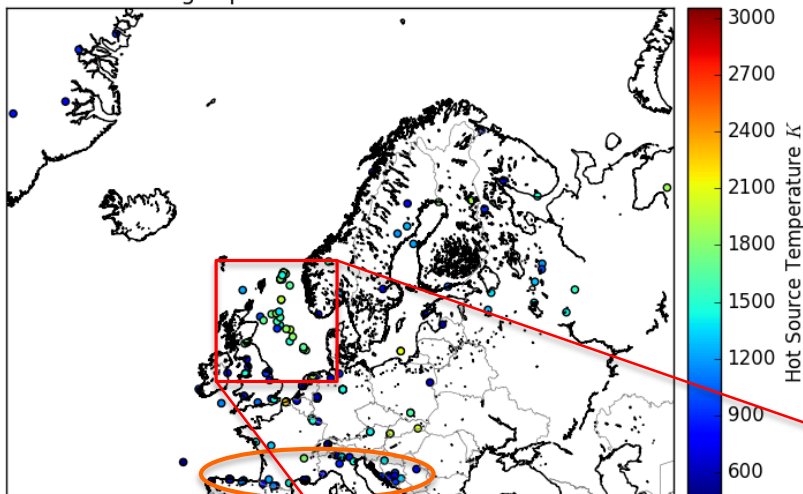
First results: North Sea

Location



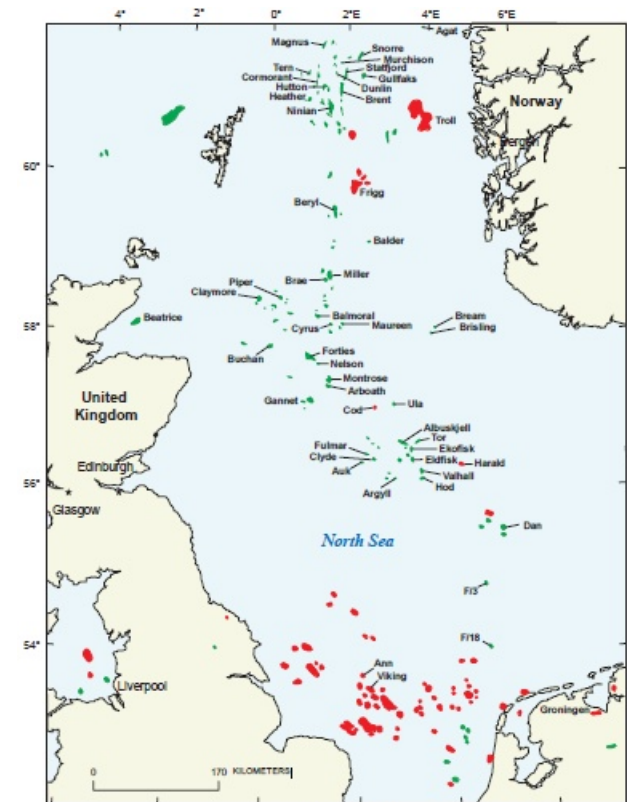
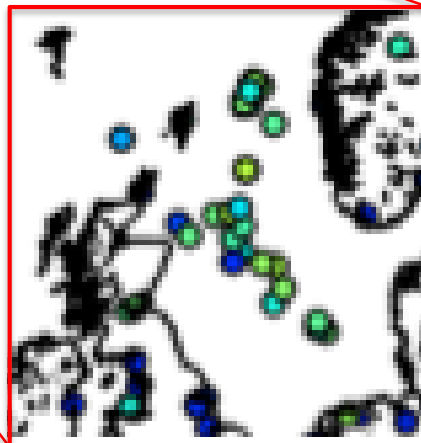
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Detections, $t = 0.999990$, 196 clusters
in 76 of 182 images processed from 20161117 to 20161218



The location of the detections
coincides with oil fields, but
not with gas fields.

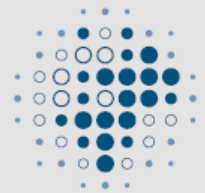
Cold detections over N Spain,
Po Valley



EXPLANATION

Oil field Gas or gas condensate field

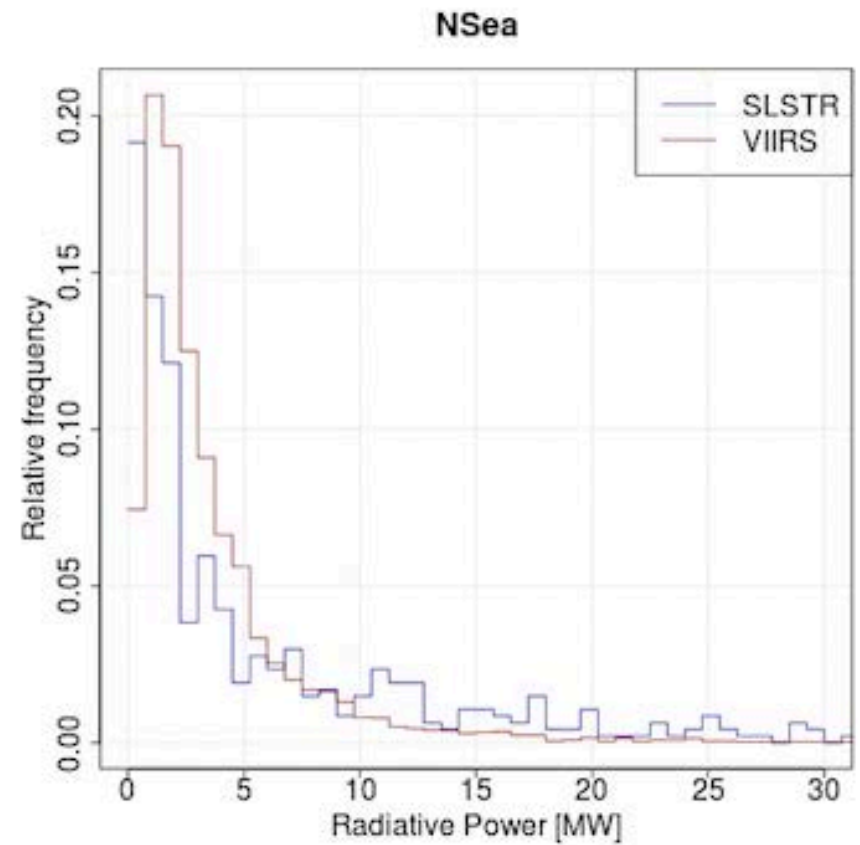
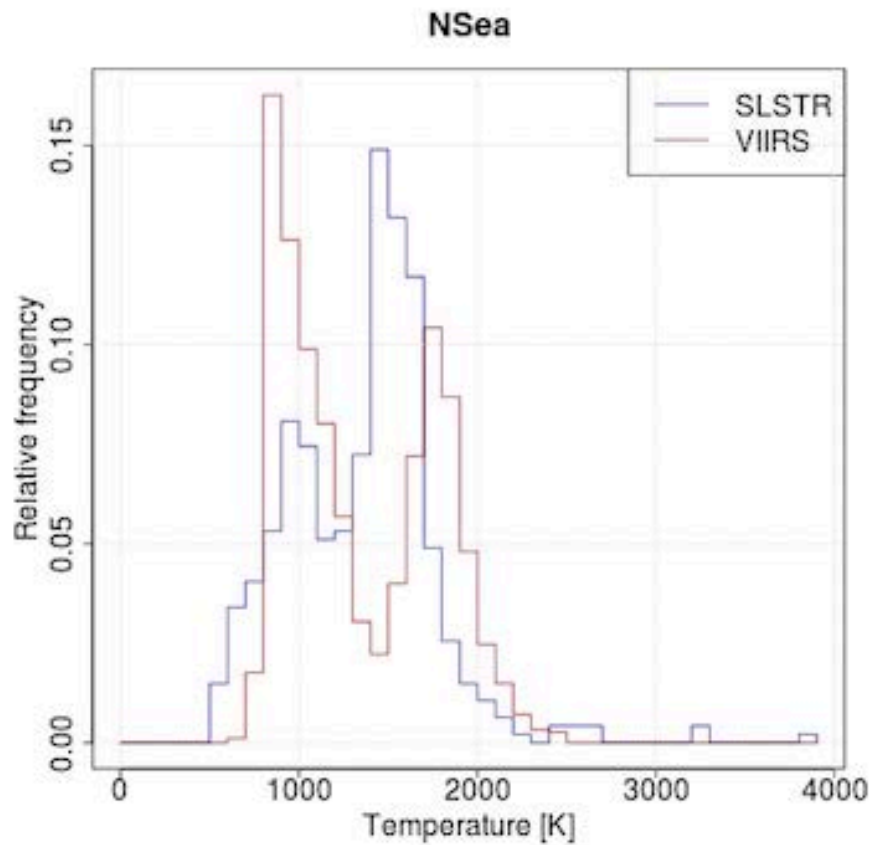
Image source: Wikipedia

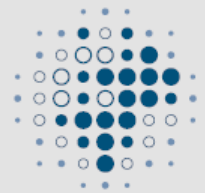


Method evaluation

Comparison between Sentinel-3 SLSTR and Suomi-NPP VIIRS

Nightfire algorithm by C. Elvidge *et al.* 2016





Comparison to TET-1

Temperature, area, FRP

Temperature and Area:

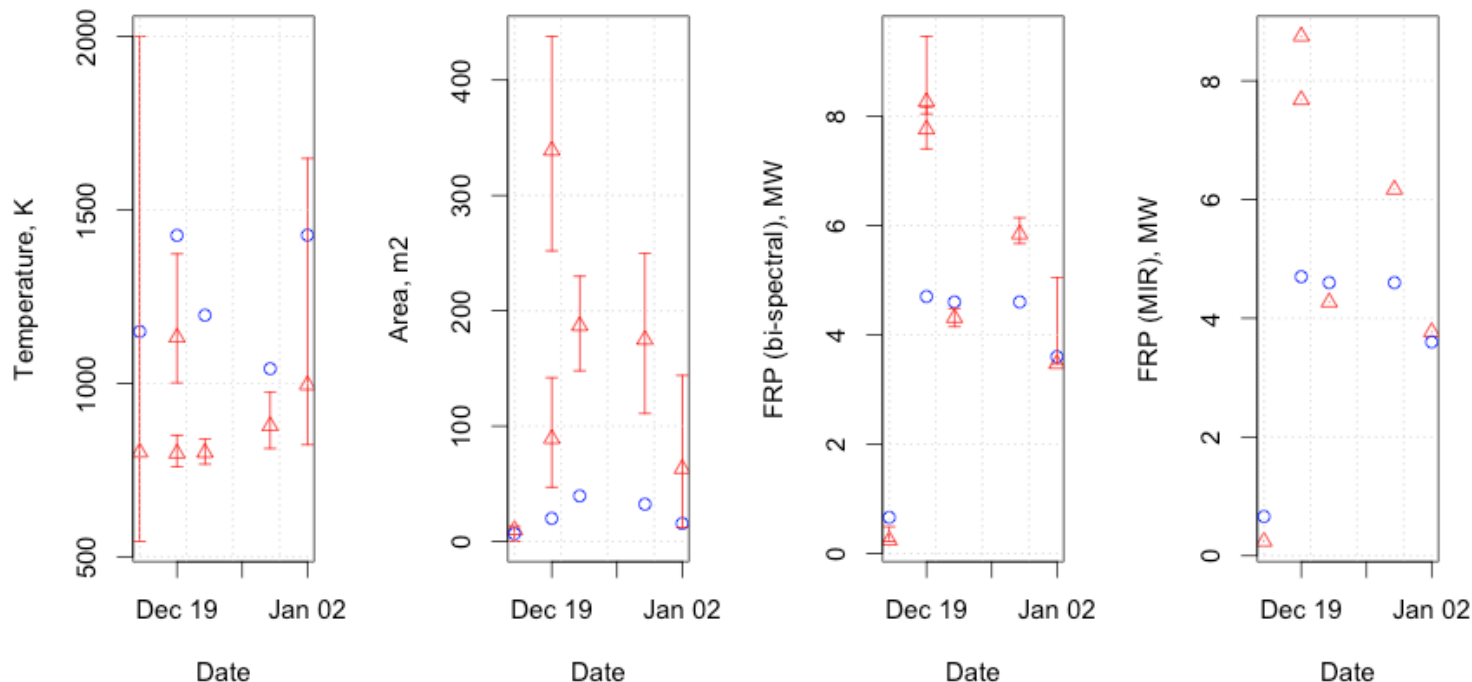
- BIRD algorithm Zhukov *et al.* 2005

FRP:

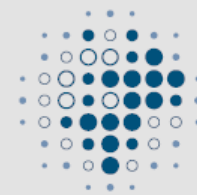
- bi-spectral method Zhukov *et al.* 2006 after Dozier 1981
- MIR method Wooster *et al.* 2003

Thanks to its high resolution, TET-1 discriminates various flares where SLSTR sees a continuous cluster at Bovanenkovo.

△ TET-1 ○ SLSTR



$$\begin{aligned} T_{\text{SLSTR}} &> T_{\text{TET-1}} \\ A_{\text{SLSTR}} &< A_{\text{TET-1}} \\ \text{FRP}_{\text{SLSTR}} &\approx \text{FRP}_{\text{TET-1}} \end{aligned}$$



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Global results – comparison with EDGAR

This study:

Number of flaring sites
(2017, 150 days)

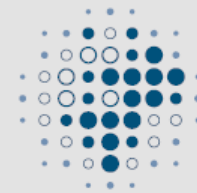
This study:

Sum of RP
(2017, 150 days)

EDGAR (v4.3) CO₂ emissions:

Venting and Flaring
(2012)

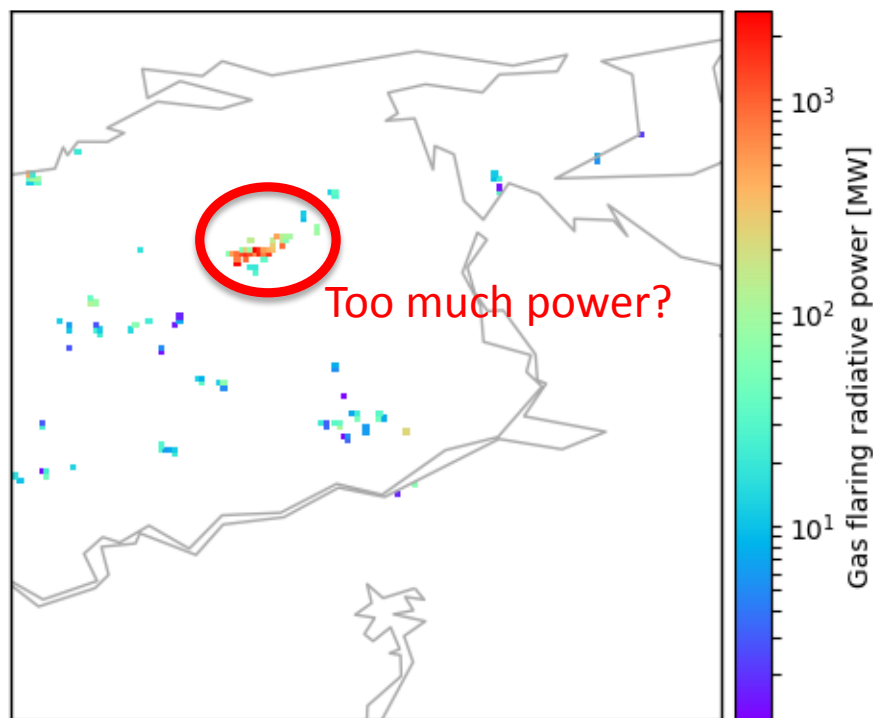
Country	This study (% of global)		EDGAR (% of global)
Venezuela	3 %	21 %	3 %
Iraq	6 %	12 %	8 %
Iran	8 %	10 %	7 %
Russia	17 %	8 %	24 %
Algeria	6 %	4 %	4 %
Nigeria	4 %	4 %	10 %
United States	10 %	4 %	6 %



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Global results – comparison with EDGAR

Venezuela



4.3) CO₂ emissions:

and Flaring

Country
Venezuela
Iraq
Iran
Russia
Algeria
Nigeria
United States

EDGAR (% of global)
3 %
8 %
7 %
24 %
4 %
10 %
6 %

Could this indeed be a *hot source*?

THE WALL STREET JOURNAL.

IN DEPTH

Venezuelan Oil Is Largely Staying in Ground or Going Up in Smoke

The country's vast oil potential isn't being realized for lack of equipment, commitment and capital

By *Anatoly Kurmanaev* | Photographs by *Miguel Gutiérrez* for *The Wall Street Journal*

Updated Oct. 23, 2016 9:08 p.m. ET

PUNTA DE MATA, Venezuela—This fading oil town has an eerie glow at night, illuminated by dozens of oil wells burning off precious oil and gas for lack of functioning equipment to process it.

Recommended Videos

- 1. Inside an Immense Farm Operation in Venezuela

Venezuela's oil industry
Up in smoke



An explosion at a refinery casts light on the gross mismanagement of PDVSA



Americas view >
Aug 27th 2012 | by P.G. | CARACAS



ON AUGUST 25th a gas leak at the Amuay oil refinery in western Venezuela set off a giant explosion. The force of the blast destroyed scores of homes and businesses in the surrounding area and has killed at least 41 people,

Strange things have been happening in the Venezuelan oil industry:

- Accidents/Explosions
- Only the lightweight oil has been kept (directly exportable to the US for the gasoline market).
The heavier oil has been flared together with the associated gas.

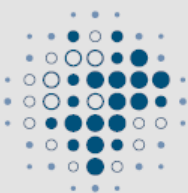
-> Is this the cause of the large RP detections?



Could this indeed be a *hot source*?

Hi-res imagery in the region not located exactly where we detected hot spots

This one is clearly a flare: visible infrastructure, soot deposits nearby.



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Ruler

Line Path Polygon Circle 3D path 3D polygon

Measure the distance or area of a geometric shape on the ground

Perimeter: 0.14 Kilometers

Area: 1,104.51 Square Meters

☒ Mouse Navigation

Save Clear

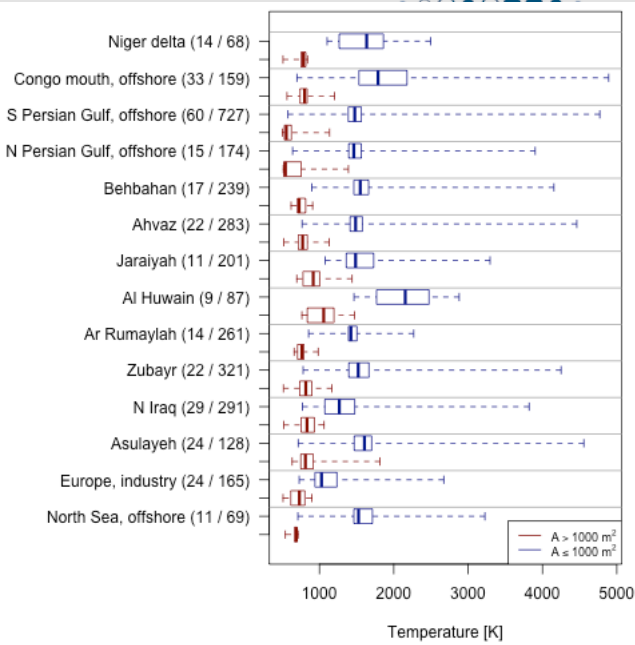
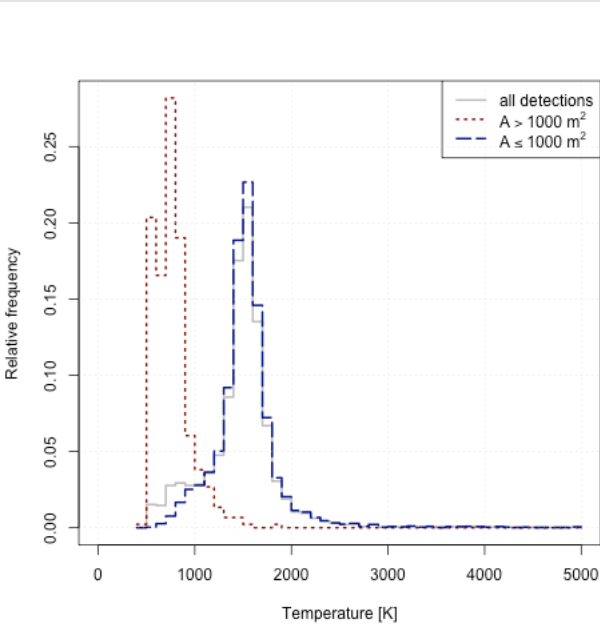
$1105 \times 1800 \times 4 \times 5.67E-8 \times 1E-6 = 657 \text{ MW}$



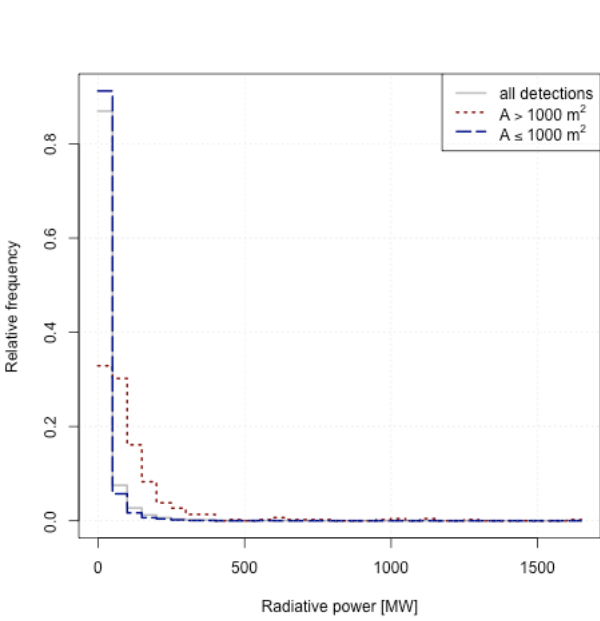
MAX-PLANCK-GESELLSCHAFT



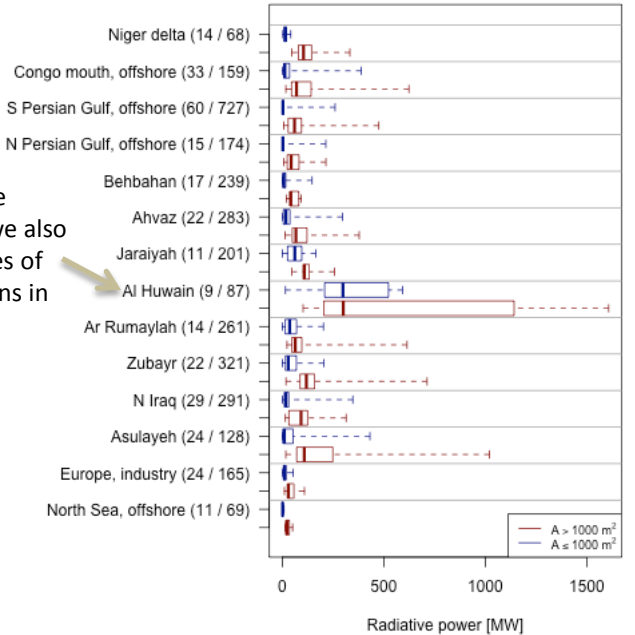
Temperature

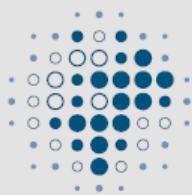


RP

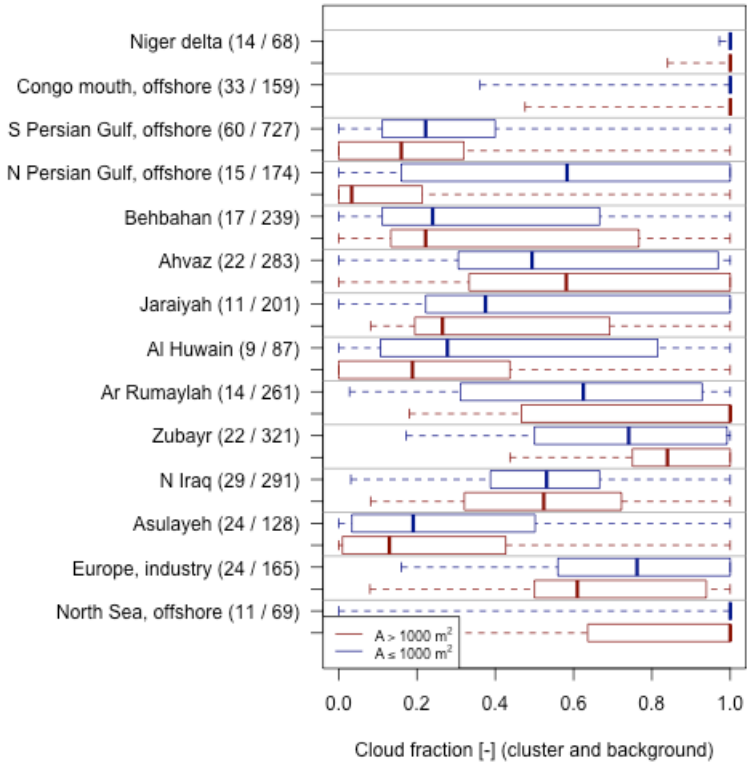
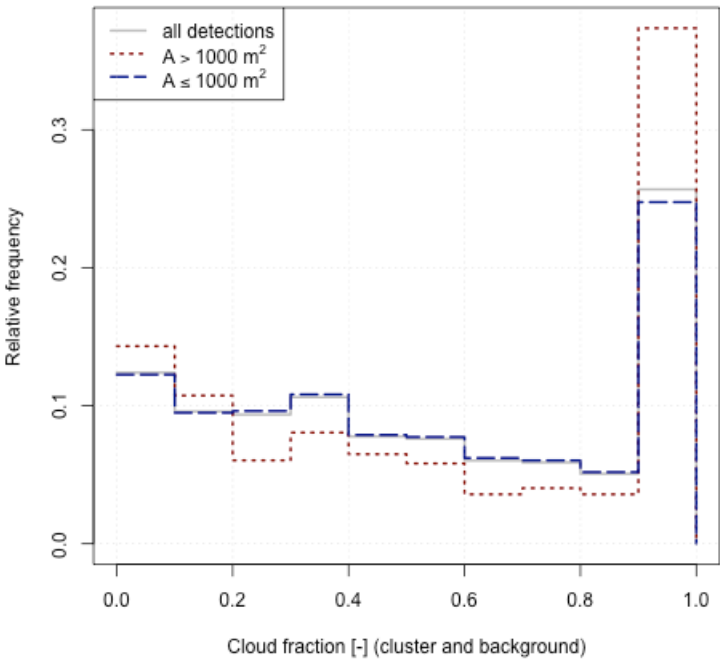


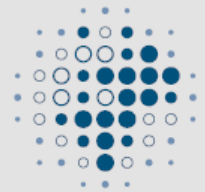
This is the same region where we also saw occurrences of ~1GW detections in 2017!





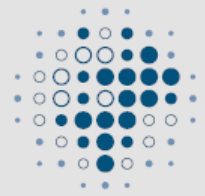
Cloud (?)





Summary

- Sentinel-3 SLSTR night-time gas flare detection algorithm implemented
- similar to VIIRS Nightfire by C. Elvidge, but
 - analyses entire hot clusters instead of their maximal pixels
 - accommodates SLSTR misregistration (and even characterises it)
- validation against VIIRS Nightfire and TET-1
- very large gas flares in Venezuela apparent, but needs better quality control



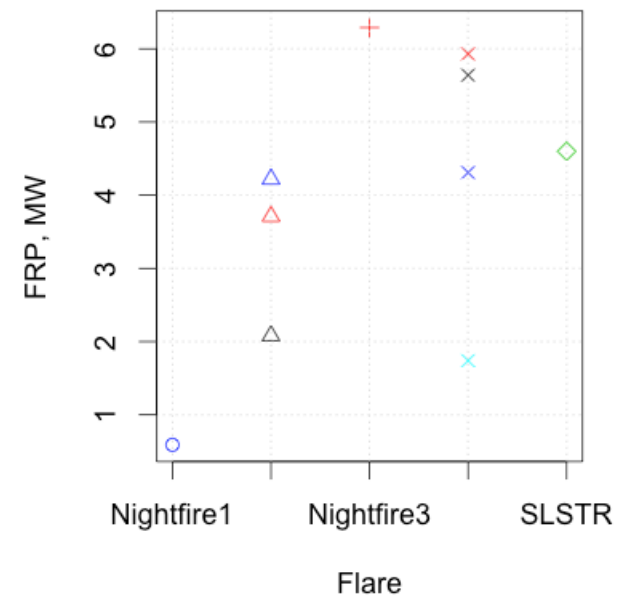
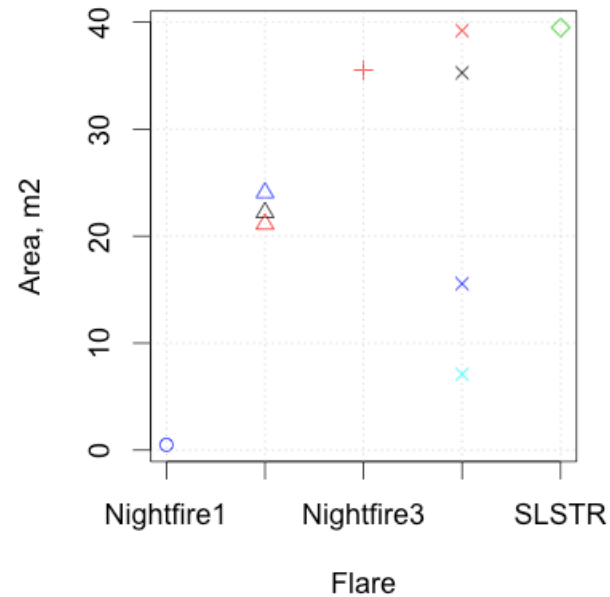
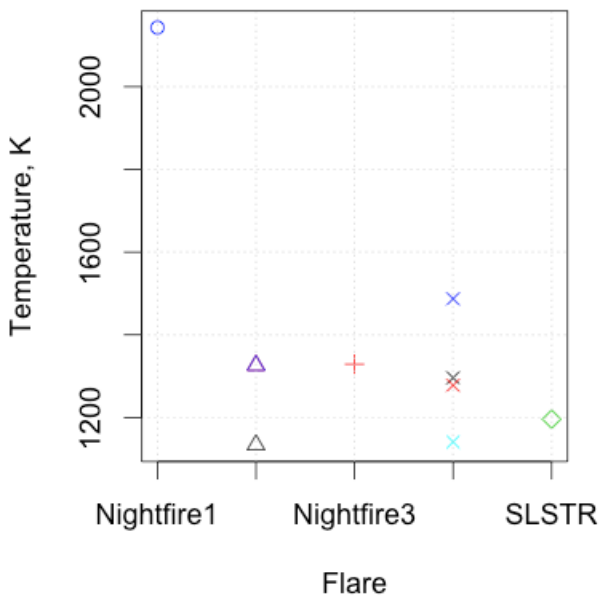
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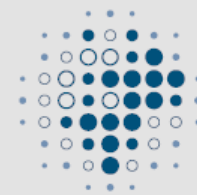
Retrieval comparison to VIIRS Nightfire

Temperature, area, FRP

○ Nightfire1 △ Nightfire2 + Nightfire3 × Nightfire4 ◇ SLSTR

• at_21:13 • at_02:31 • at_00:52 • at_22:54 • at_07:24



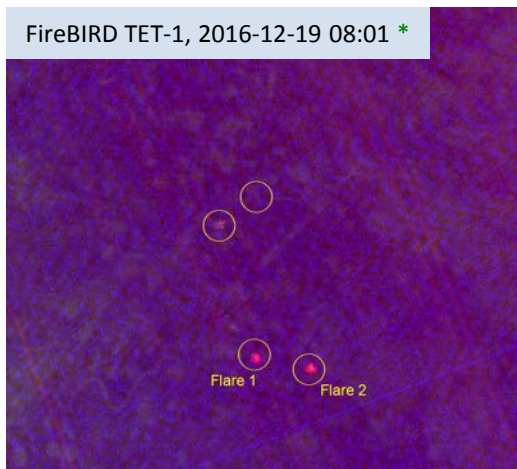


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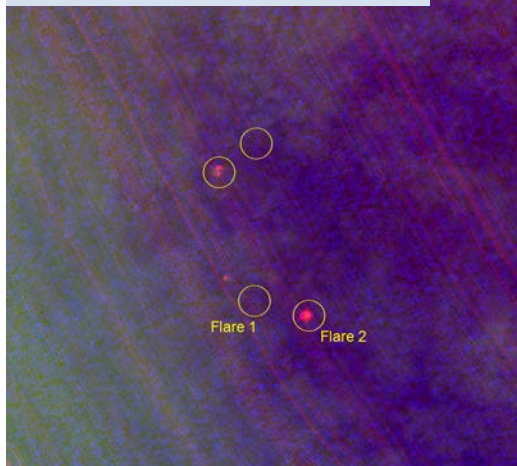
Comparison to TET-1

Flare at Bovanenkovo

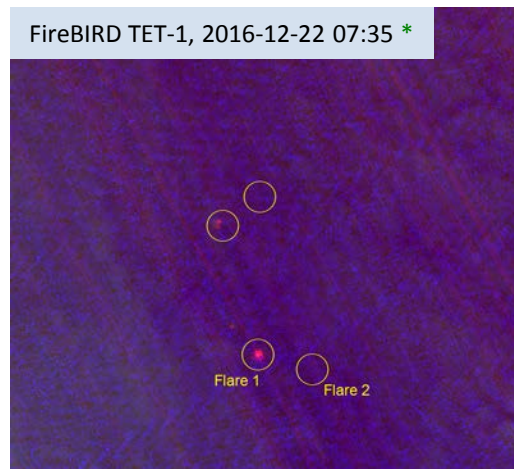
FireBIRD TET-1, 2016-12-19 08:01 *



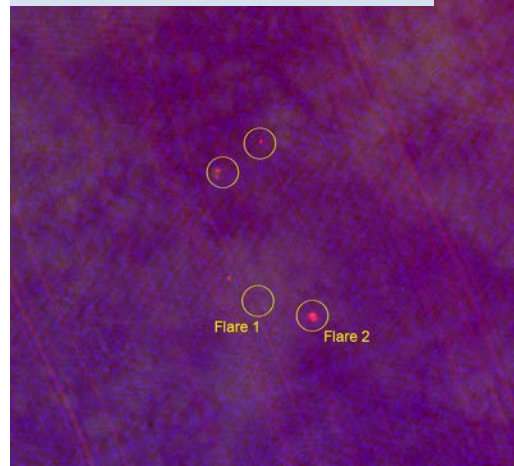
FireBIRD TET-1, 2016-12-29 07:36



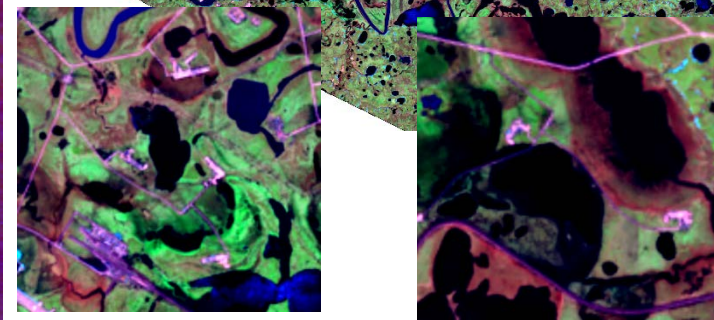
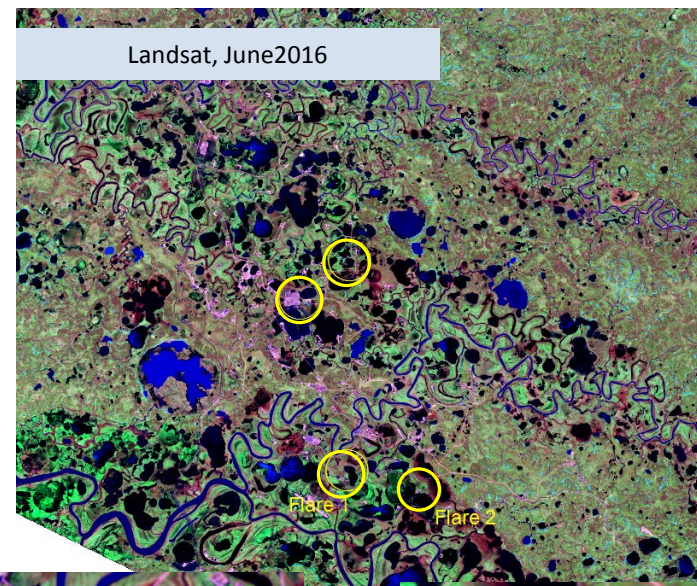
FireBIRD TET-1, 2016-12-22 07:35 *



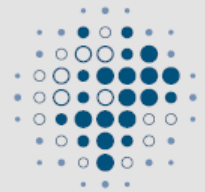
FireBIRD TET-1, 2017-01-02 07:34



Landsat, June 2016



4 overpasses, 2 of which very close to SLSTR overpasses (marked with *).



First results over a flaring region

Goals:

- Analyse statistics over many gas flare detections

ROI known for flaring activity, no a priory knowledge of GF locations considered:

- **North Sea**, data from the Public Hub (17 Nov – 18 Dec, 182 products)

Offshore and onshore

night-time acquisitions of S1-S4

- Thank you to EUMETSAT/ESA for making these!
- analysis not (yet) conclusive
 - indication for possible signal in S4
 - We need better handle on coregistration of S4 vs S5/S6 (vs F1)

radiance comparison to VIIRS over gas flares

- S8/S9 agree within 1%
- (S5-S7 comparison method needs improvements)

new gas flare detection and characterisation algorithm

- finds locations
- L2 compares quantitatively to TET-1 and VIIRS, plus typical temperatures
- benefits strongly from recent L1 reprocessing