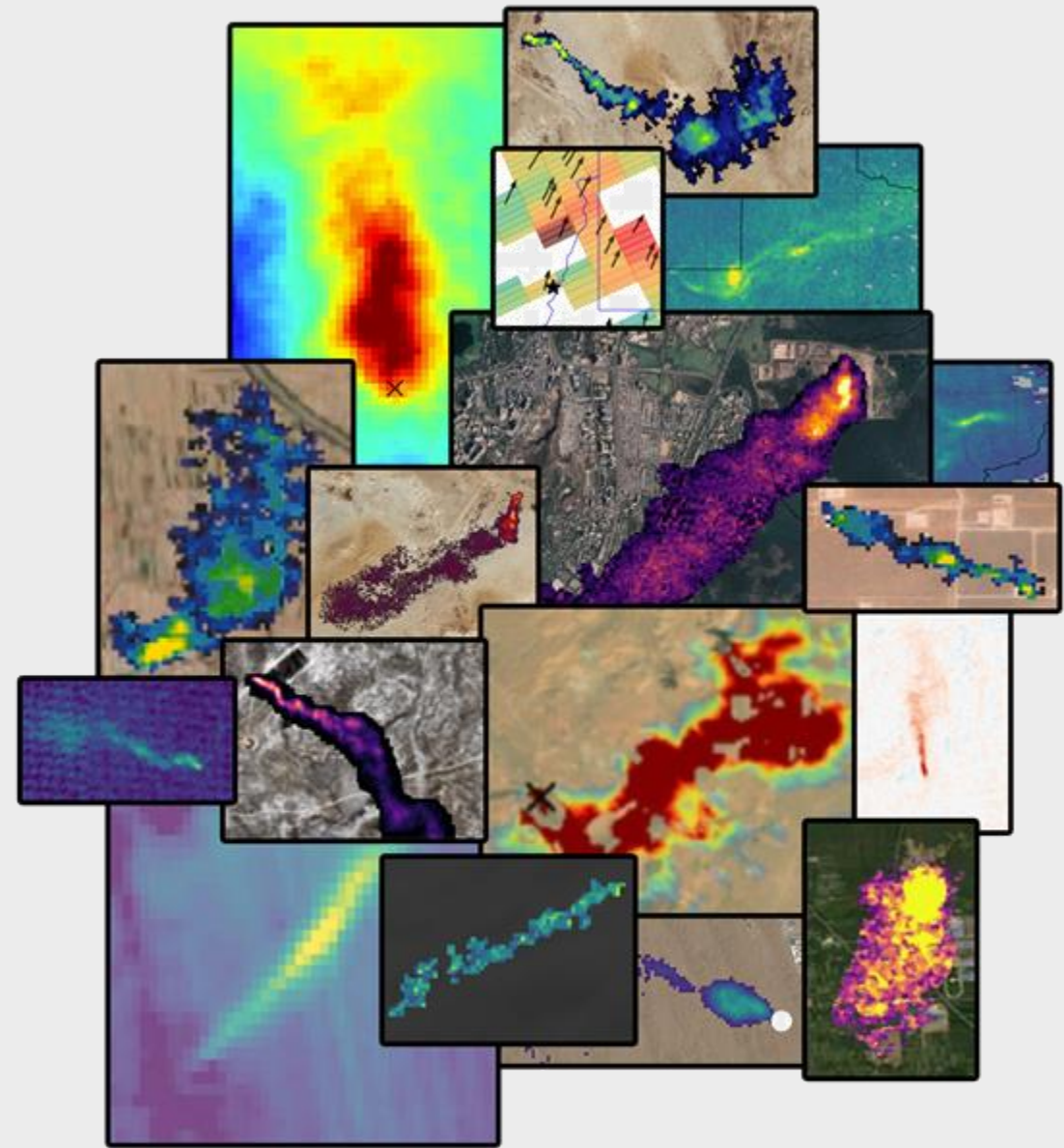


Methane Emissions Detection Using Satellites Assessment

Ilse Aben, SRON Netherlands Institute for Space Research

Start : 10 April 2024 (3 years)



Simon Pinnock, ESA TO MEDUSA



Why is methane so 'hot' ?

- Methane ~30% of global warming
- 30x stronger GHG (than CO₂)
- Lifetime of ~ 10 years
- 25% of emission reduction at no net cost, 55% technically feasible (*Ocko et al., 2021*)



Methane important target short term climate mitigation

Over 150 countries signed the Global Methane Pledge

30%



13%



9%



20%

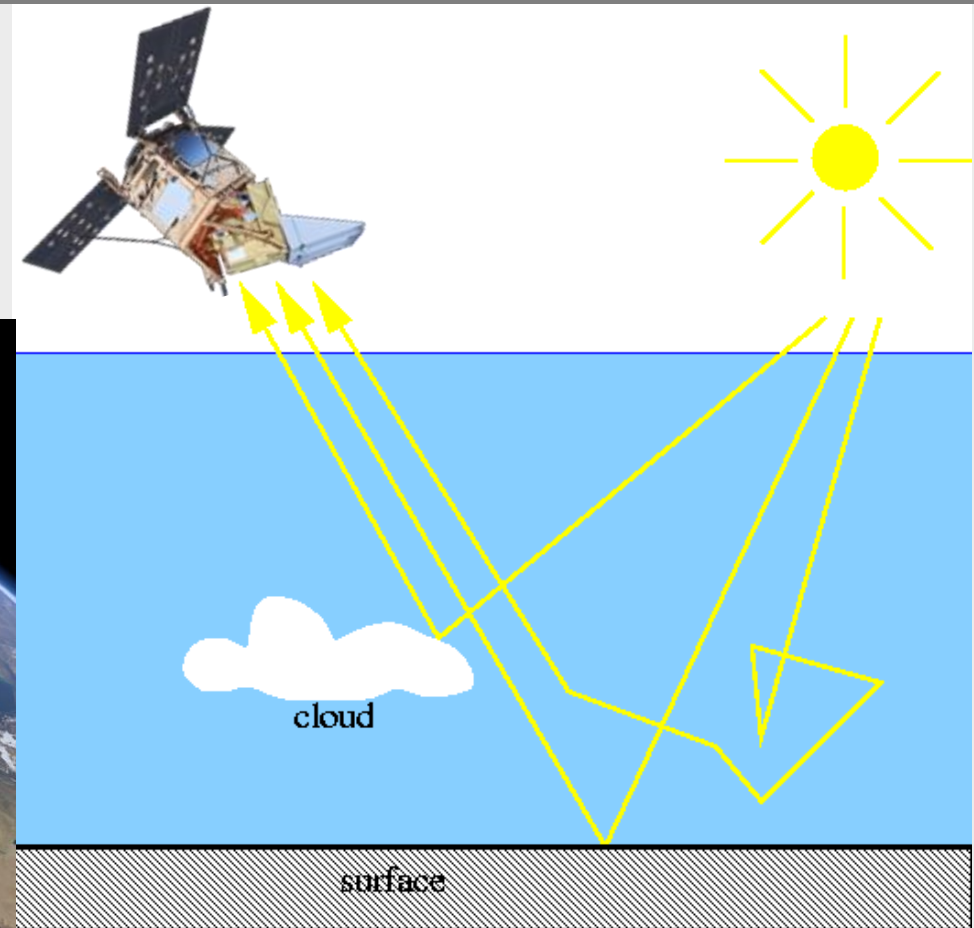
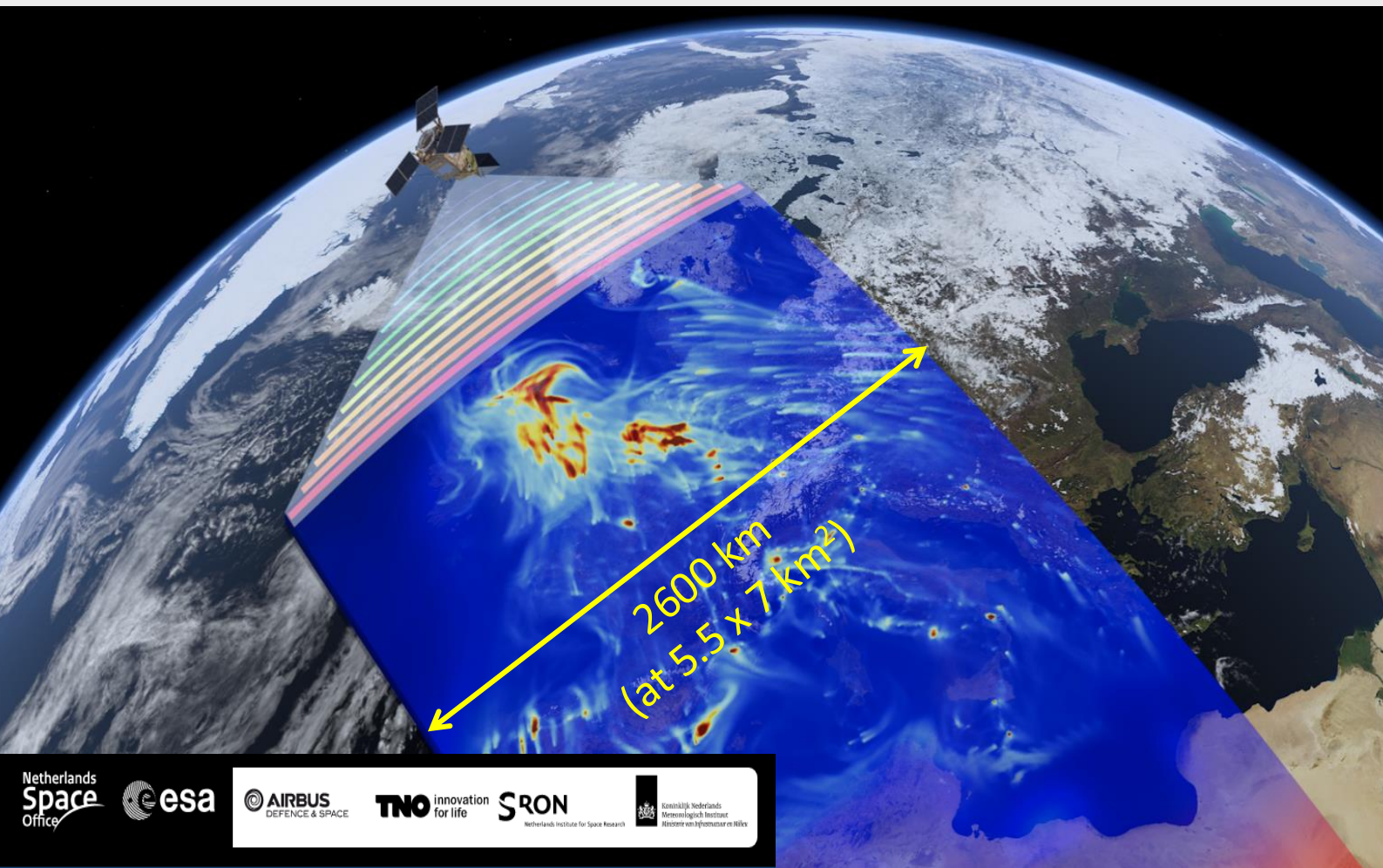


10%



TROPOMI on ESA's Sentinel-5 Precursor

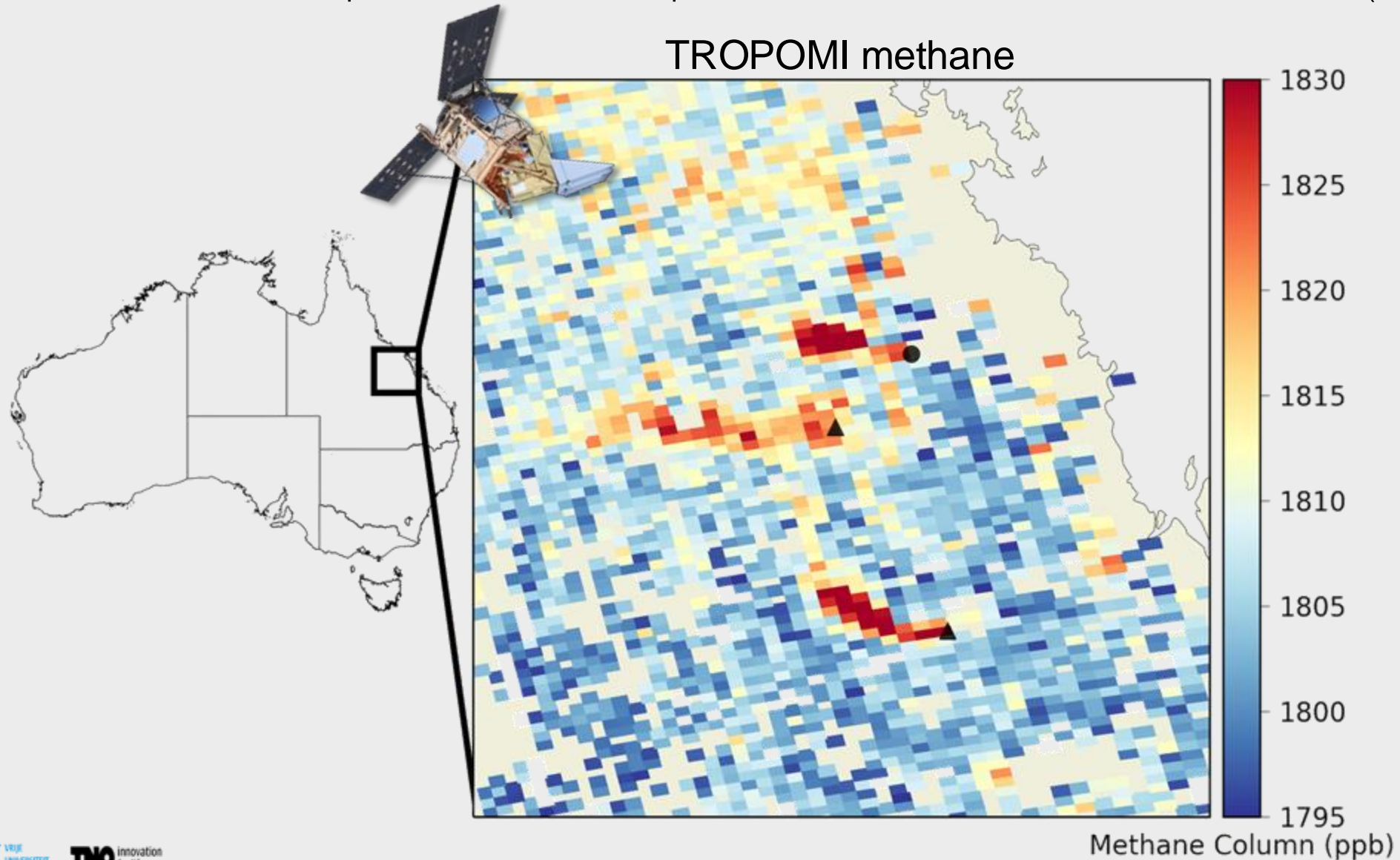
- Collaboration between the Netherlands and ESA
- Launched Oct. 2017, ESA's precursor Sentinel-5
- Part of EU Copernicus programme, data publicly available (free)
- Measures many species : Ozone, NO₂, SO₂, CO, **methane**, ...



- Unique: **daily global coverage** & high spatial resolution (5.5 x 7 km²)
- Ideal for the detection of so-called **methane super emitters**

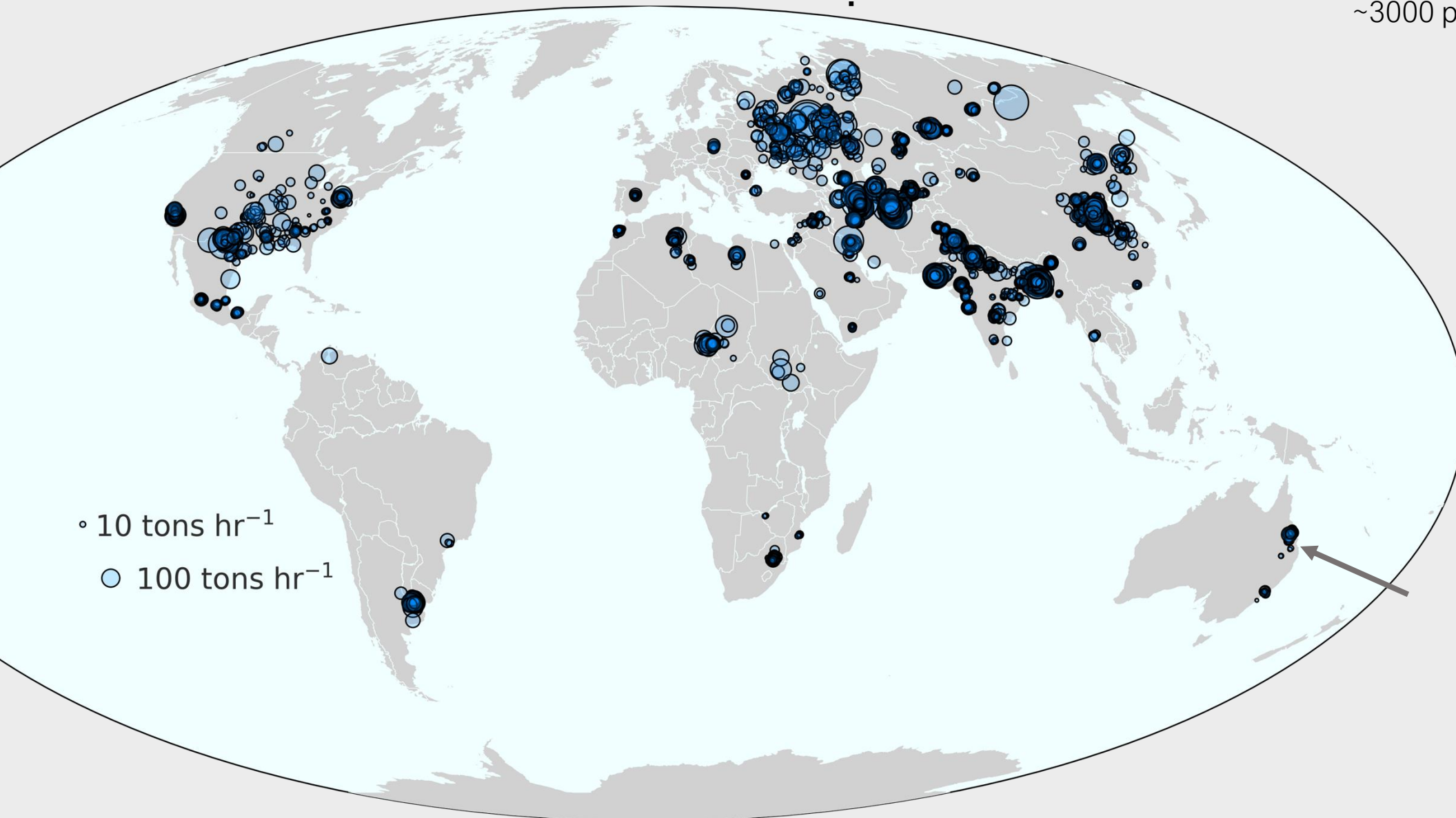
Detecting methane plumes from space, e.g. emissions from coal mines

One surface coal mine: 1% coal production, 24% reported emissions from all Australian coal (**super emitter**)



TROPOMI : 1st global view on super emitters – Machine Learning

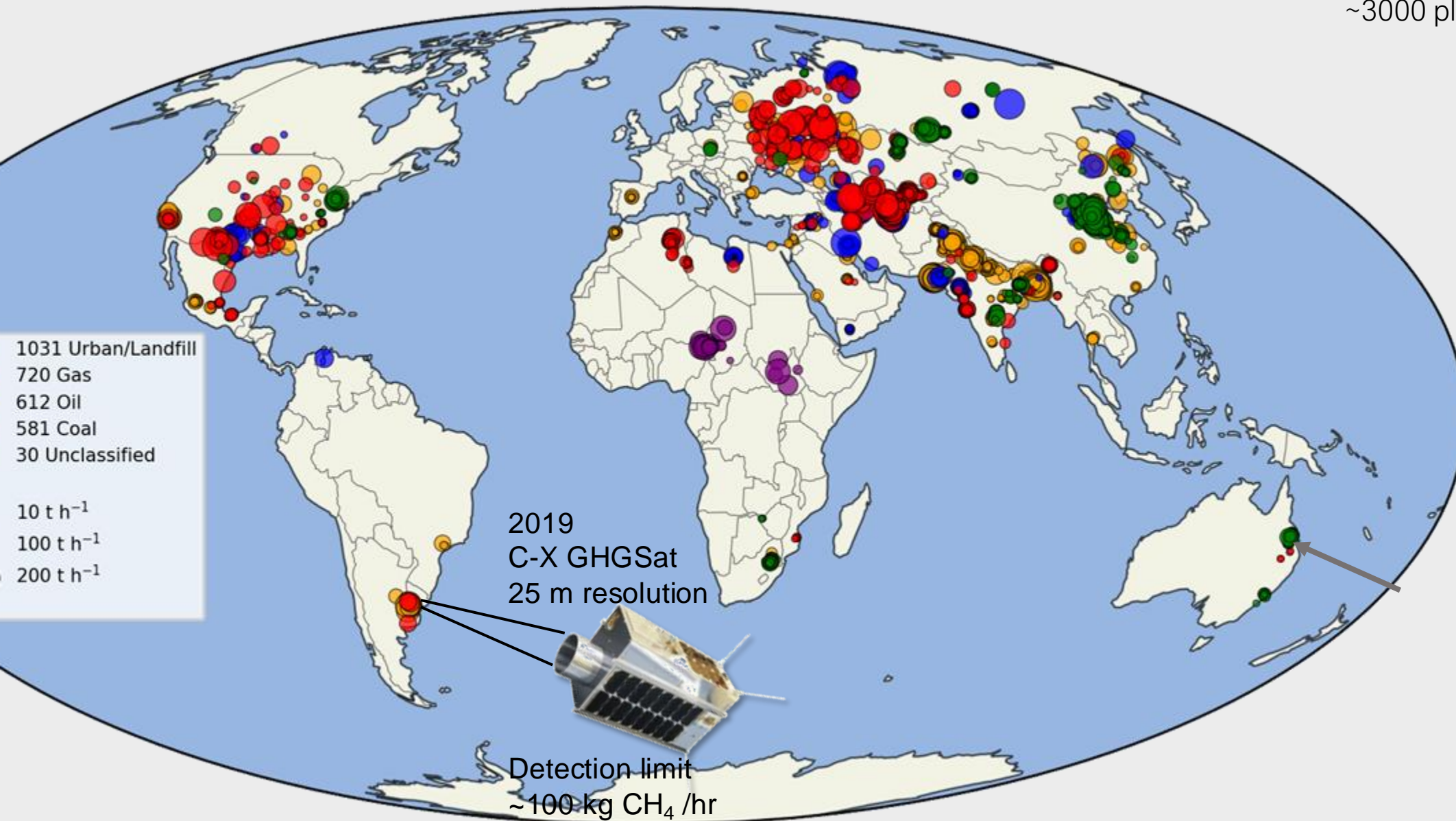
~ few million observations/day
~3000 plumes detected in 2021



TROPOMI : 1st global view on super emitters – Machine Learning

TROPOMI-detected Methane Plumes in 2021

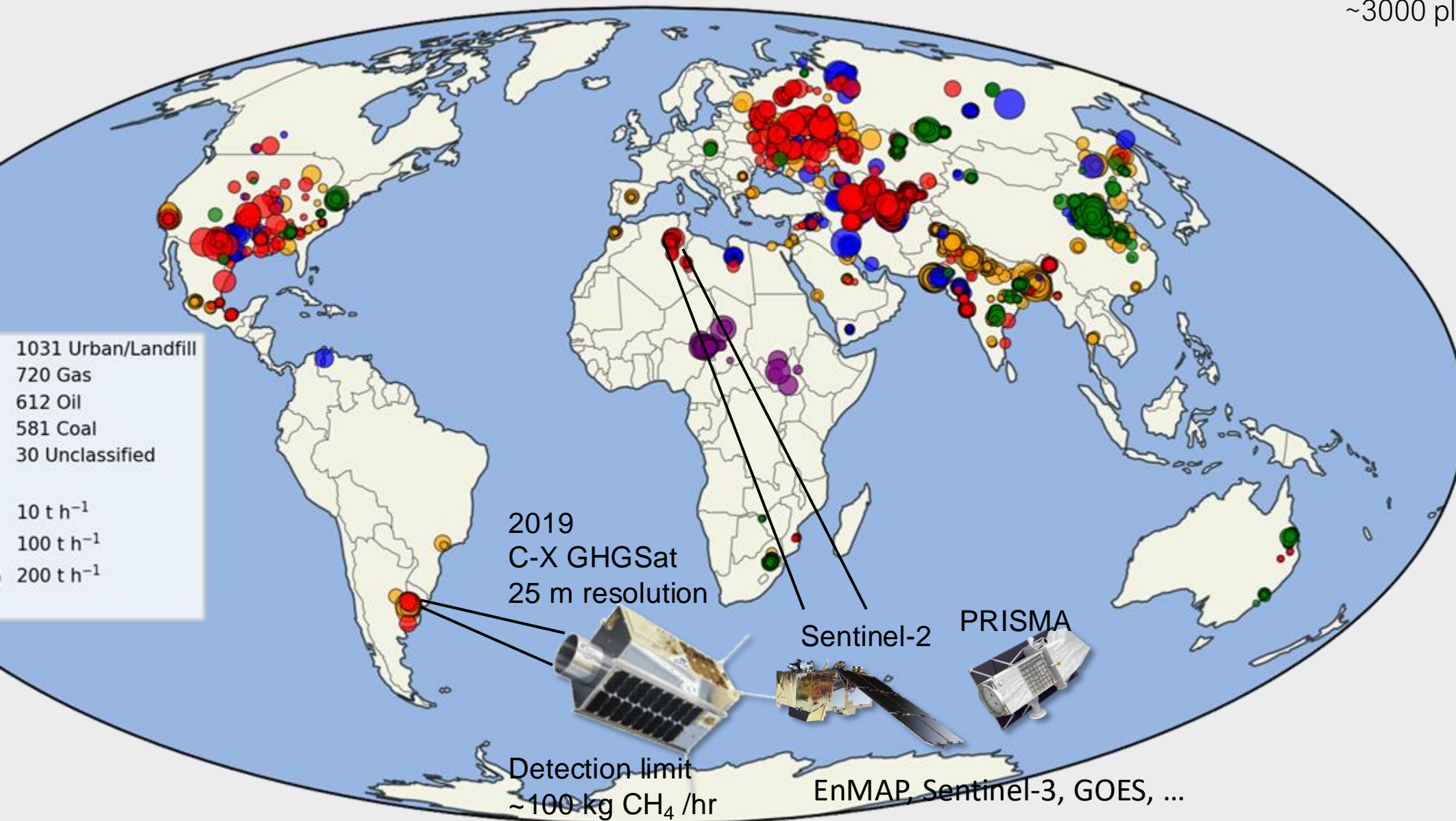
~ few million observations/day
~3000 plumes detected in 2021



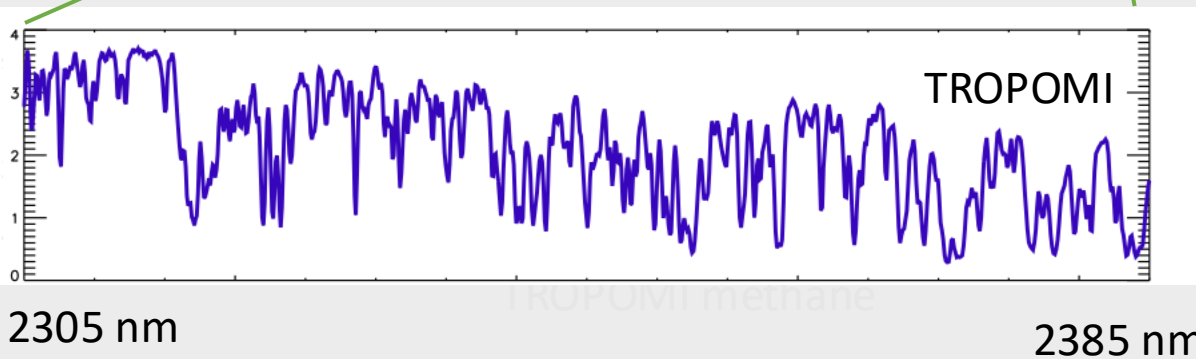
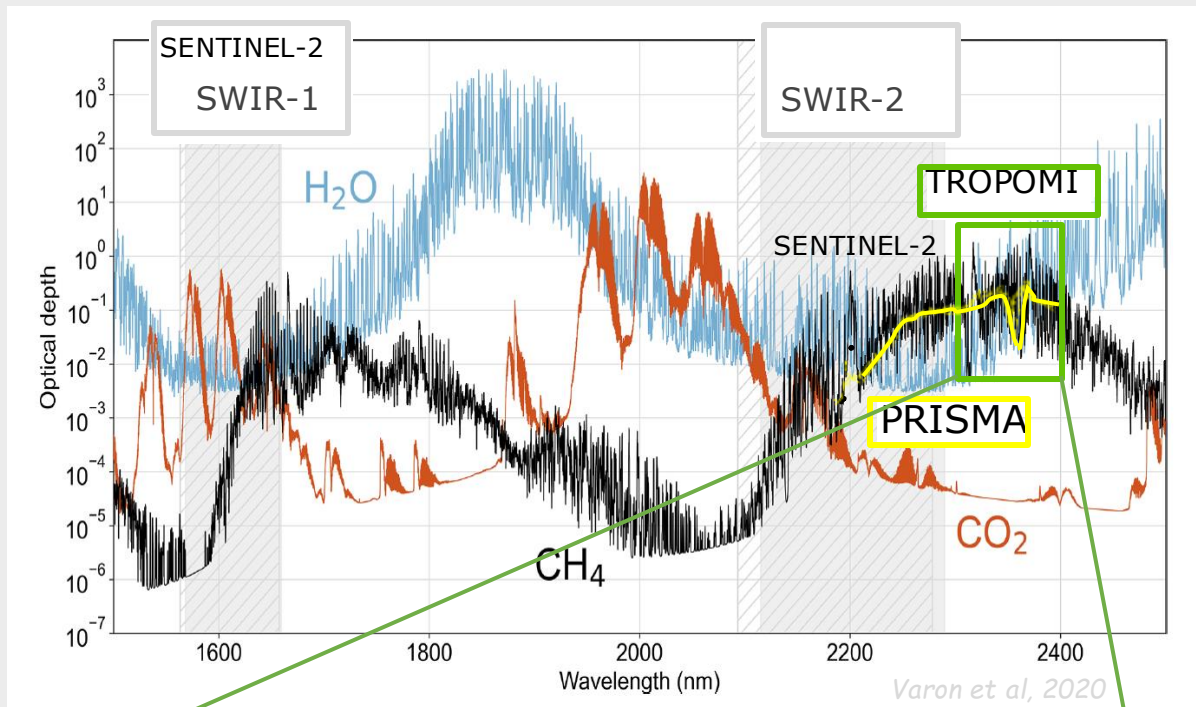
TROPOMI : 1st global view on super emitters – Machine Learning

TROPOMI-detected Methane Plumes in 2021

~ few million observations/day
~3000 plumes detected in 2021



Land imagers : hyperspectral, band spectrometers



TROPOMI high spectral resolution (**0.25 nm**),
medium spatial resolution (**7 x 5.5 km²**)
Daily global coverage

Land imagers :

high spatial resolution **~20-60 m - few hundred meters**
Low spectral resolution (**10 – 200 nm**)

Band imagers ~100 nm :

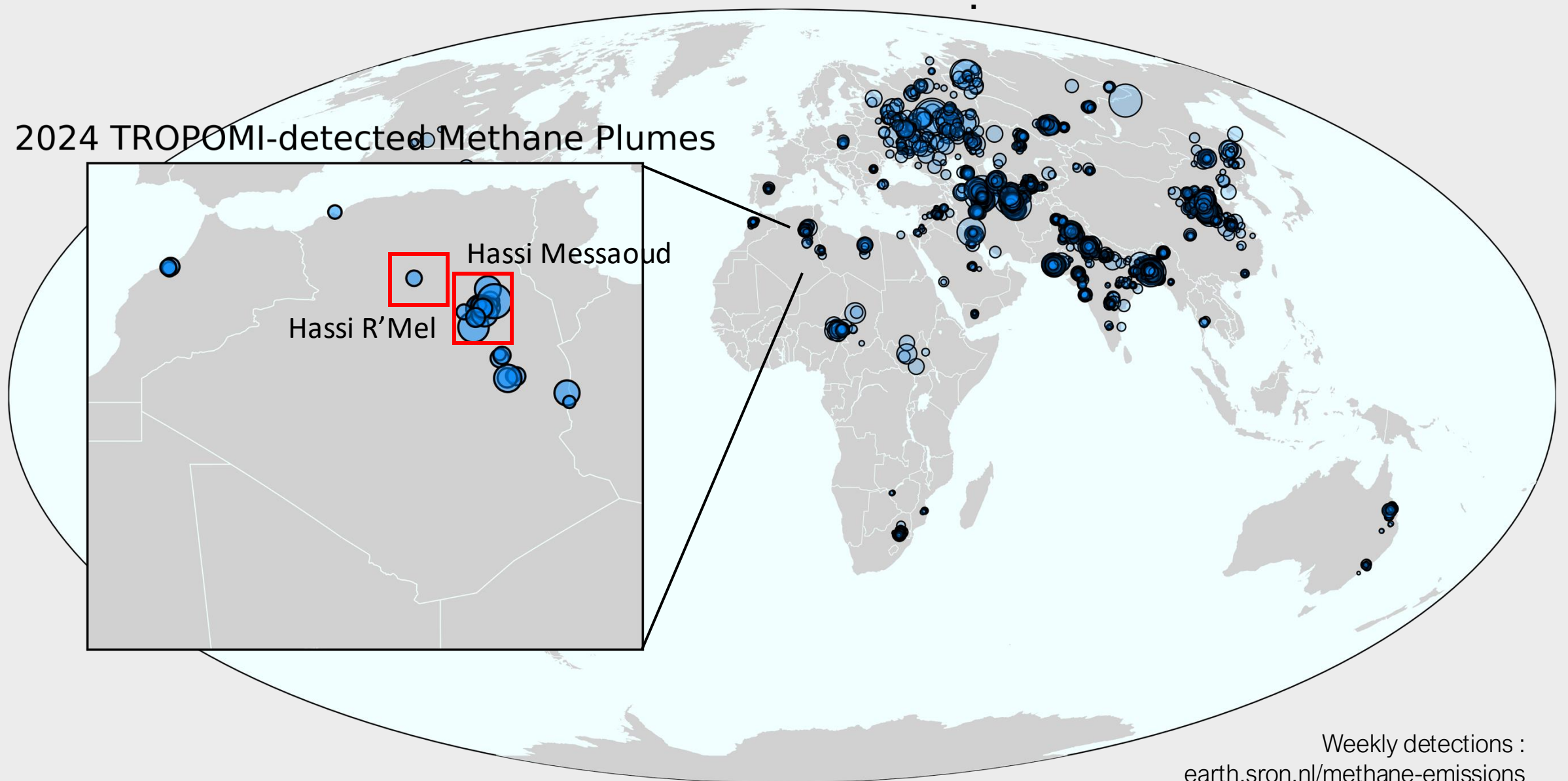
Sentinel-2 (2 sats, global coverage 5 days) 60 m, Landsat, ...
Sentinel-3 (2 sats, daily global), 500 m
VIIRS – 3 satellites (3x daily global) – 750 m

Hyperspectral imagers ~ 10 nm :

PRISMA (30m, 400-2500 nm), EnMAP, EMIT, ...
(**targeted obs.**, 30x30 km²)

Regional emission estimates Algeria

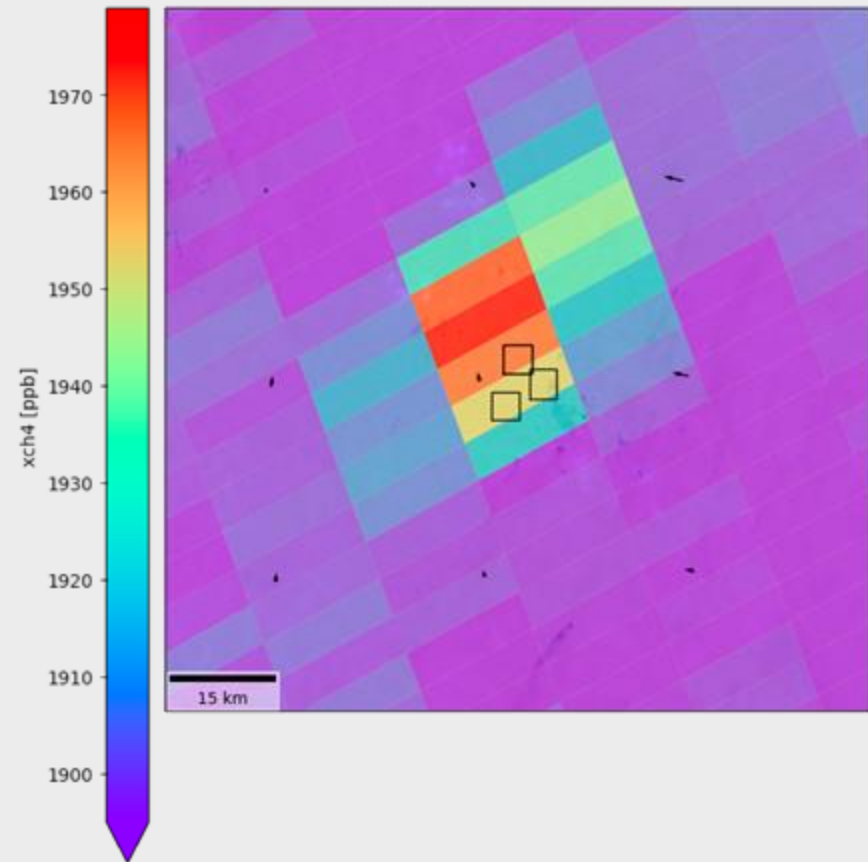
2024 TROPOMI-detected Methane Plumes



Weekly detections :
earth.sron.nl/methane-emissions

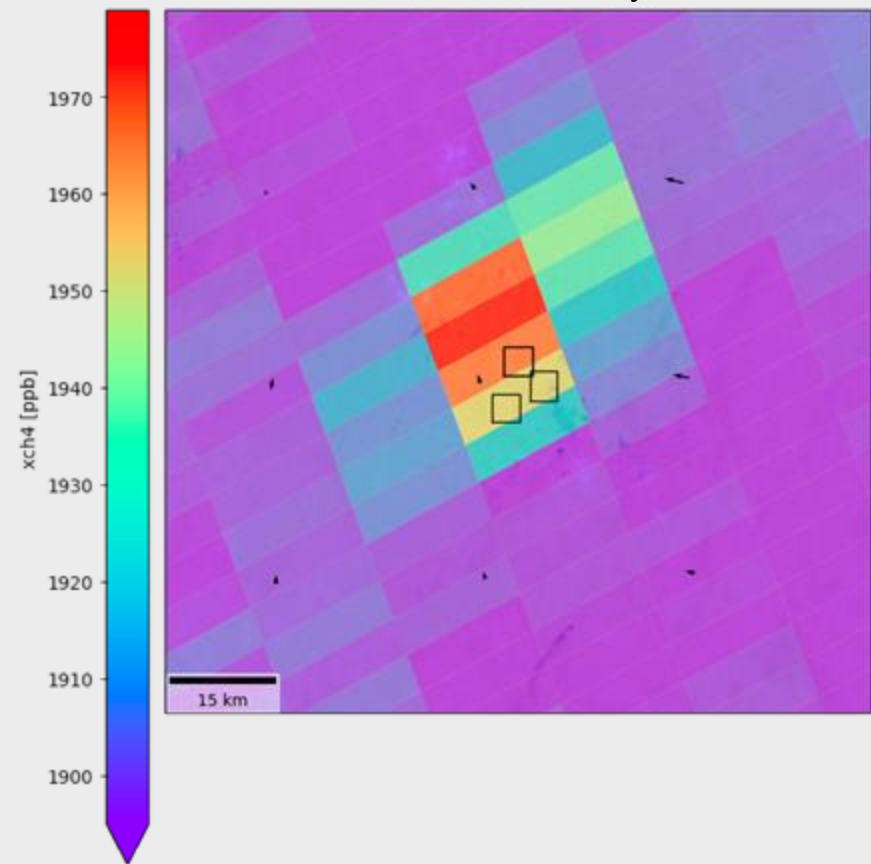
Hassi Messaoud detection on January 28, 2024

TROPOMI on January 28, 2024

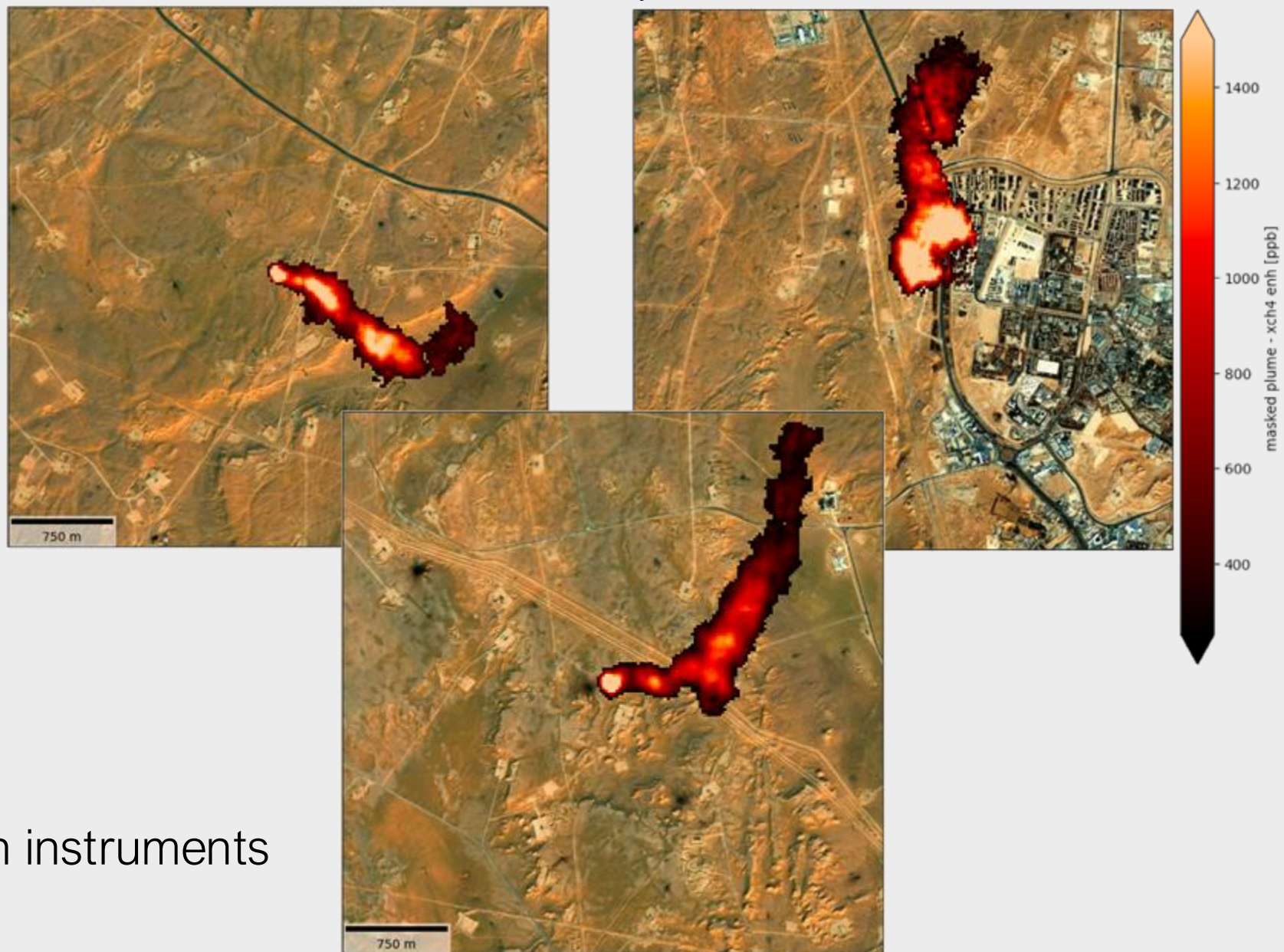


Hassi Messaoud detection on January 28, 2024

TROPOMI on January 28, 2024



Sentinel-2 on January 28, 2024

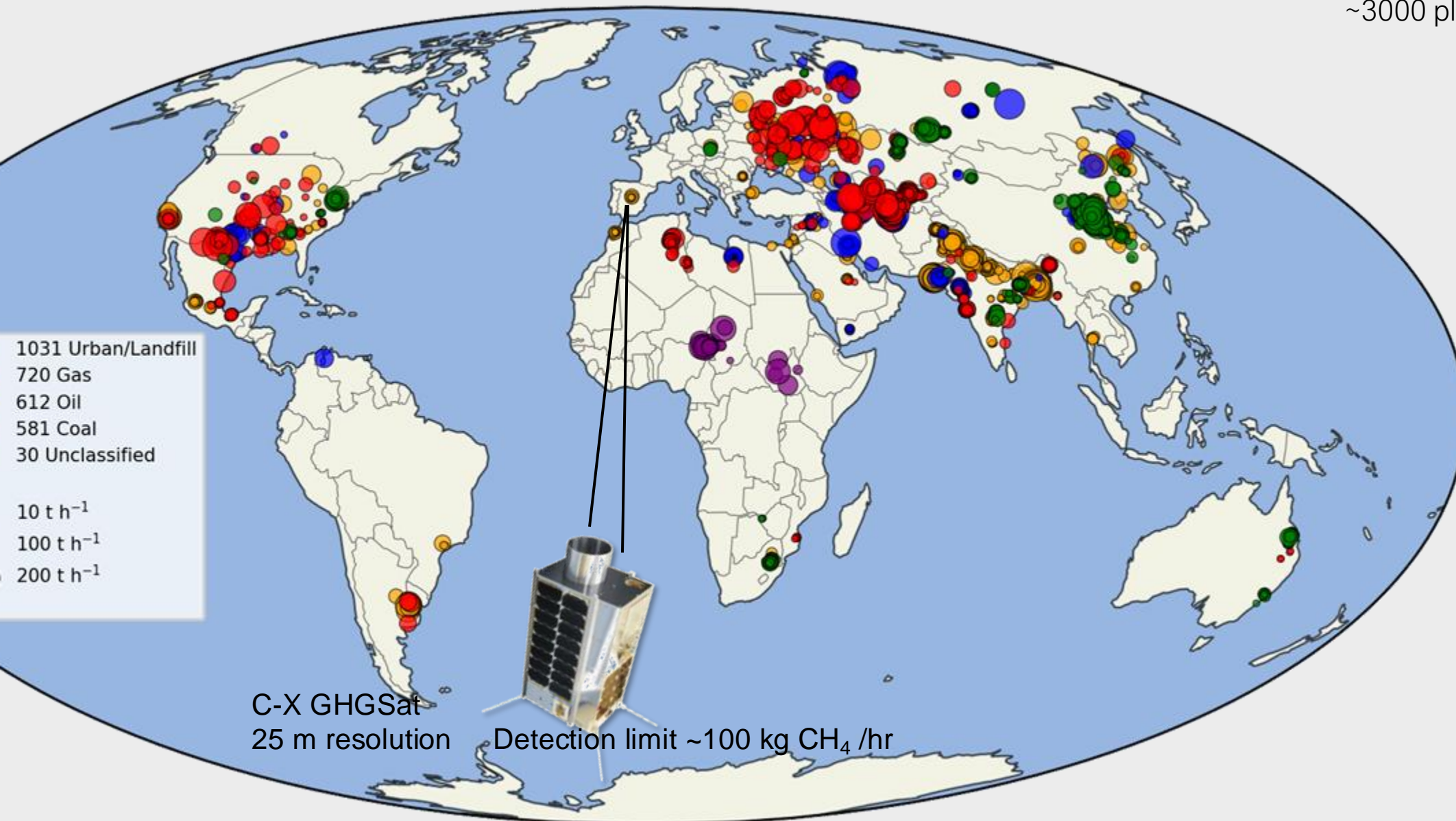


Zooming in with high-resolution instruments allows pinpointing sources

TROPOMI : 1st global view on super emitters – Machine Learning

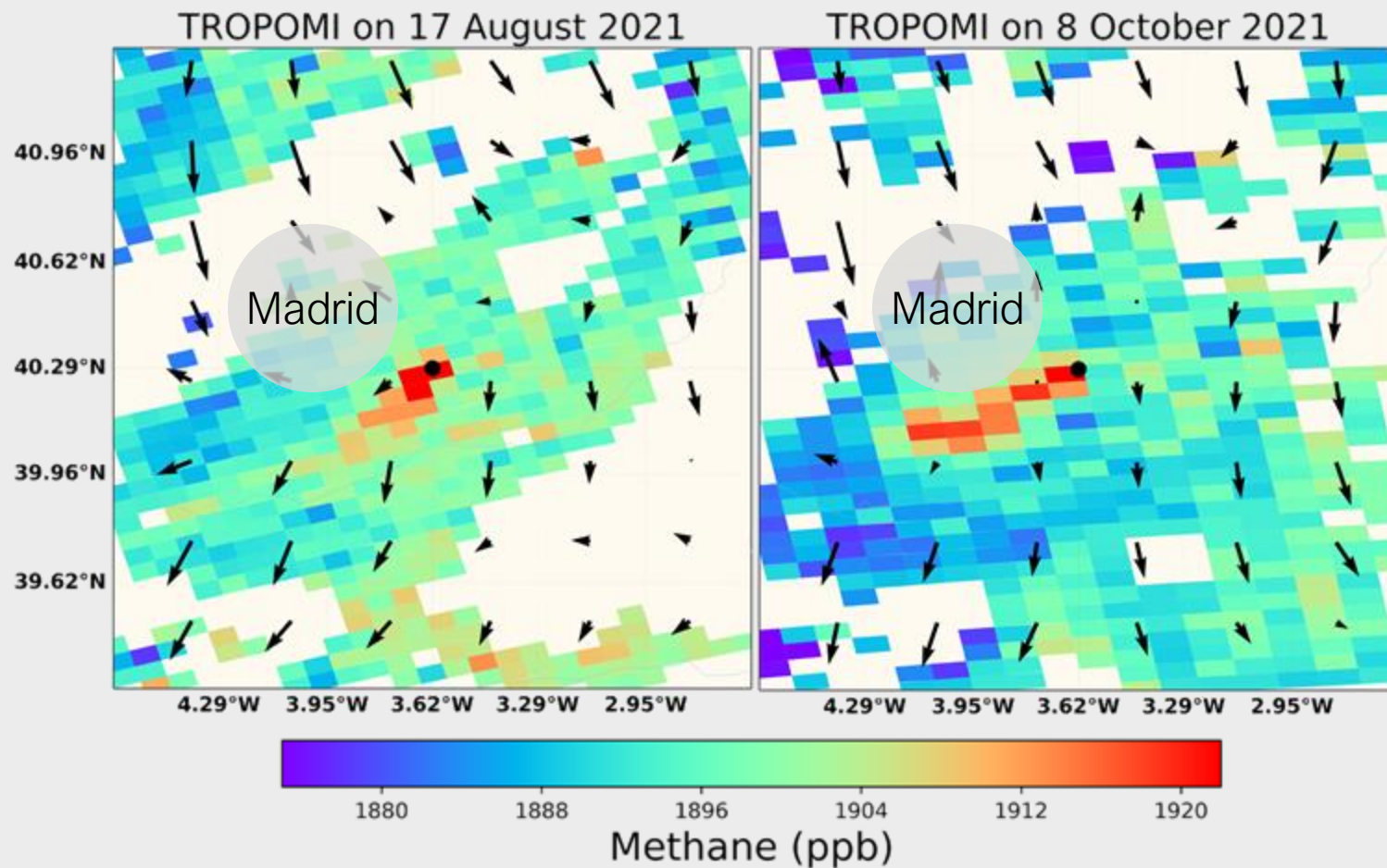
TROPOMI-detected Methane Plumes in 2021

~ few million observations/day
~3000 plumes detected in 2021

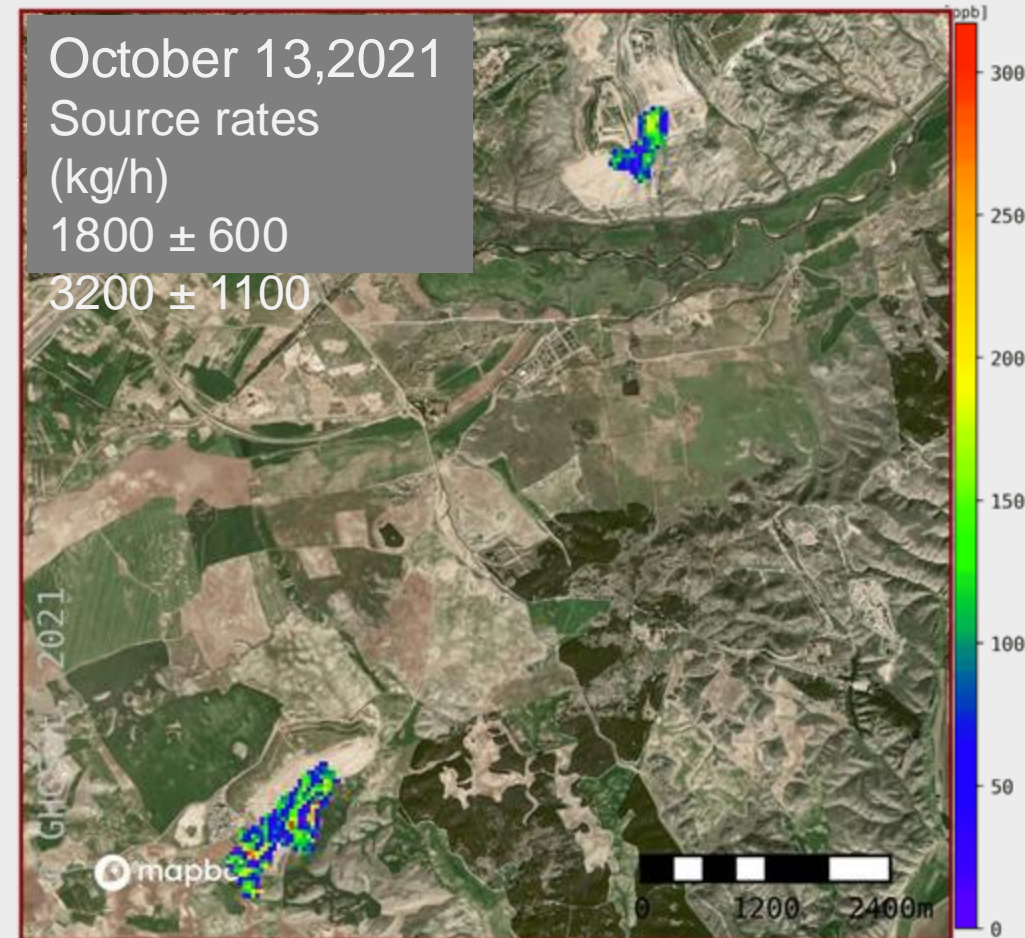


Landfill emissions are also detected in Europe

Guided by long-term TROPOMI data, GHGSat detected large emissions from landfills near Madrid on multiple days in 2021.



**Landfill - Madrid, Spain
CH₄ Concentration Map**



Background Image:
© Mapbox: <https://www.mapbox.com/about/maps>
© OpenStreetMap: <http://www.openstreetmap.org/copyright>
© Maxar: <https://www.maxar.com>

By now have observed methane emissions from 150+ sites

UNEP's IMEO : Methane Alert Response System (MARS)

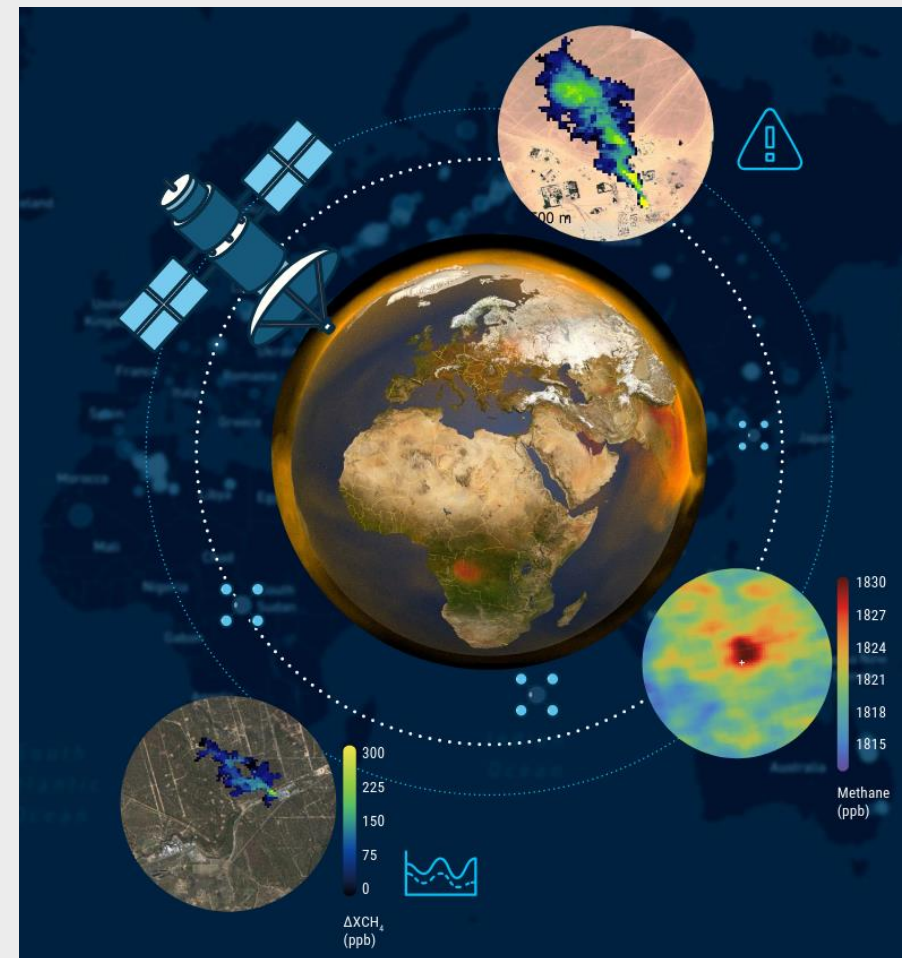
IMEO supports governments and companies to reduce their emissions as agreed in the Methane Pledge



Focus first on Super Emitters Oil & Gas sector

Fully operational since 1 Dec'23 (>400 plume notifications)

<https://www.methanedata.unep.org>



Countries where

2/3 of MARS oil and gas emissions were detected in 2023 now participate with nominated focal points.

MARS now has dedicated focal points representing over

60% of global oil and gas production.



With contributions from :



Overview of satellites observing methane hot spots/plumes

Global flux mappers



Daily global, city-scale res.
~8 t/hr

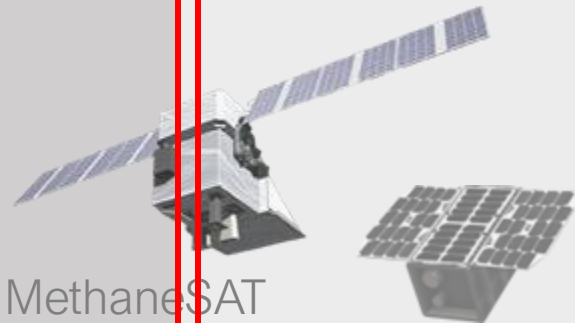
Sentinel-5P
(TROPOMI)



GOSAT-GW



Sentinel-5



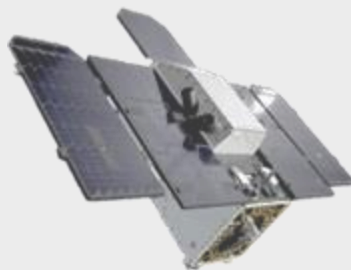
MethaneSAT

Designed for methane

private company
~100 kg/hr



GHGSat



Carbon Mapper

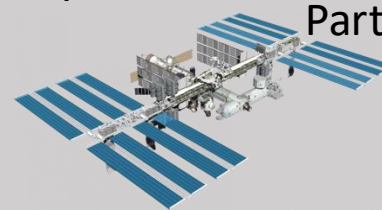


GEISAT, Satlantis
private companies

Point source imagers

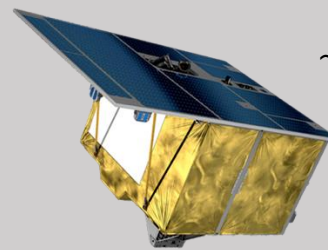
Hyperspectral

Targeting, facility-scale



EMIT/ISS

~1 t/hr



EnMAP



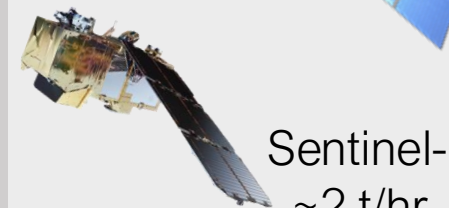
PRISMA

Band Imagers

scientific products
Part of the data



Landsat



Sentinel-2
~2 t/hr

Sentinel-3



GOES
>>10 t/hr

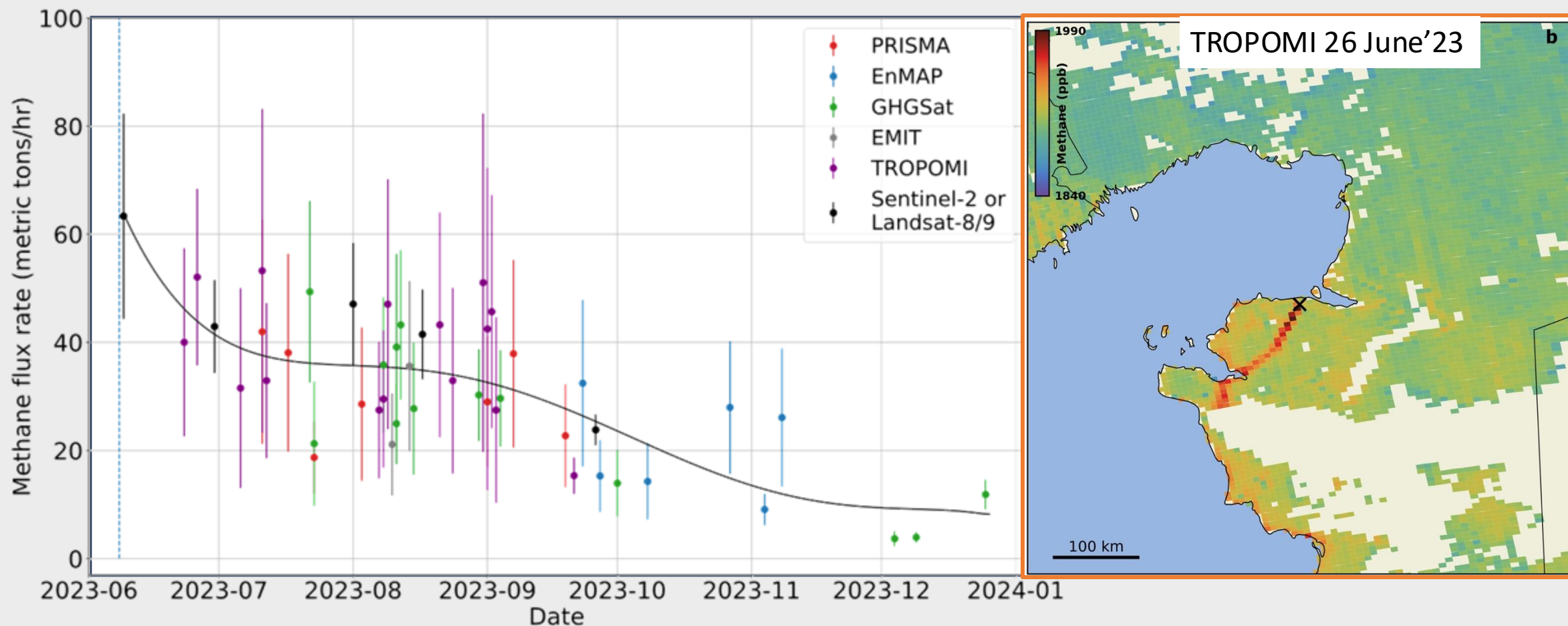


VIIRS

Animation of GHGSat. Absolut sensing

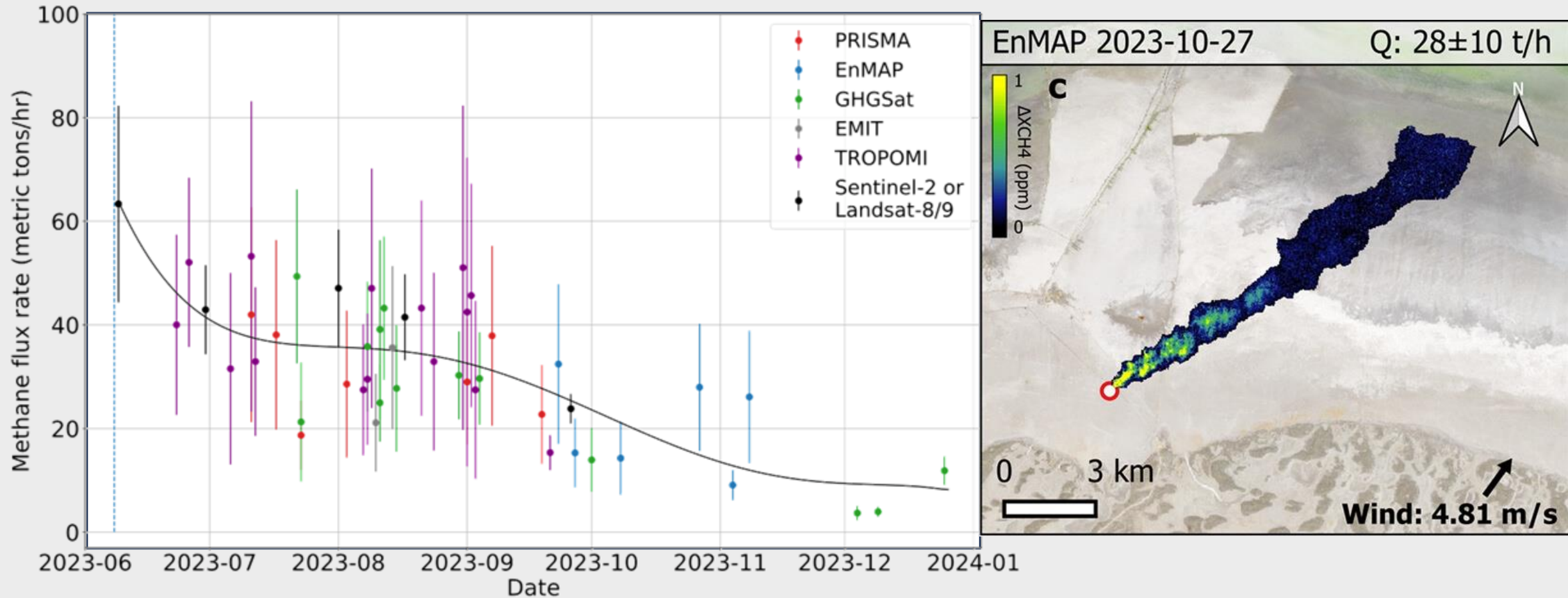
MEDUSA – Objective

‘To develop the techniques and a pre-operational system to harmonize and integrate global information on subnational (urban, hot spot) to facility scale anthropogenic methane emissions derived using diverse satellite instruments and algorithms.’



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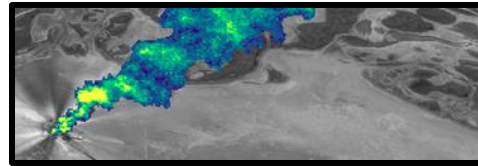


MEDUSA – Setup

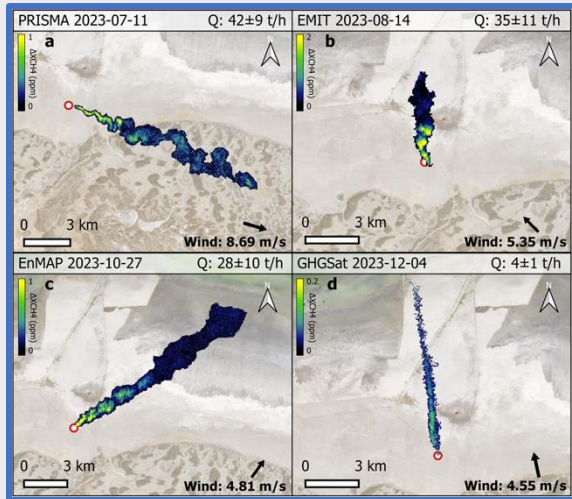
Bloomberg

Scientists Say They've Detected a Huge Methane Leak in Kazakhstan

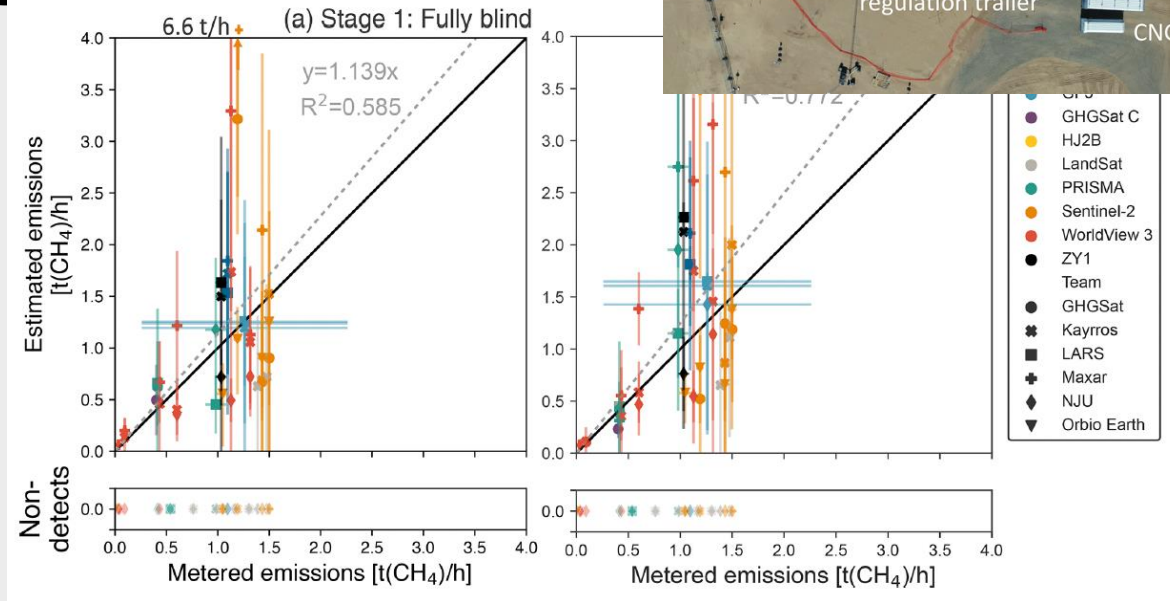
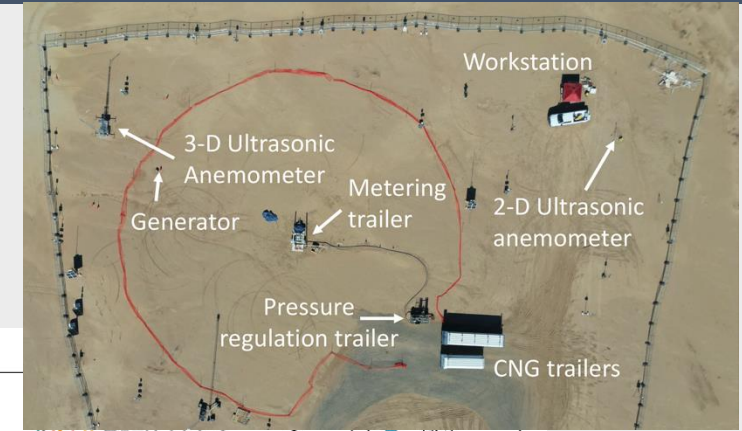
Satellite imagery suggests large-scale release of the potent greenhouse gas, though the company developing the well claims it is mainly hot vapor.



High resolution instruments



Validation of high-resolution imagers against controlled releases (gold standard)



Controlled releases

Sherwin et al. (2024)

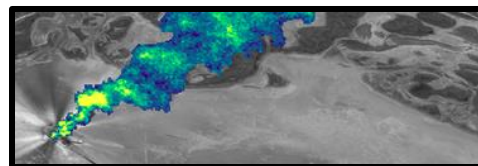
Two in public domain so far. One on-going. Need more and more diverse. Expand by : simulations adding plumes to L1 data; observations of same emissions with same and different satellites

MEDUSA – Setup

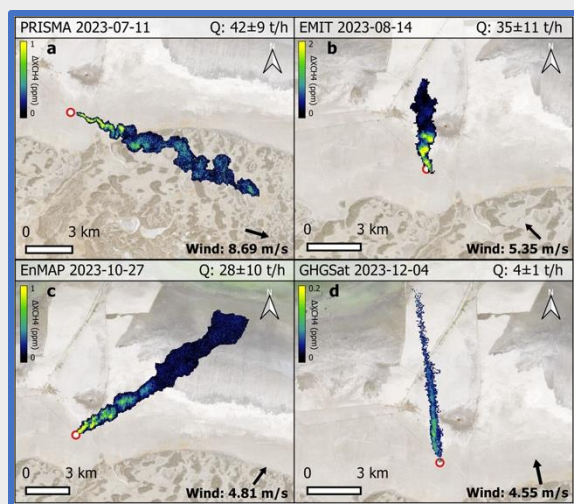
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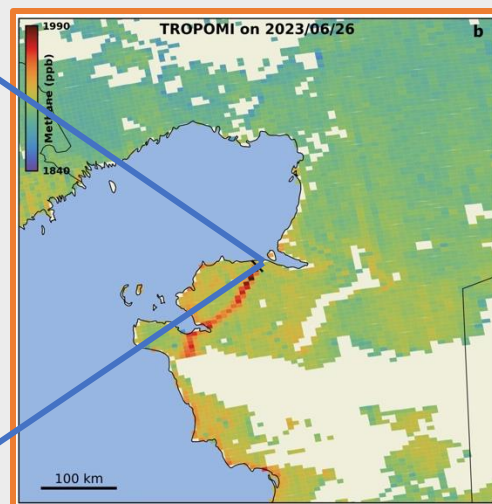
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High resolution instruments



Coarse resolution instruments



Validation of high-resolution imagers against controlled releases (gold standard)

Linking coarse resolution mapper observations on relevant cases

1

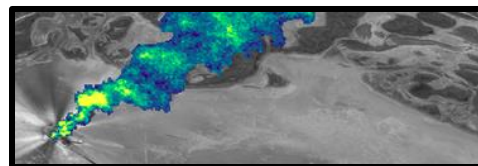
Validation of emission estimates

MEDUSA – Setup

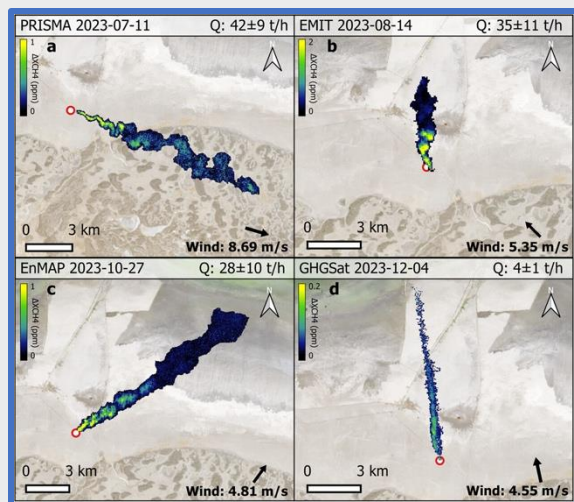
Bloomberg

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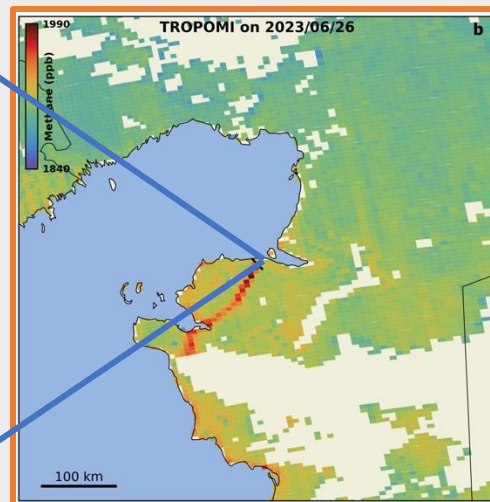
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High resolution instruments



Coarse resolution instruments



Validation of high-resolution imagers against controlled releases (gold standard)

Linking coarse resolution mapper observations on relevant cases

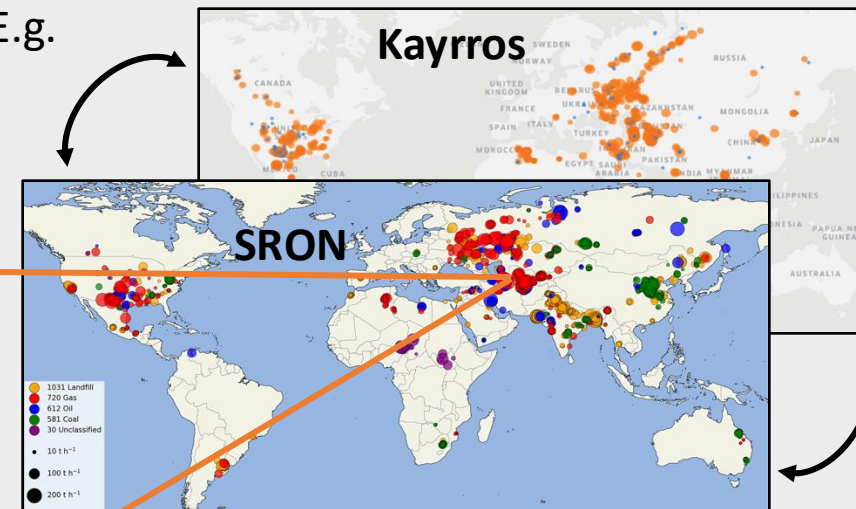
1

Validation of emission estimates

2

Intercomparison of different results from same satellite

E.g.

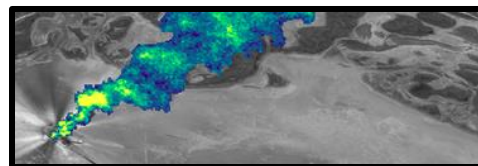


MEDUSA – Setup

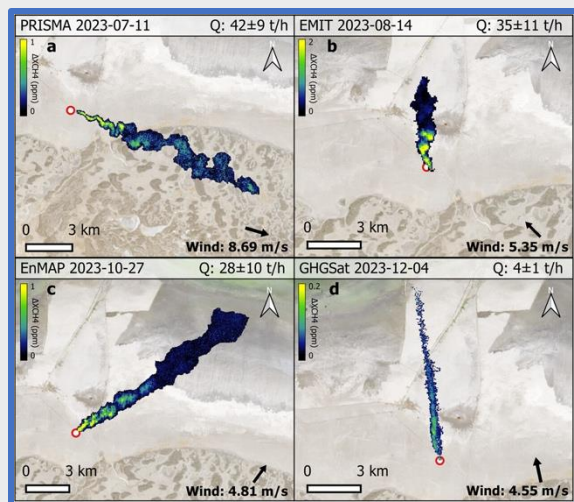
Bloomberg

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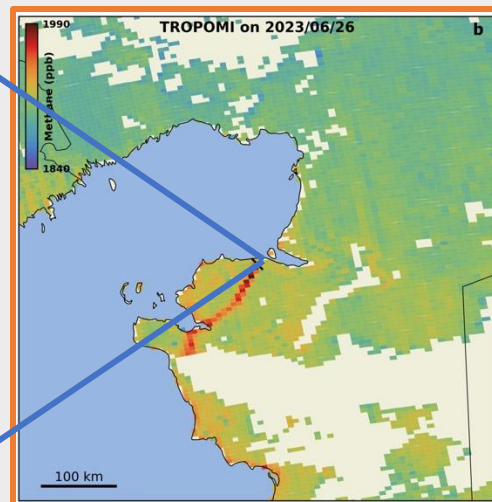
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High resolution instruments



Coarse resolution instruments



Validation of high-resolution imagers against controlled releases (gold standard)

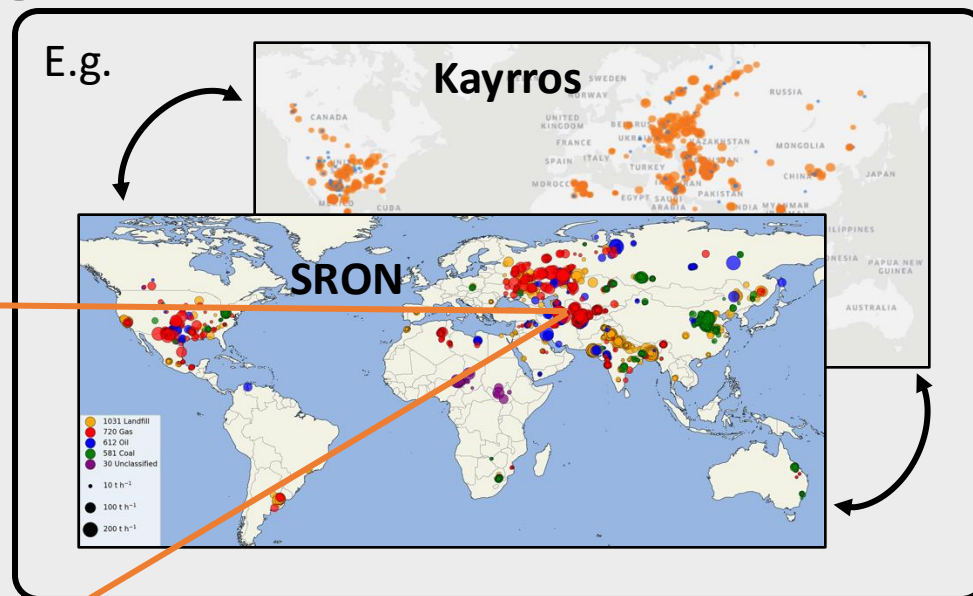
Linking coarse resolution mapper observations on relevant cases

1

Validation of emission estimates

2

Intercomparison of different results from same satellite



3

Uncertainty calculation

Develop common approach/guidelines

4

Integration and case studies

5

High-resolution satellite CO₂ observations

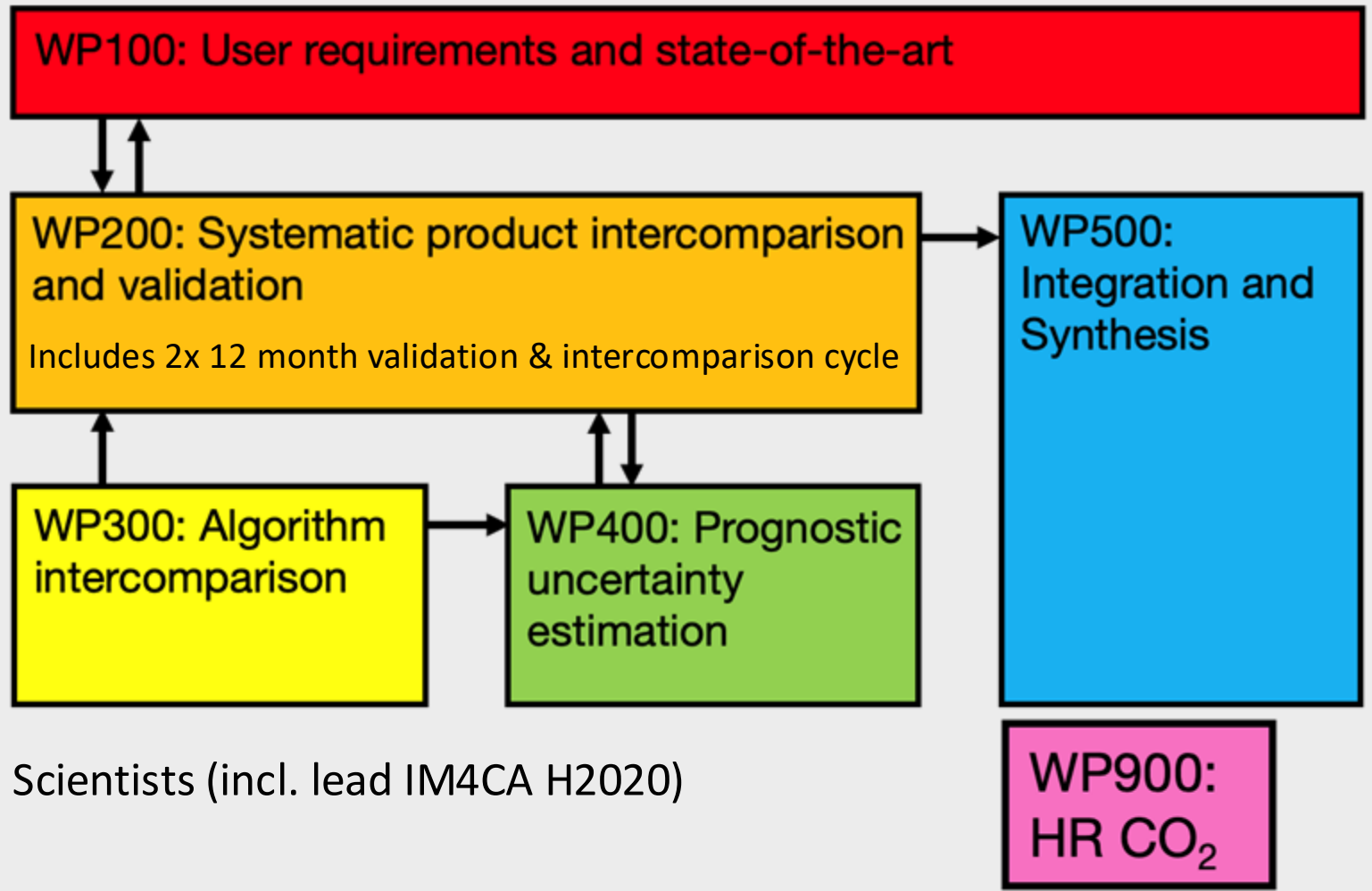
MEDUSA Objective (started 10 April 2024, 3-year project)

‘To develop the techniques and a pre-operational system to harmonize and integrate global information on subnational (urban, hot spot) to facility scale anthropogenic methane emissions derived using diverse satellite instruments and algorithms.’

WP200/300 now starting the validation and intercomparisons

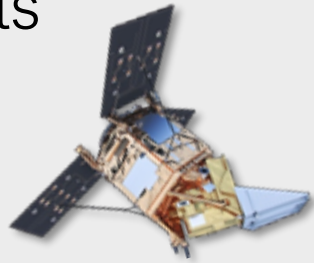
User Group :
IMEO MARS, CAMS, IEA, WMO IG3IS, TNO

Adv. Board :
EC DC Energy, IMEO MARS, ESA/CEOS, NPL, Scientists (incl. lead IM4CA H2020)



MEDUSA – Covered instruments

Covered instruments



| Instrument type | Instrument / Satellite |
|---|--|
| Flux Mappers | TROPOMI/S5P |
| | <i>Sentinel-5</i> |
| | <i>GOSAT-GW</i> |
| Hyperspectral Imagers | PRISMA |
| | EnMAP |
| | EMIT |
| Band Imagers | Landsat 8 |
| | Sentinel-2 |
| | GOES |
| | Sentinel-3 |
| | <i>MTG</i> |
| Methane-specific | GHGSat |
| | <i>Potentially: Absolute Sensing & Satlantis</i> |
| Methane-specific instruments (Publicly available L4) | <i>Carbon Mapper</i> |
| | <i>MethaneSAT</i> |

Future data products in gray

Summary

- Field of methane observations from space wrt hot spots/plumes has seen a true revolution over the past 5 years (huge support to action to mitigate emissions, e.g. basis IMEO MARS)
- multiple satellites (>10) not designed to measure methane are able to detect the largest methane super emitters under favorable conditions
- MEDUSA is an important project to assess the quality of the many different methane hot spot emission products through intercomparisons and validation (where possible), and develop a framework/guidelines to assess uncertainties
- In addition we will illustrate the combined use of data from various satellites through use cases (such as leak-detection and repair at Madrid landfills)