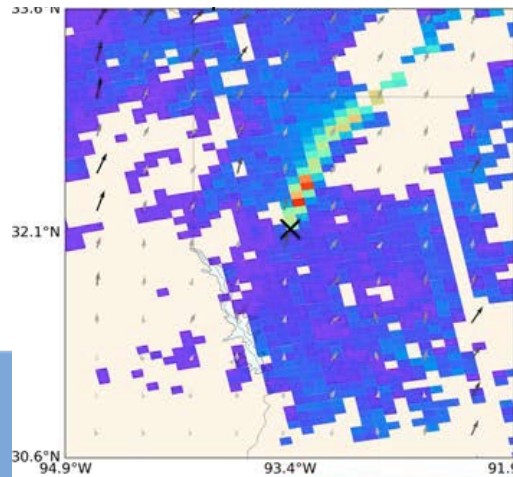


# Satellite observations : Methane is 'hot'

How satellite observations can support emission reductions

*Ilse Aben + SRON TROPOMI-team and collaborators*

*i.aben@sron.nl*



The methane hunters

Using satellites to spot industry's methane leaks

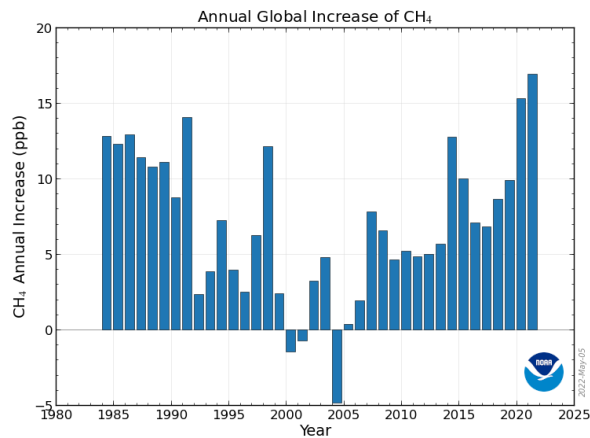
To help combat climate change



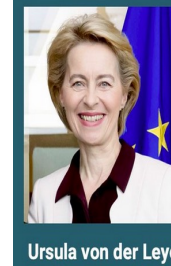
# Why is methane so 'hot' ?

- Methane ~30% of global warming
- 34x stronger GHG than CO<sub>2</sub>
- 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



Methane showed record growth in 2020, 2021



Ursula von der Leyen  
President, European Commission

"Methane is one of the most dangerous gases for our climate. We urgently need to reduce methane emissions to keep our climate targets in reach."

Better satellite monitoring is essential and the EU is proud to support the creation of the International Methane Emissions Observatory."



**COP27**  
SHARM EL-SHEIKH  
EGYPT 2022



Natural : 1/3



24%



12%

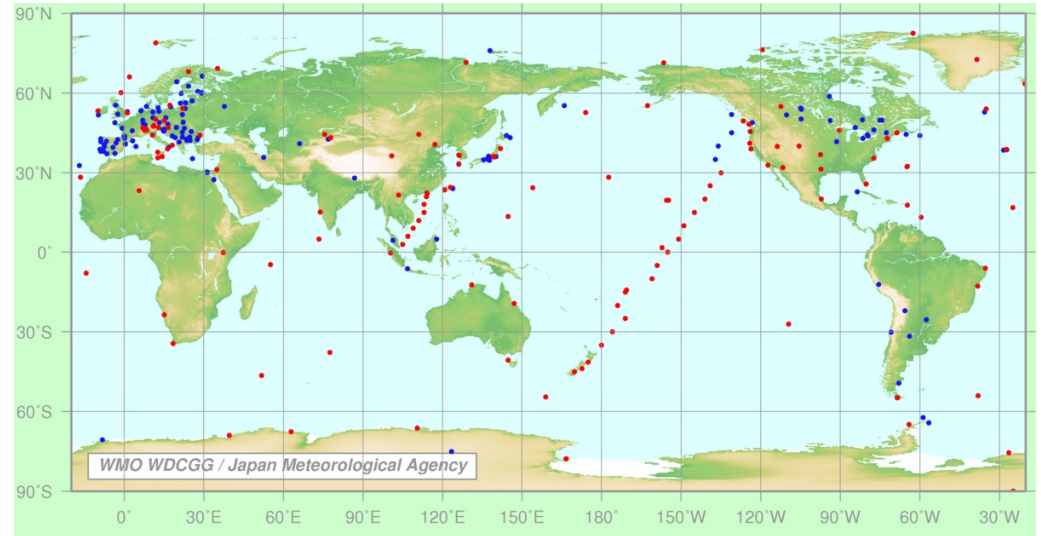
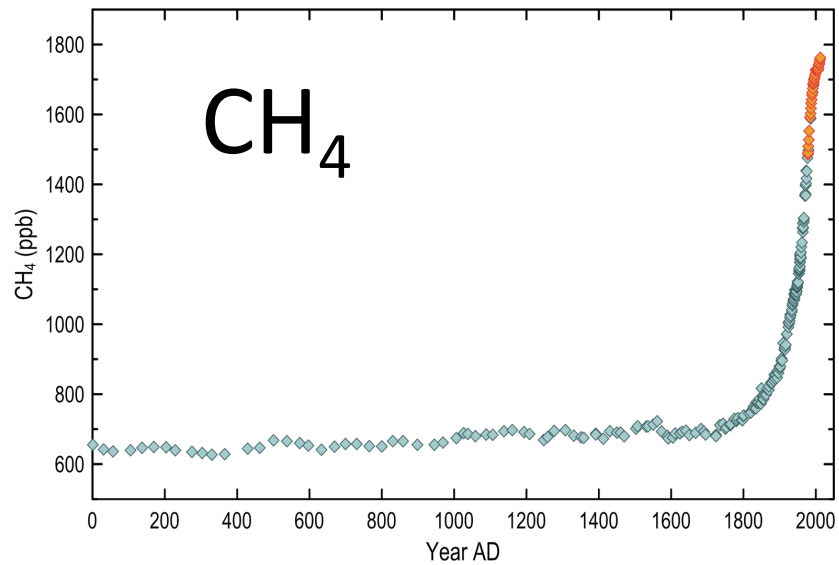


30%



18%



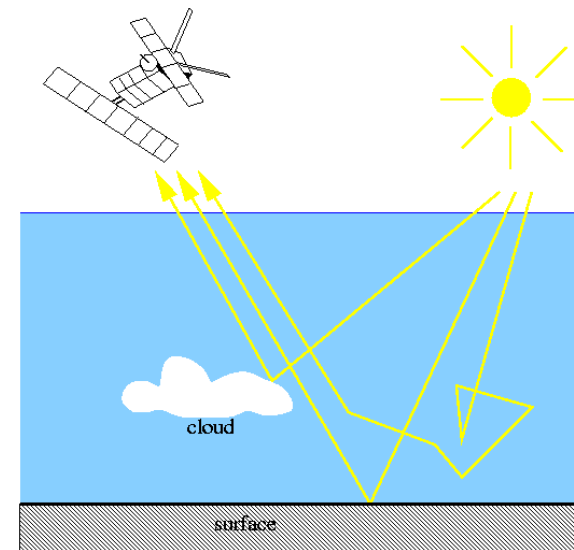
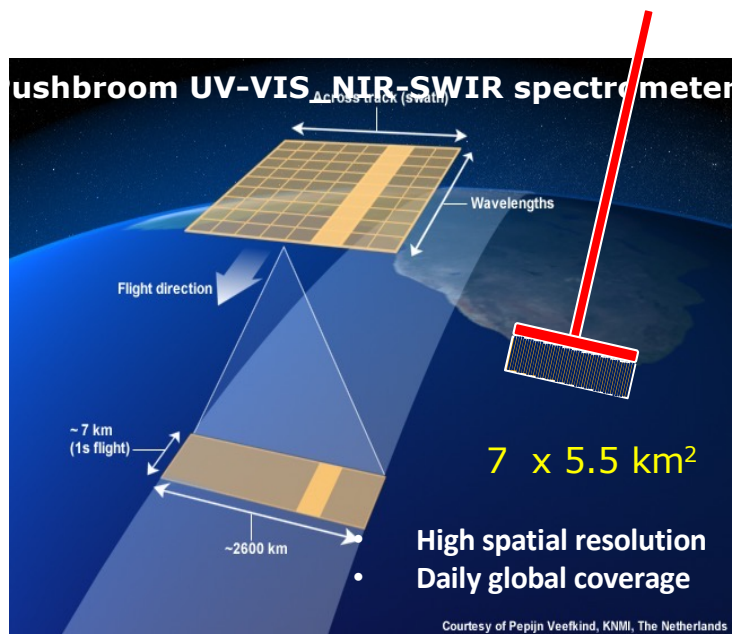


CH<sub>4</sub> increased by > 150% since pre-industrial

Some areas limited/no coverage

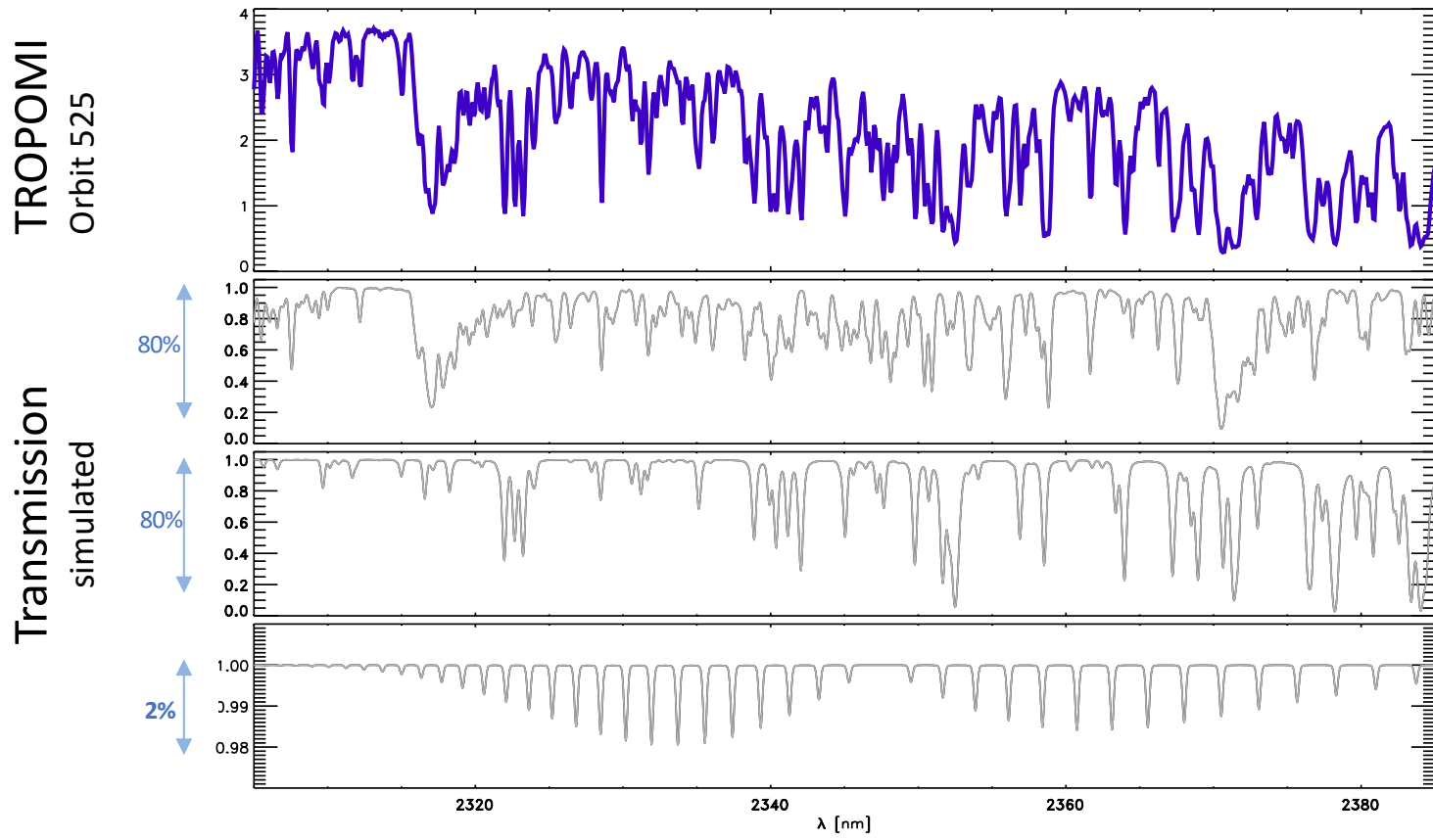
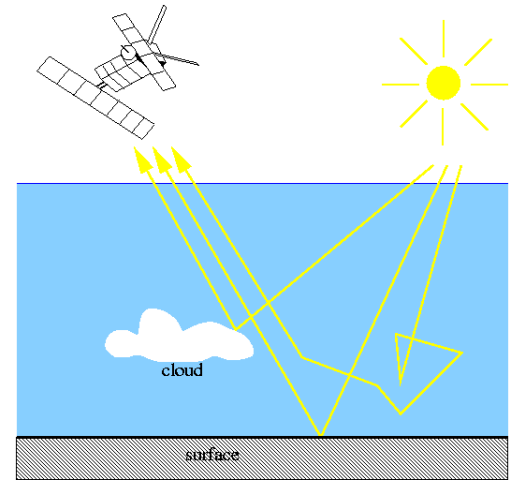
# TROPOMI on Sentinel-5 precursor : game changer

- Launched in Oct. 2017, EU Copernicus programme
- Collaboration between the Netherlands and ESA
- Measuring many atmospheric species ( $O_3$ ,  $CO$ ,  $NO_2$ ,  $SO_2$ , incl.  $CH_4$  – total columns), data freely available within 3 hours ( $CH_4$  2 days)
- **Unique** capability : daily global coverage &  $7 \times 5.5 \text{ km}^2$  individual observations
- Precursor to Sentinel-5 (2024 – 2044+)





# TROPOMI SWIR spectrum



methane

water  
HDO/H<sub>2</sub>O

carbonmonoxide

2305 nm

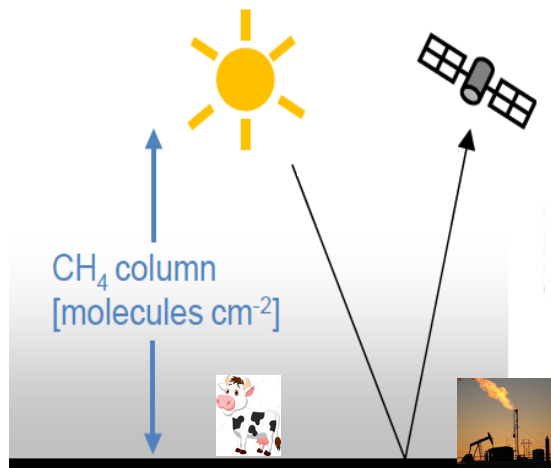
2385 nm

# Satellite observations of methane

Where are the large methane emissions ?  
→ Satellites can help

Satellites complementary to surface network

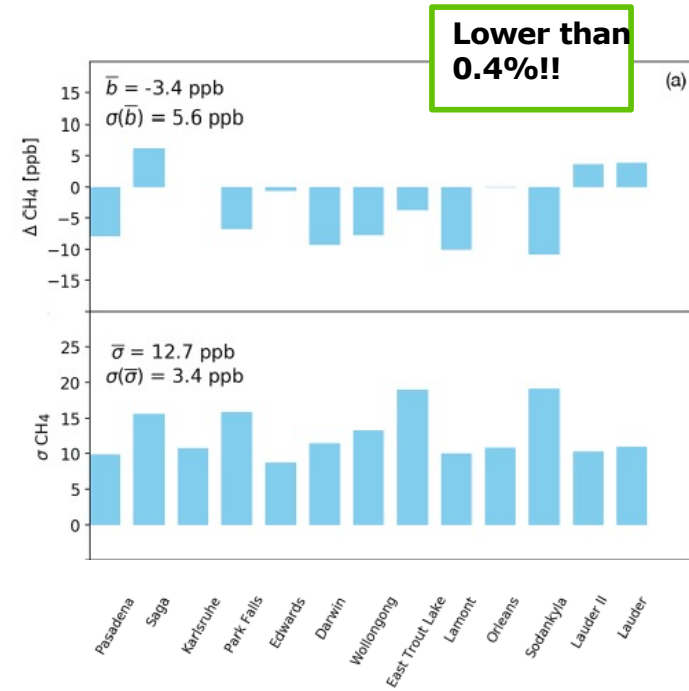
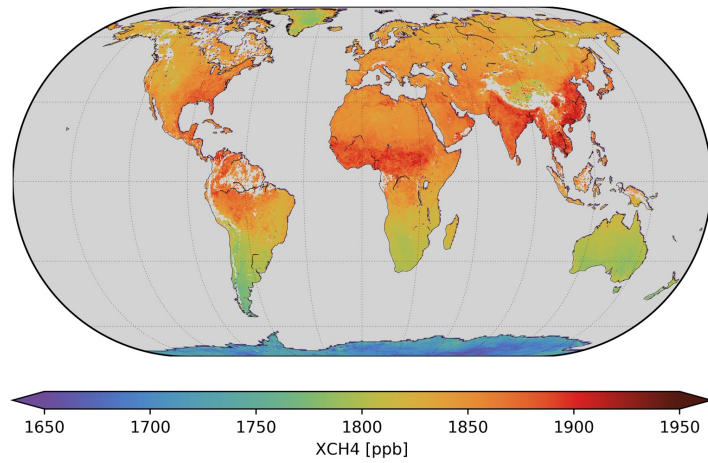
- Global
- challenging



Source gives **very small gradient**  
in concentration field total columns.

→ o.a. cloud-free (few % data used)

# TROPOMI L2: Methane (CH<sub>4</sub>) data product

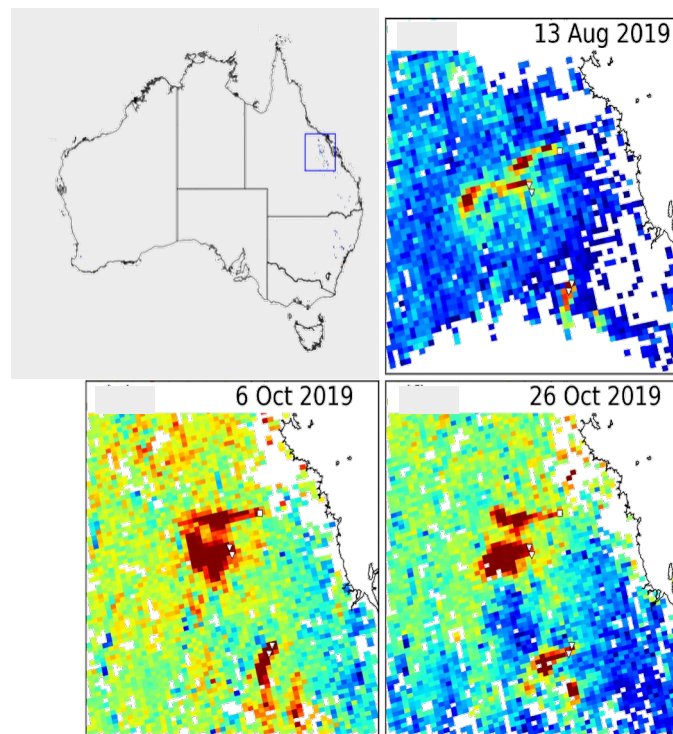


Validation TCCON stations

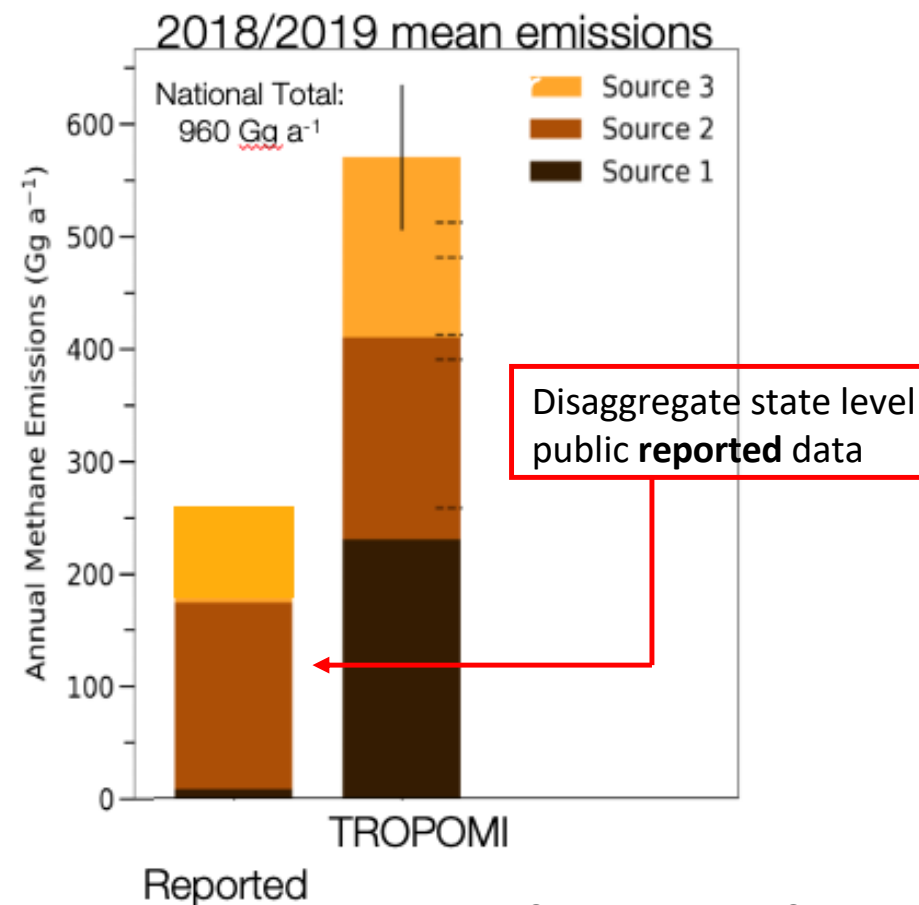


*Lorente et al., 2021*

# TROPOMI detects super emitting coal mines Australia



TROPOMI methane



*Sadavarte et al., ES&T, 2021*

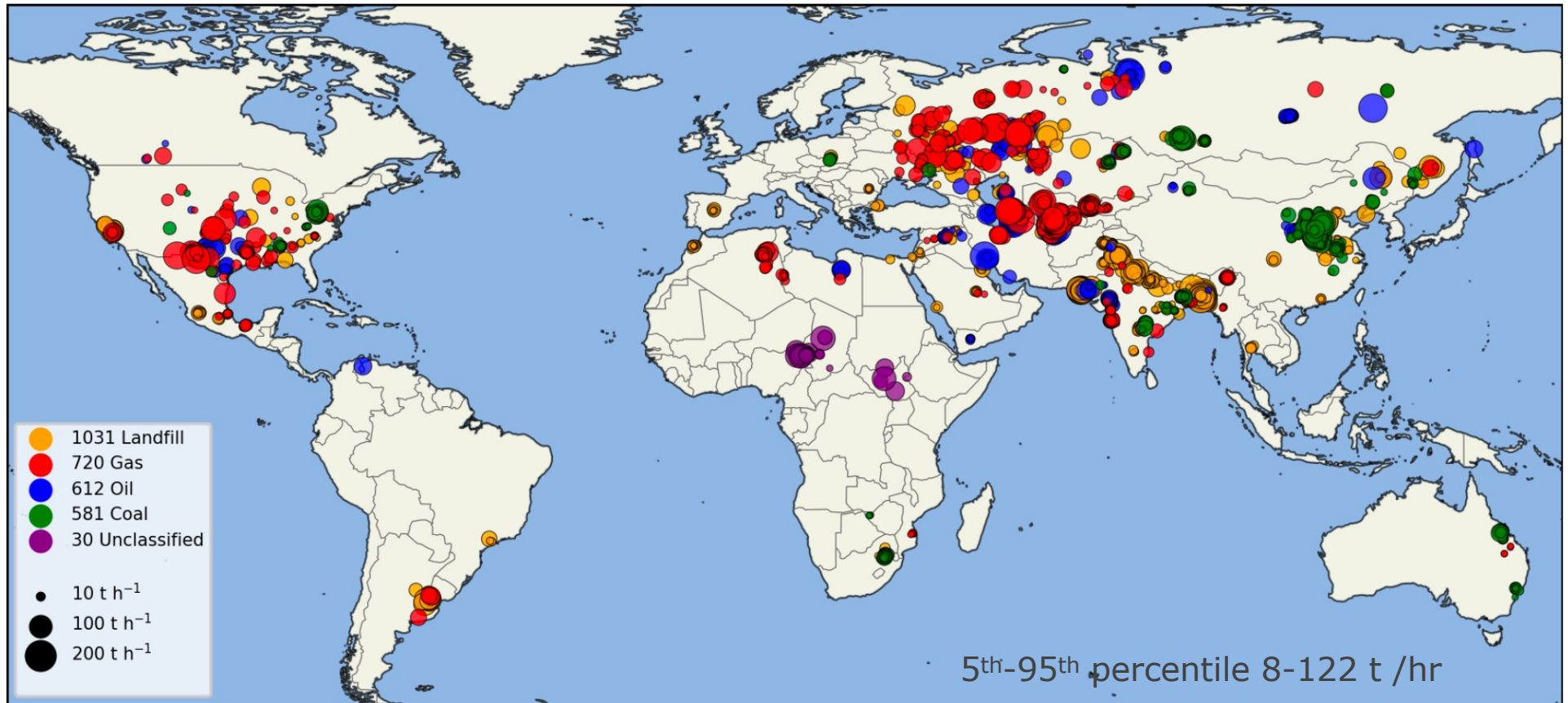
Three super emitting coal mine (clusters).

6 mines : 7 % AUS. coal production, 55% reported AUS CH<sub>4</sub> total coal emissions

One surface coal mine 1% coal production, 24% of reported emissions all coal mines AUS.



# TROPOMI detection methane Super emitters 2021

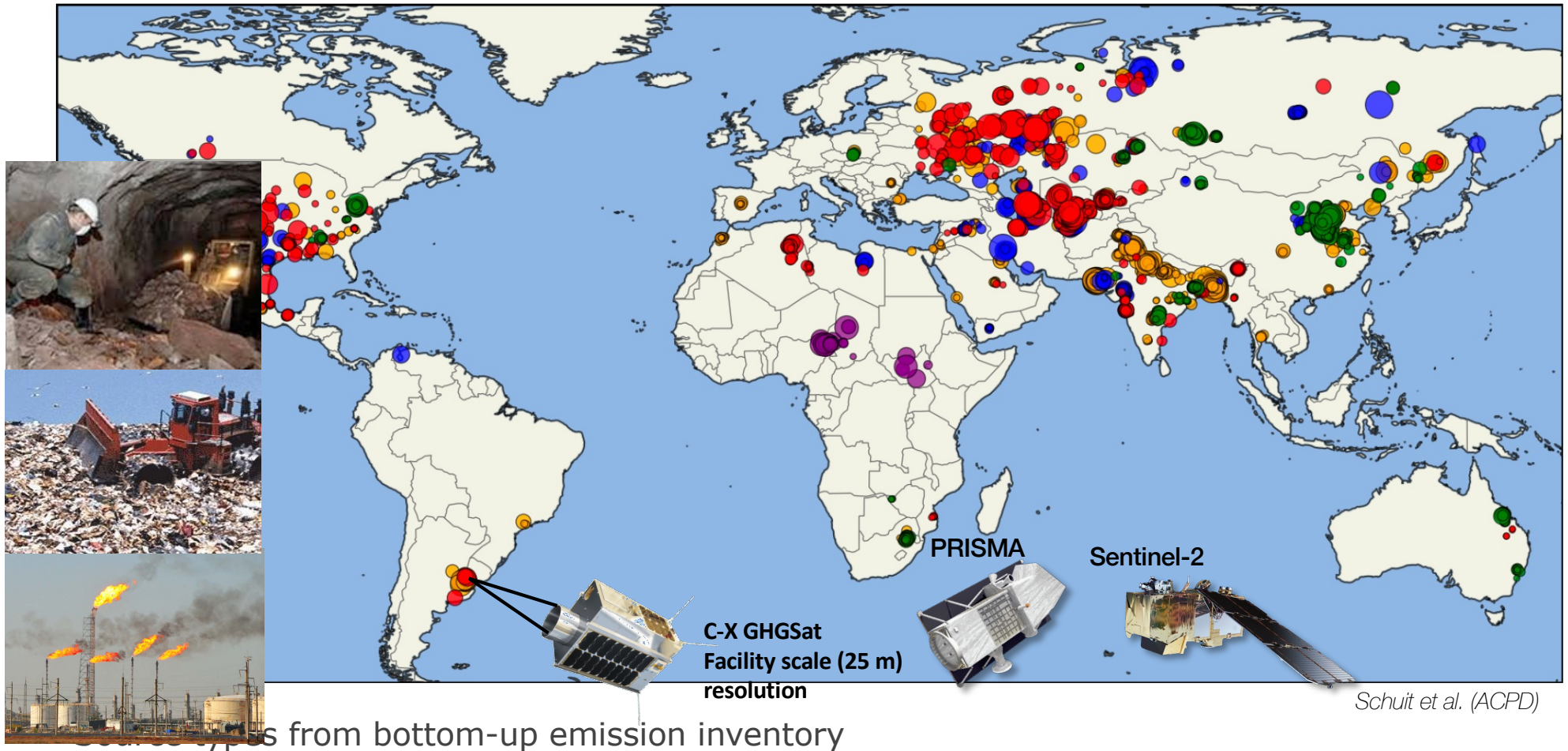


Schuit et al. (ACPD)

Source types from bottom-up emission inventory

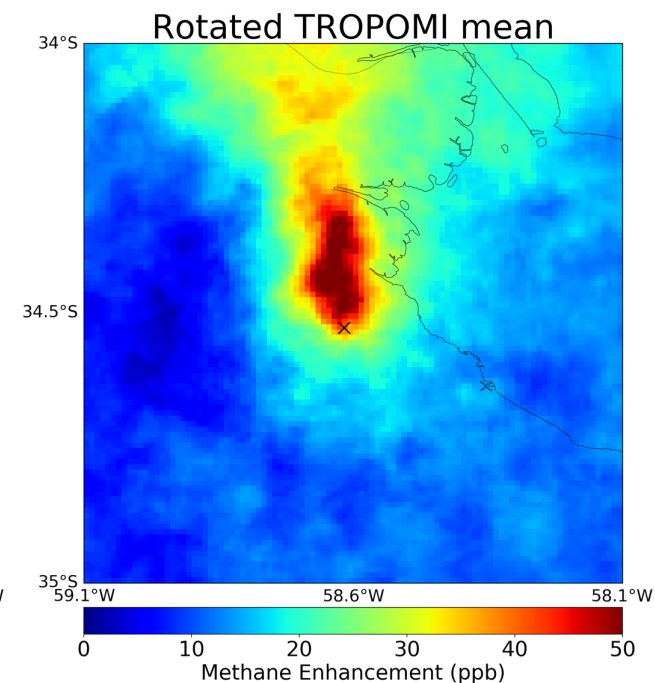
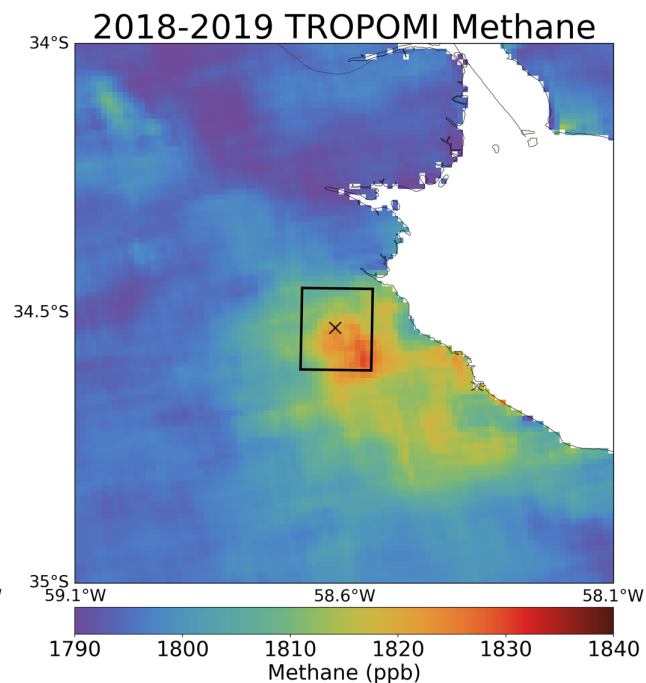
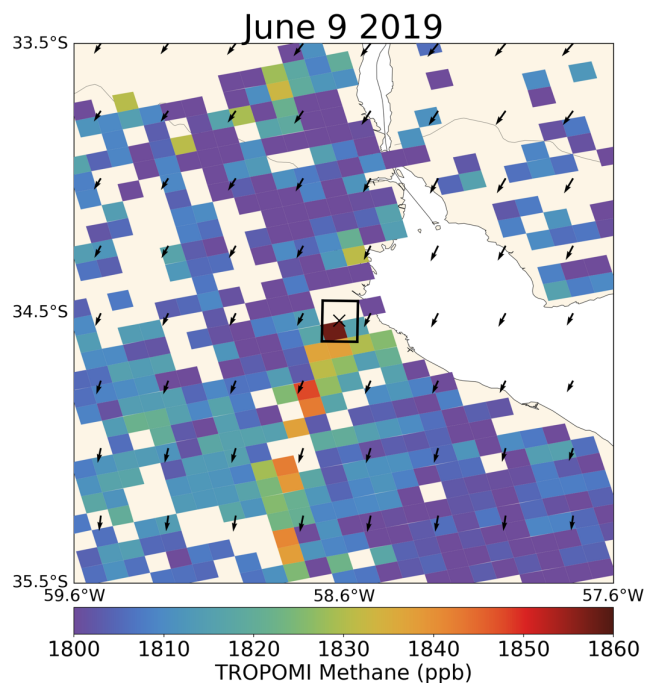
*Low hanging fruit wrt climate mitigation*

# TROPOMI detection methane Super emitters 2021



What are the exact sources responsible for these super emitter signals ?

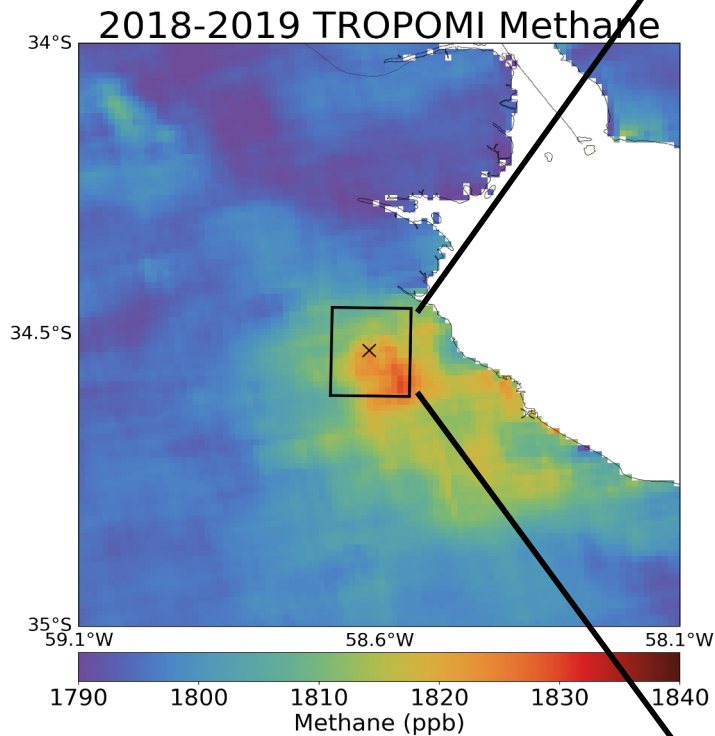
# TROPOMI 'tip-and-cue' GHGSat : persistent emissions Buenos Aires (Arg.)



*Maasackers et al. (2022)*

# Methane emissions from landfill in Buenos Aires

## TROPOMI

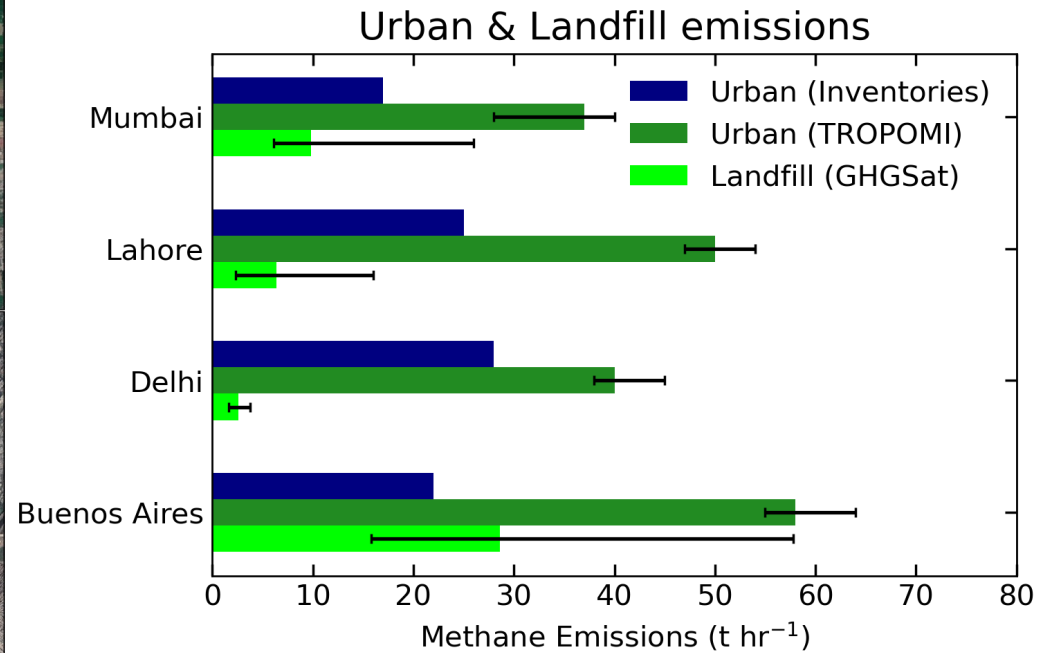
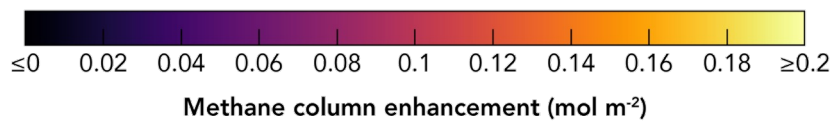
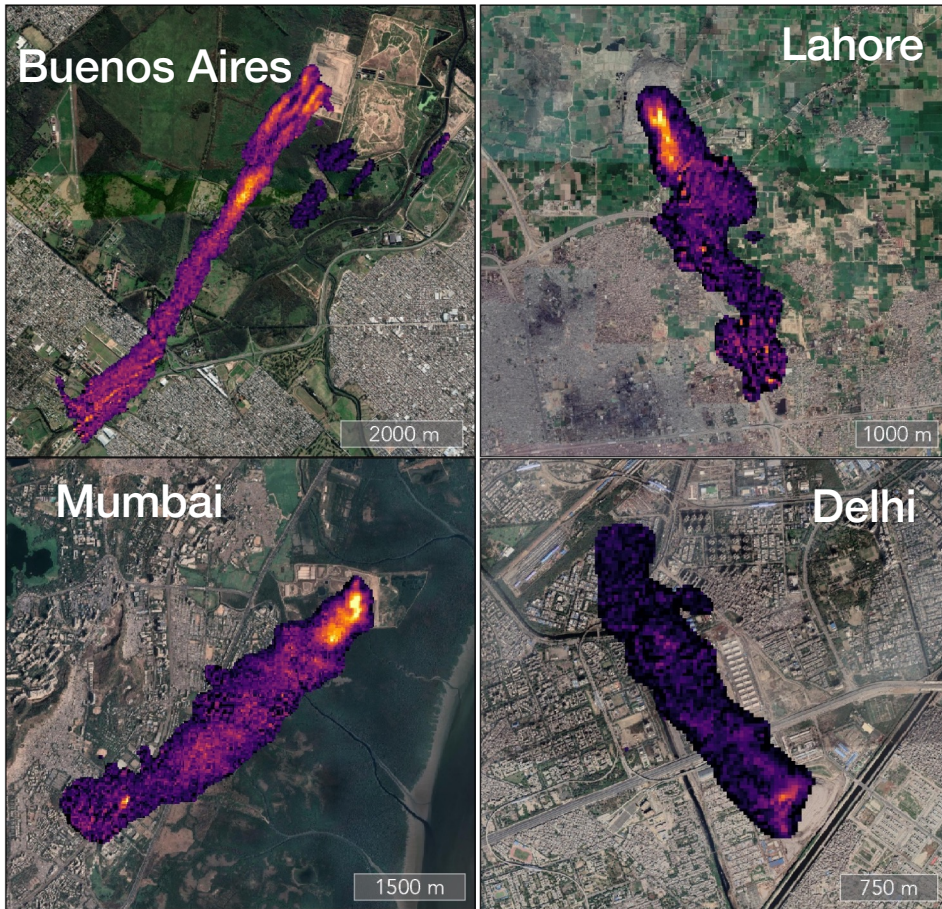


*Maasackers et al. (2022)*

Amount equal to ~10% of methane Permian basin  
(largest Oil (and Gas) production basin US)

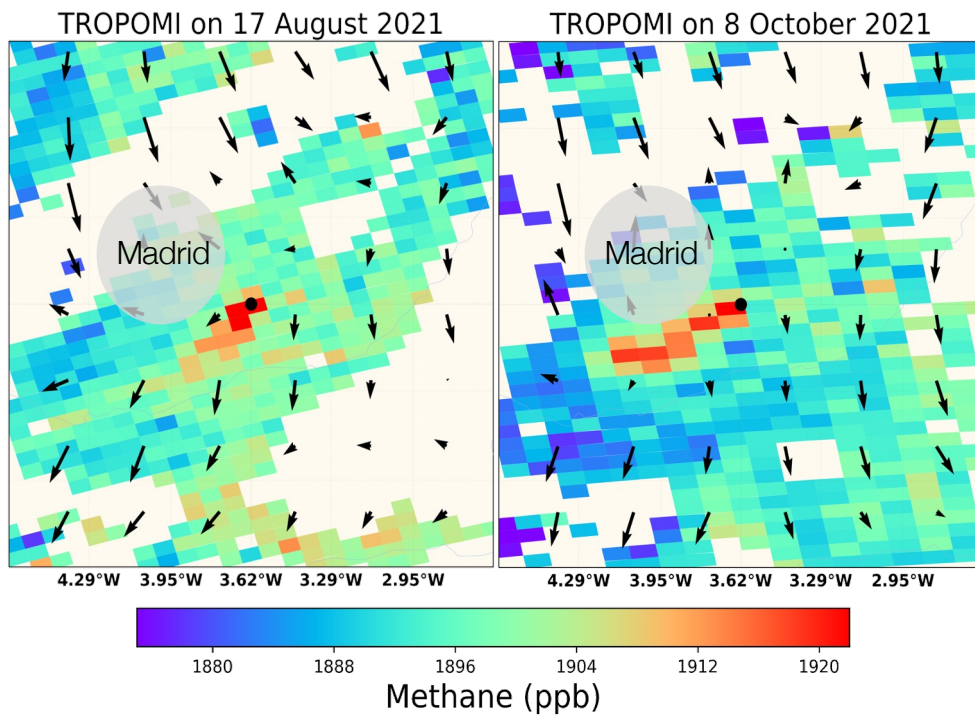


# TROPOMI & GHGsat : emissions landfills

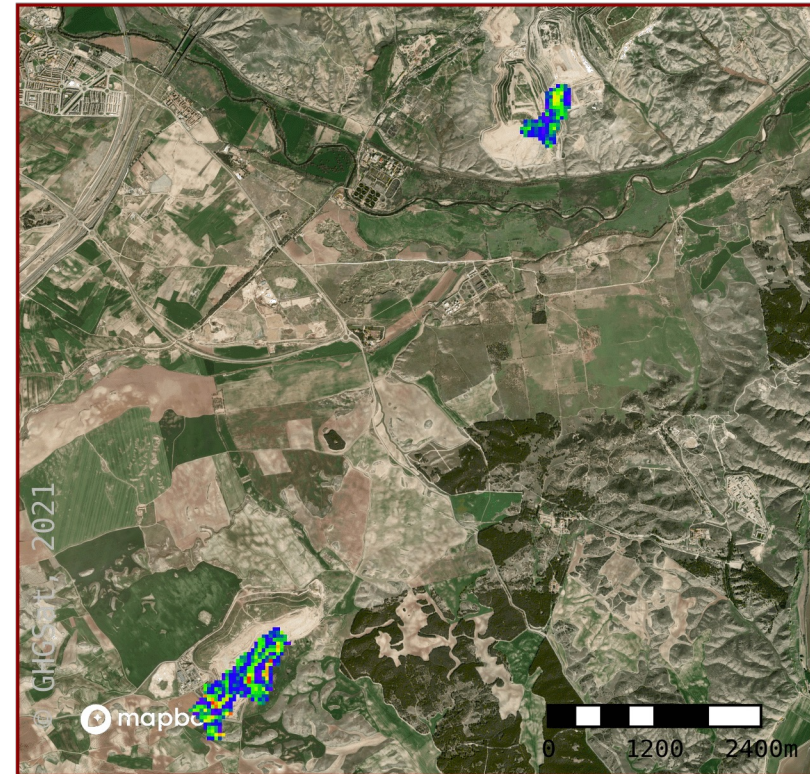


Maasackers et al. (2022)

# Landfill emissions : Madrid



Landfill - Madrid, Spain  
CH<sub>4</sub> Concentration Map



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

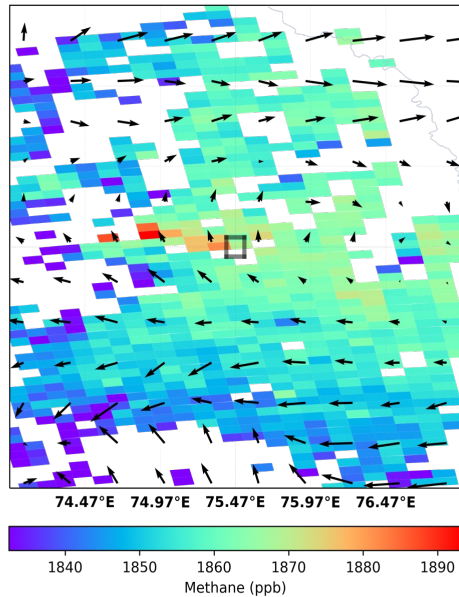
ESA aircraft campaign summer 2022



Figure Credit: Gourav Mahapatra. ESA web story from November 11, 2021.

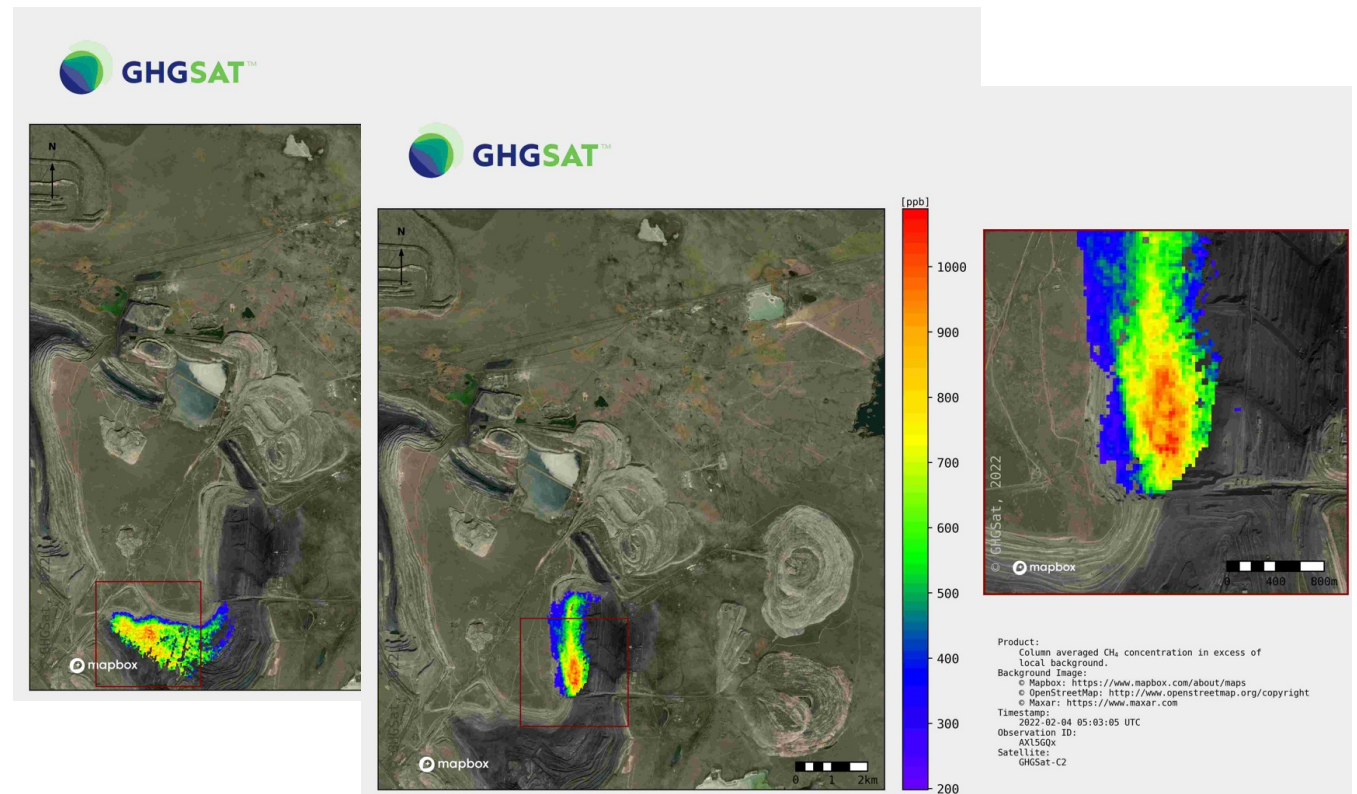


# Methane emissions from coal mines : surface mines !!



TROPOMI

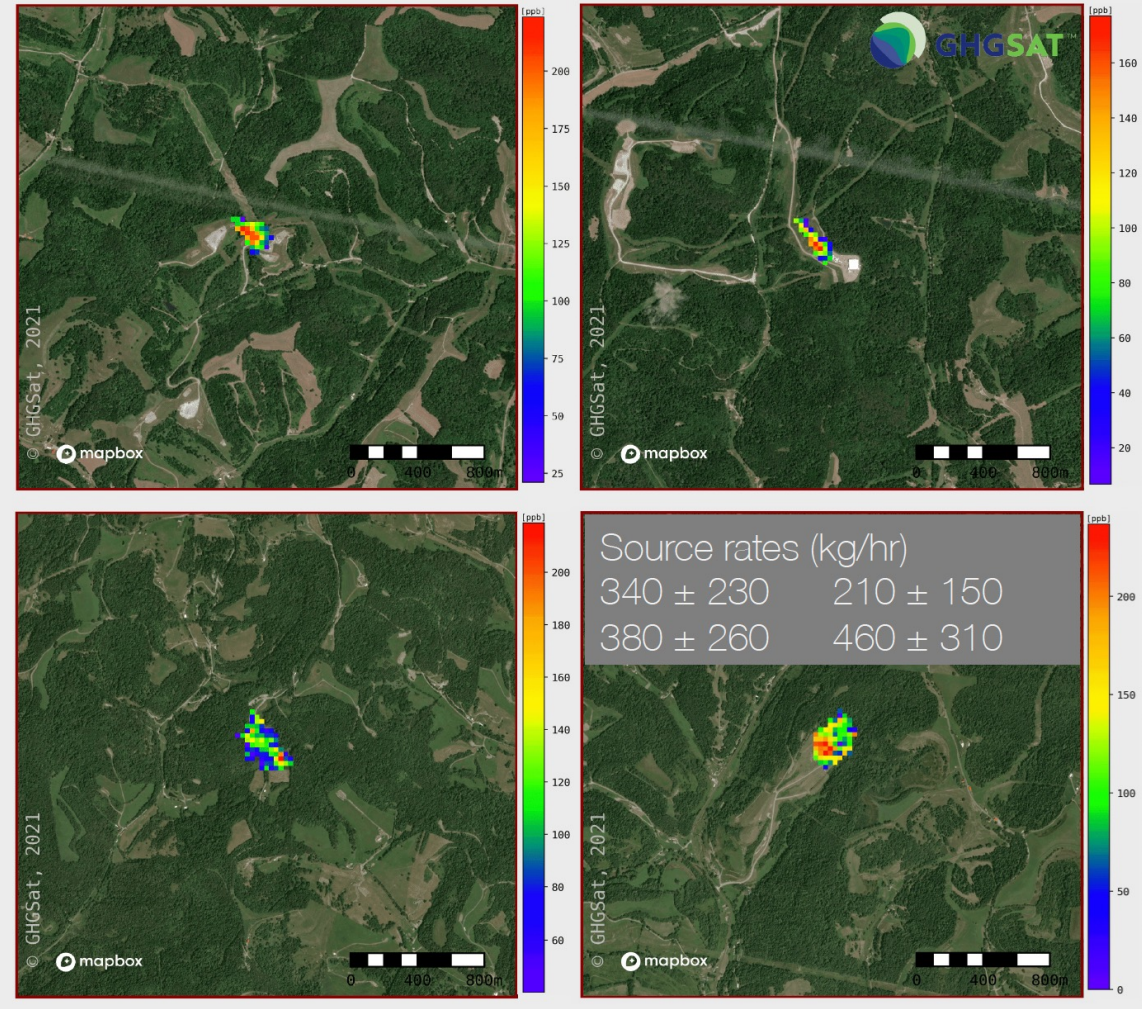
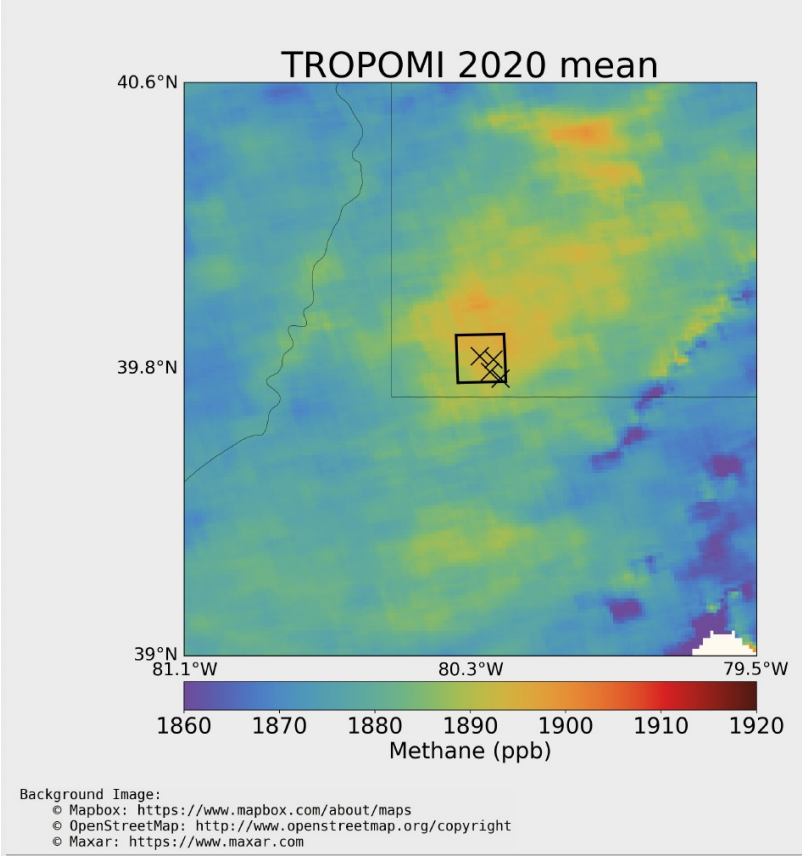
Ekibastuz region  
(Kazachstan)



Point source 1: 37,455 kg/hr  $\pm$ 42%

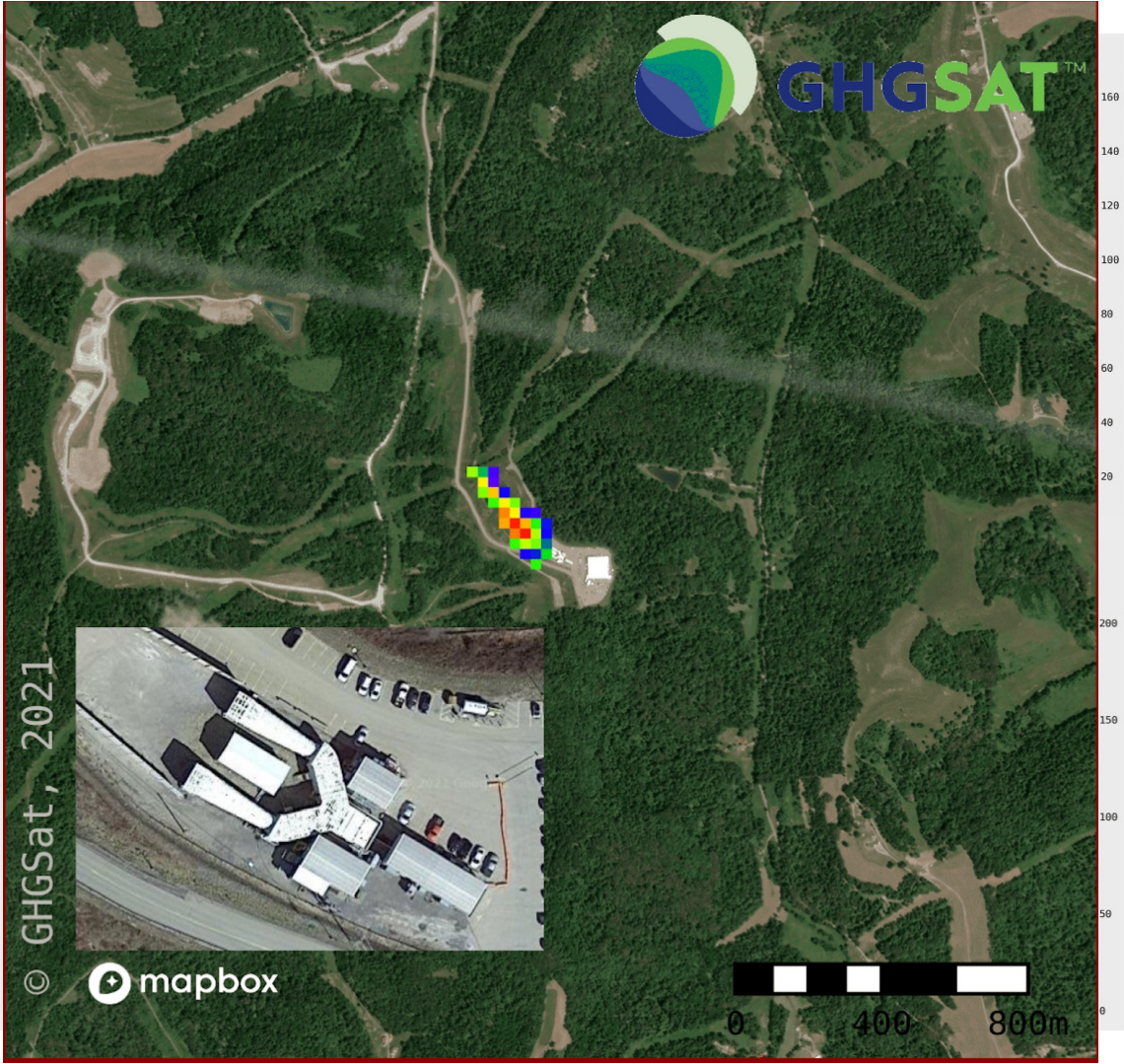
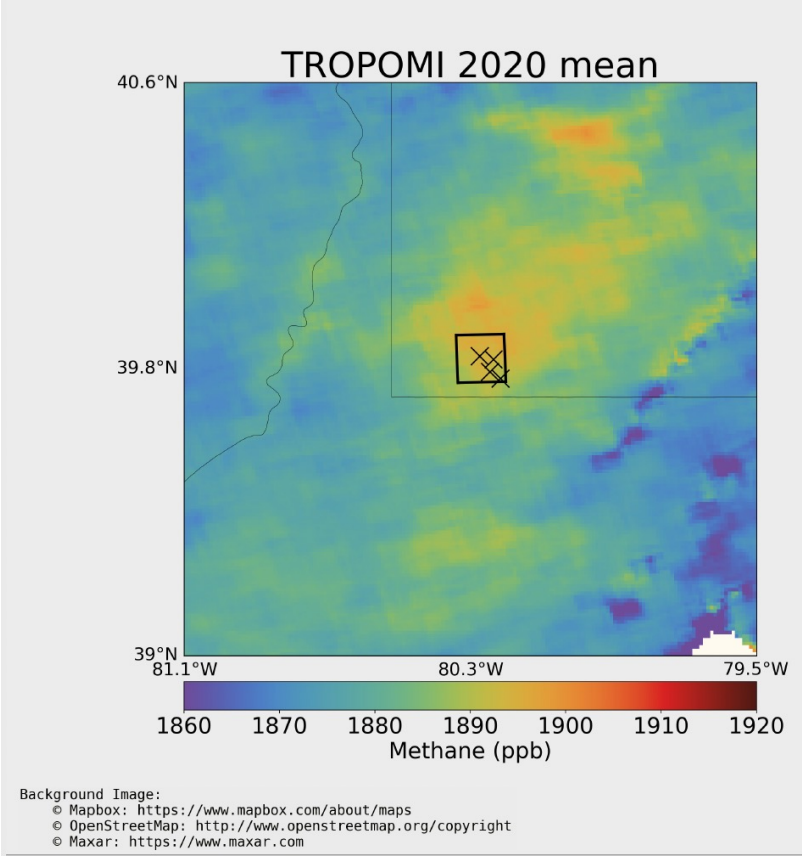
Point source 2: 23,081 kg/hr  $\pm$ 42%

# Underground mines in pennsylvania (USA)



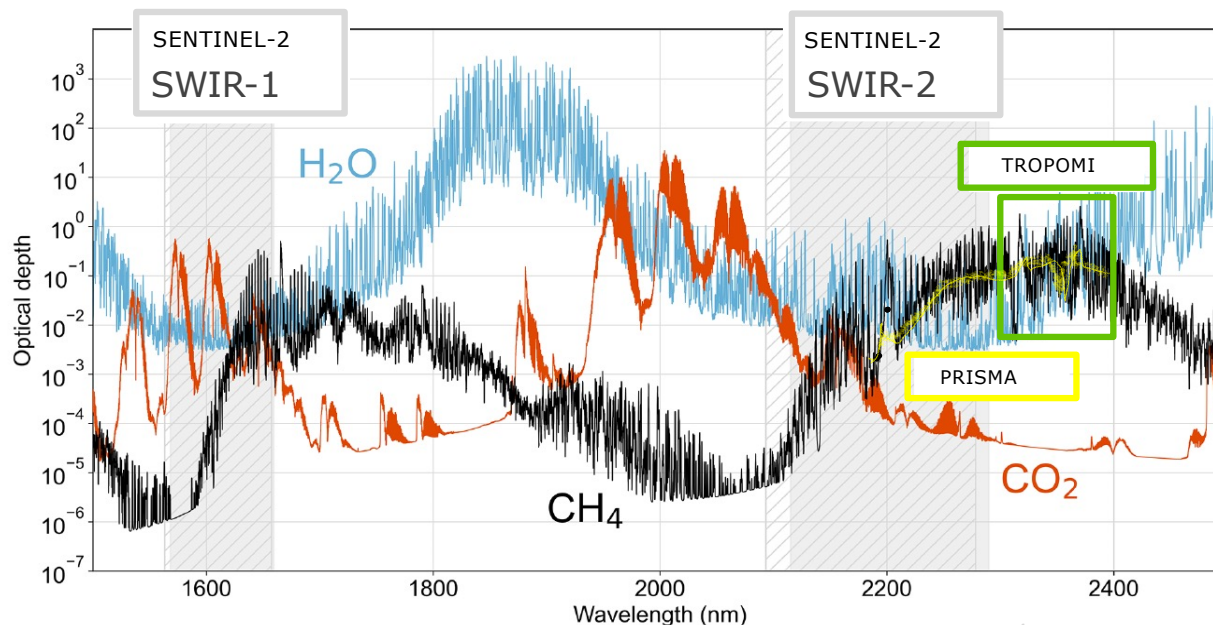


# Underground mines in pennsylvania (USA)



# Land imagers (e.g.Sentinel-2, PRISMA) can detect methane super emitters favorable conditions

- SWIR methane absorption band
- Very strong localised methane source, homogeneous terrain
- Very high spatial resolution ~20-50 m
- Sentinel-2 global coverage 2-5 days, PRISMA targeting
- Data publicly available



Varon et al, 2020

TROPOMI, 5.5x7km<sup>2</sup>, 0.25 nm  
Daily global coverage

PRISMA, 25x25 m<sup>2</sup>, 10-20 nm  
Targeting

Sentinel-2, 20x20 m<sup>2</sup>, 100 nm  
Global coverage in 5 days

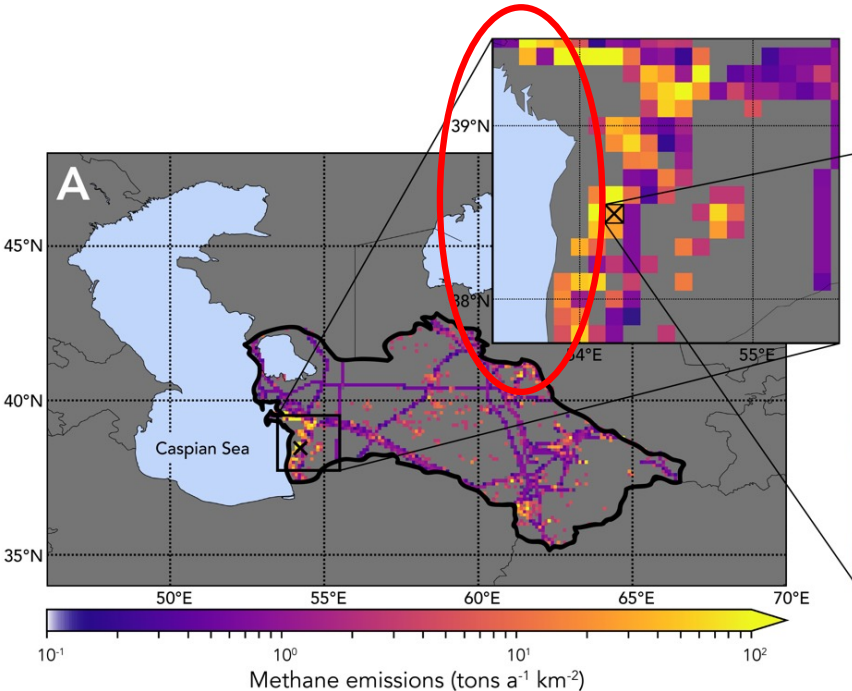
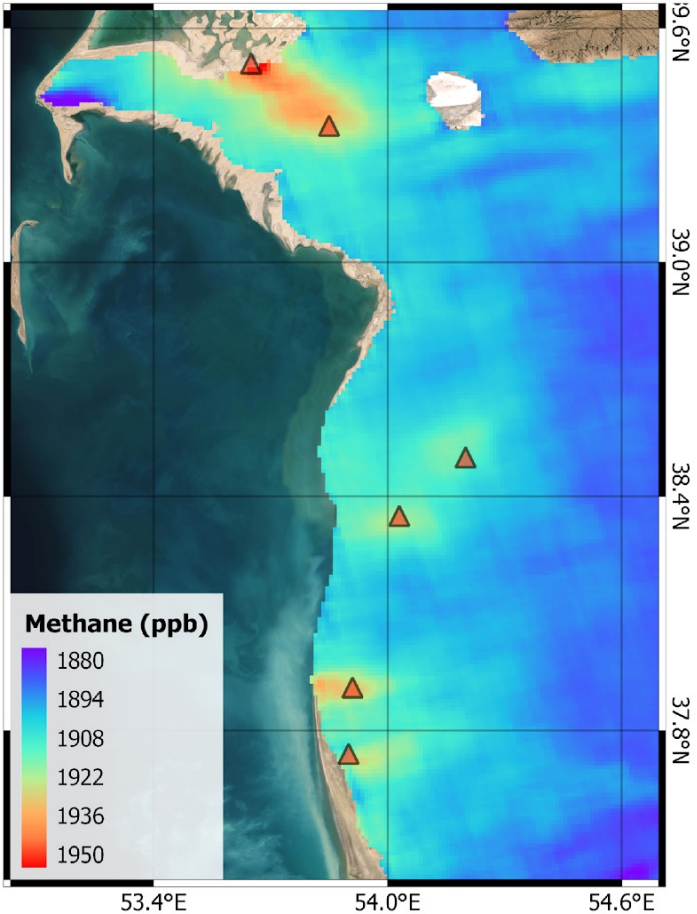
....

GHGSat : no public data



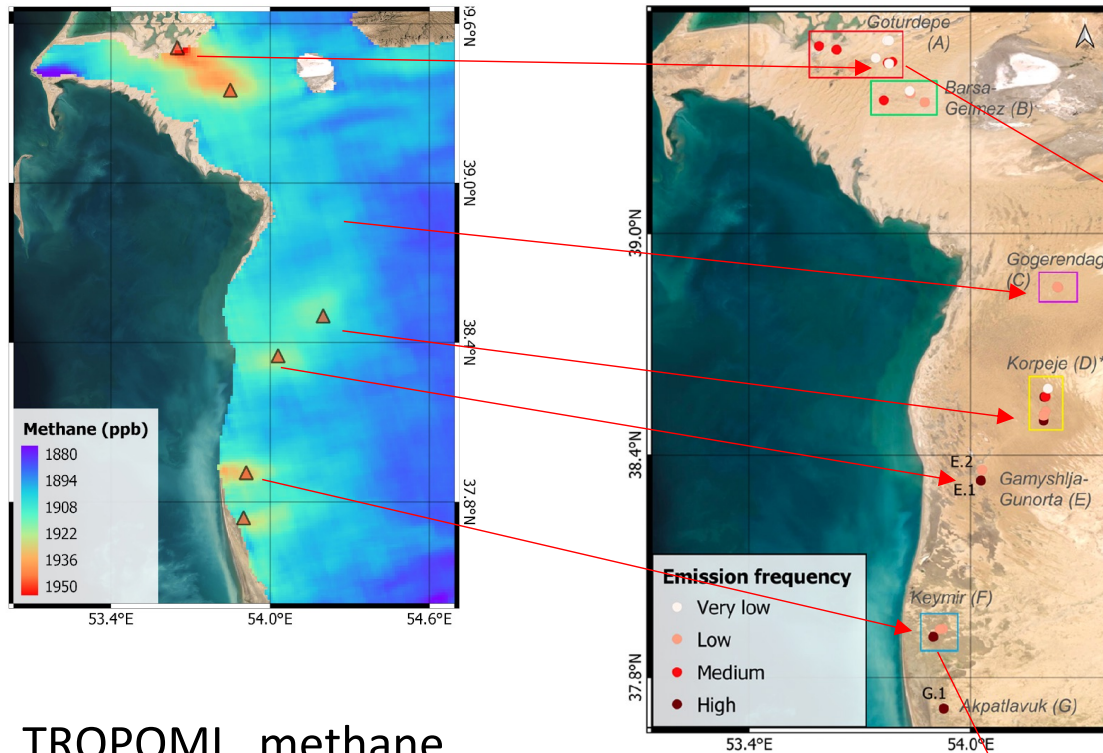
# West Turkmenistan

## TROPOMI methane



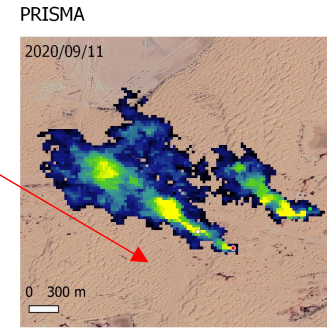
*Irakulis, et al. ES&T, 2022*

# West Turkmenistan



TROPOMI methane  
(~5.5 km x 7 km)

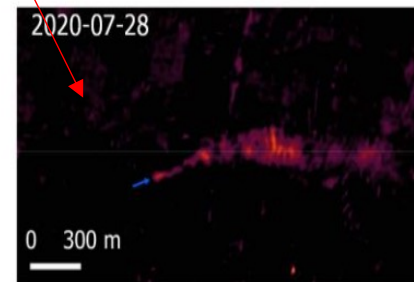
*Irakulis et al, 2022*



PRISMA methane  
(~20 m,  
Imager hyperspec.)



Unlit flares causing huge methane emissions  
29 sources, 24 not burning flares –



Sentinel-2 methane  
(~20 m, band imager spectrometer)



pubs.acs.org/est



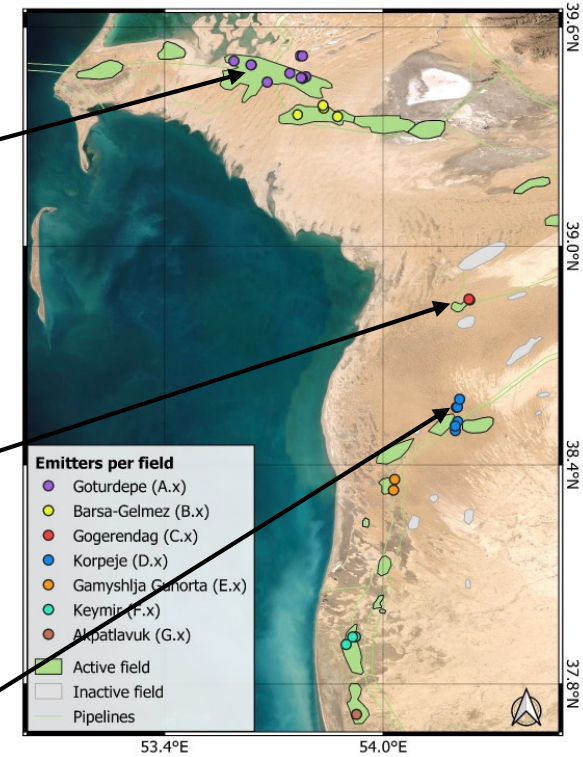
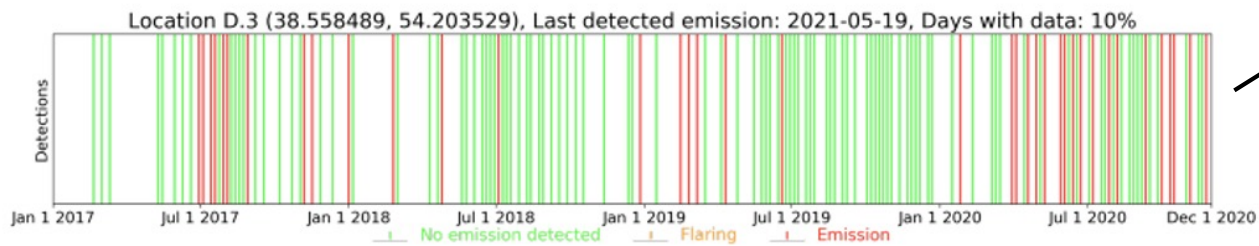
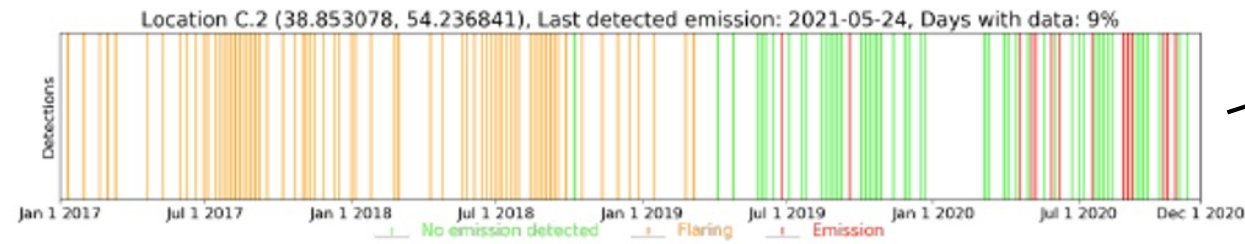
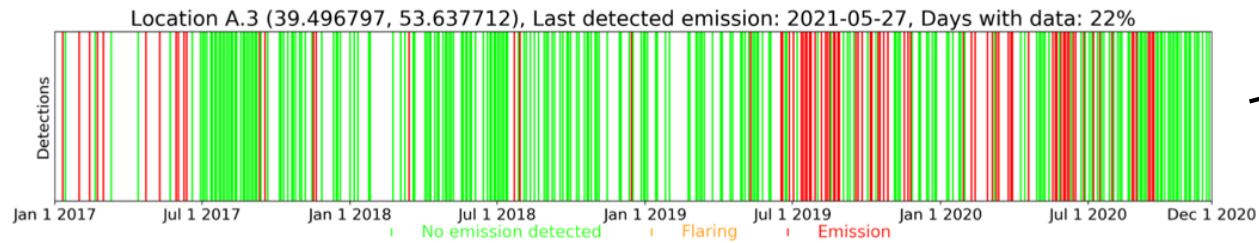
Article

Satellites Detect Abatable Super-Emissions in One of the World's Largest Methane Hotspot Regions

Itziar Irakulis-Loitxate,\* Luis Guanter, Joannes D. Maasackers, Daniel Zavala-Araiza, and Ilse Aben



# Monitor in time with Sentinel-2



- Emission
- Flaring
- Observation

# IMEO - MARS



UNEP's International Methane Emissions Observatory launched the Methane Alert and Response System (MARS) at COP27, a new initiative to accelerate implementation of the Global Methane Pledge by transparently scaling up global efforts to detect and act on major methane emissions sources.



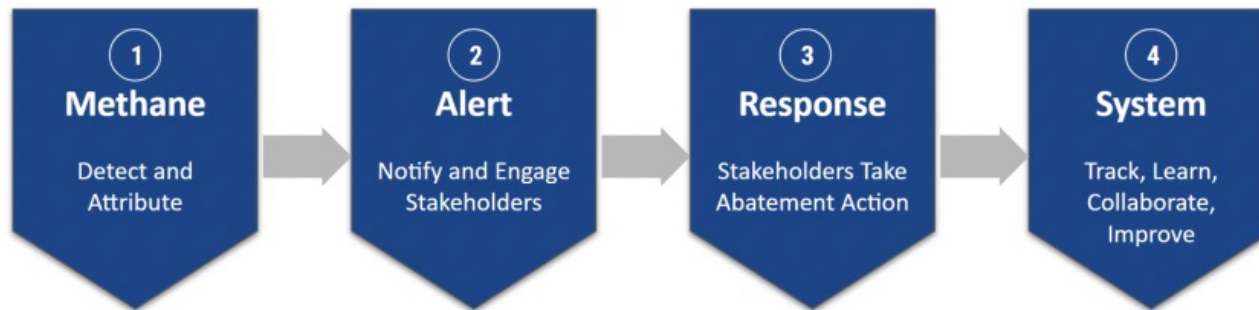
*Start operational 1 June/July*

NOS Nieuws • Vrijdag 11 november, 17:08 •  
Aangepast vrijdag 11 november, 19:41

**Wereldwijd alarmeringssysteem gelanceerd tegen methaanuitstoot**



MARS has four components:



Methane SEs (TROPOMI+)  
Large emission events  
*Low hanging fruit*

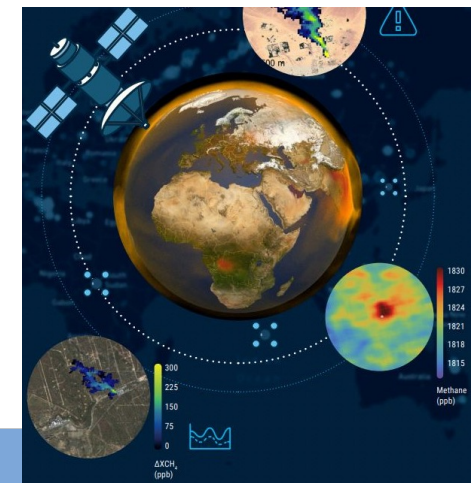
Governments & companies (e.g. OGMP2.0)

MARS will support

Transparent, open data : 45-75 days

Focus 1st FF

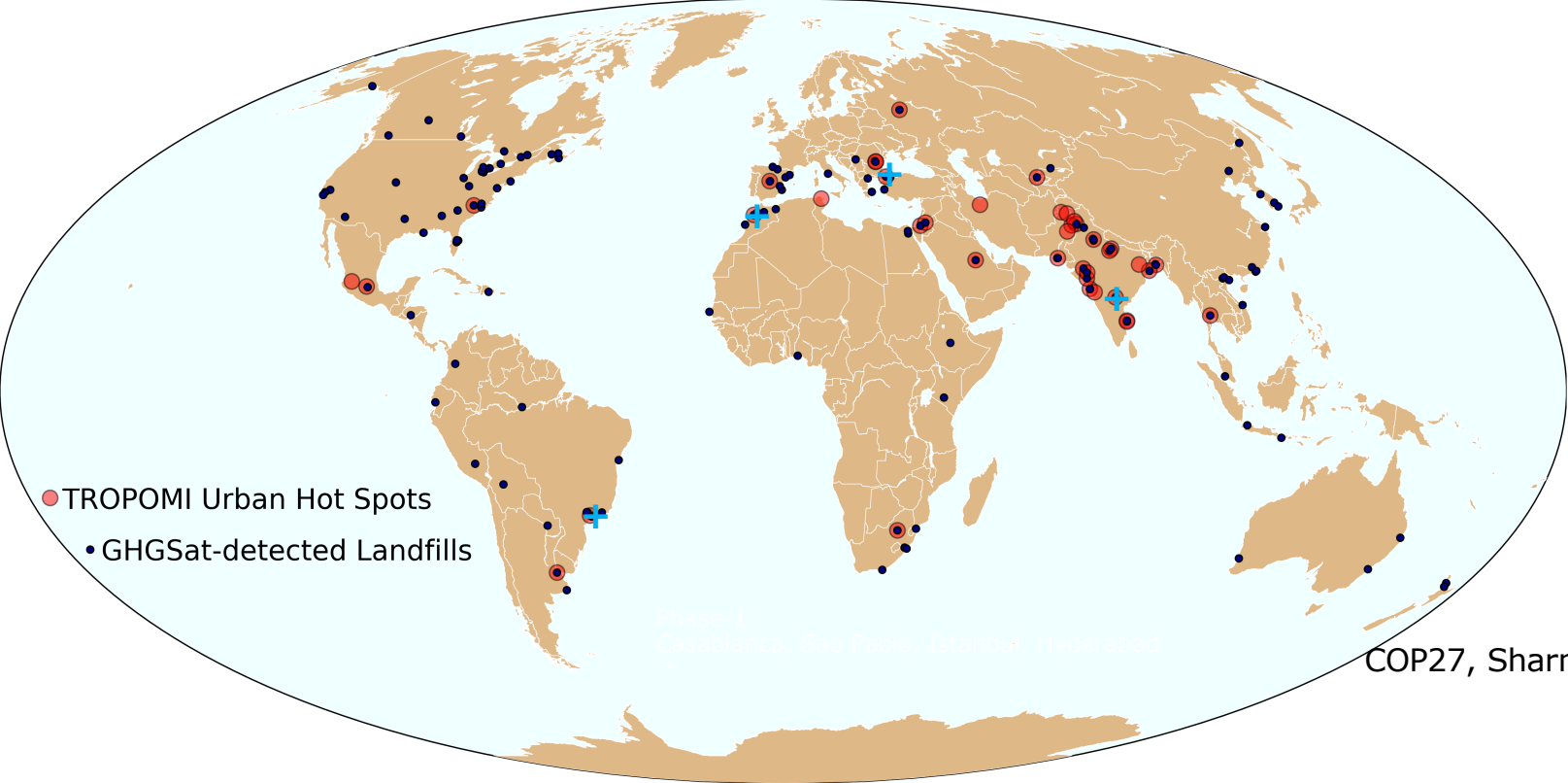
**SRON is core partner to MARS (Component-1)**



# Global Methane Hub – landfill emissions

Global Methane Hub, SRON and GHGSat started new project to characterize, study and monitor landfills globally, working with NGOs and local partners on mitigation

## Satellite-detected urban and landfill methane emissions

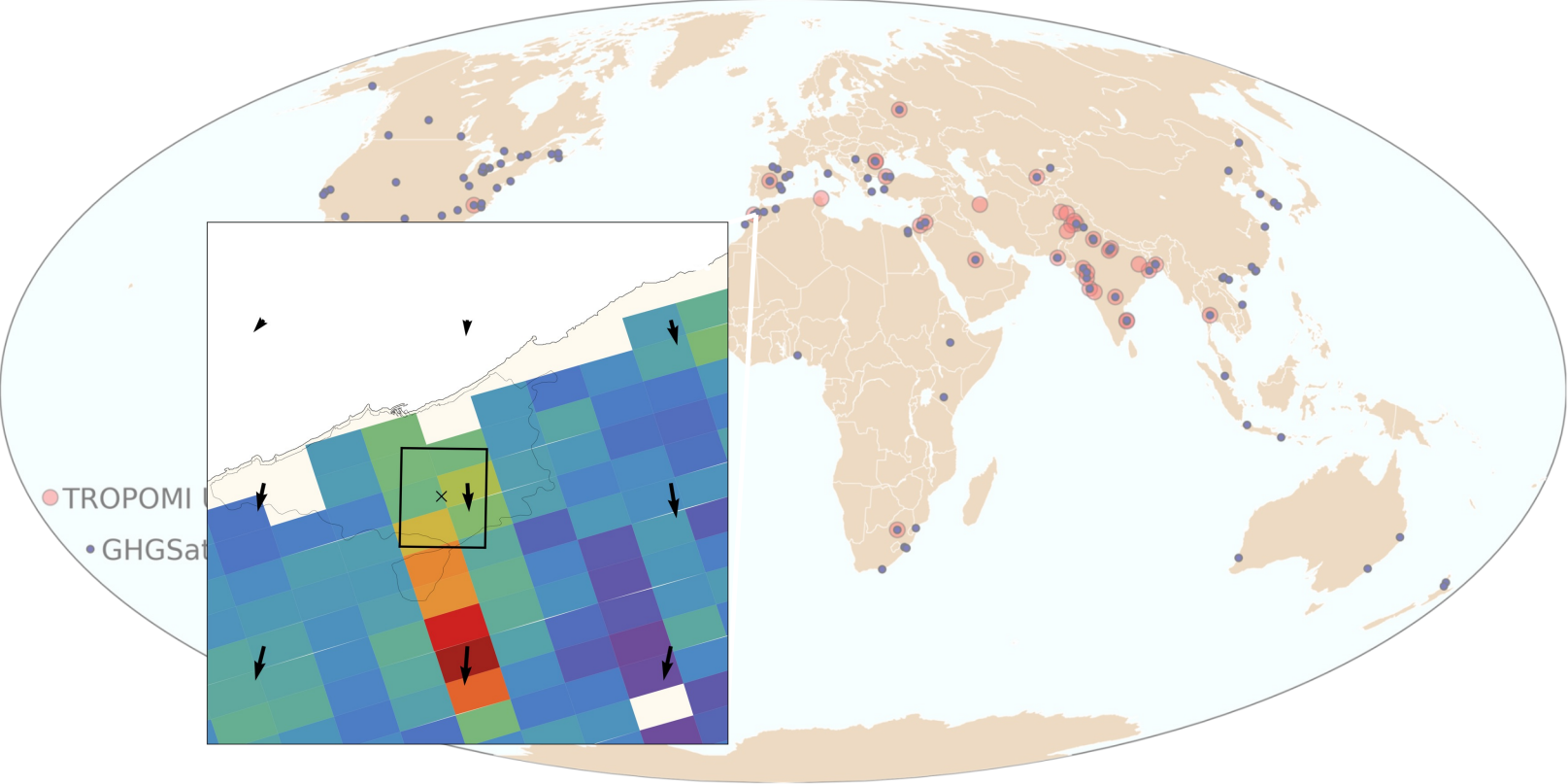




# Global Methane Hub – landfill emissions

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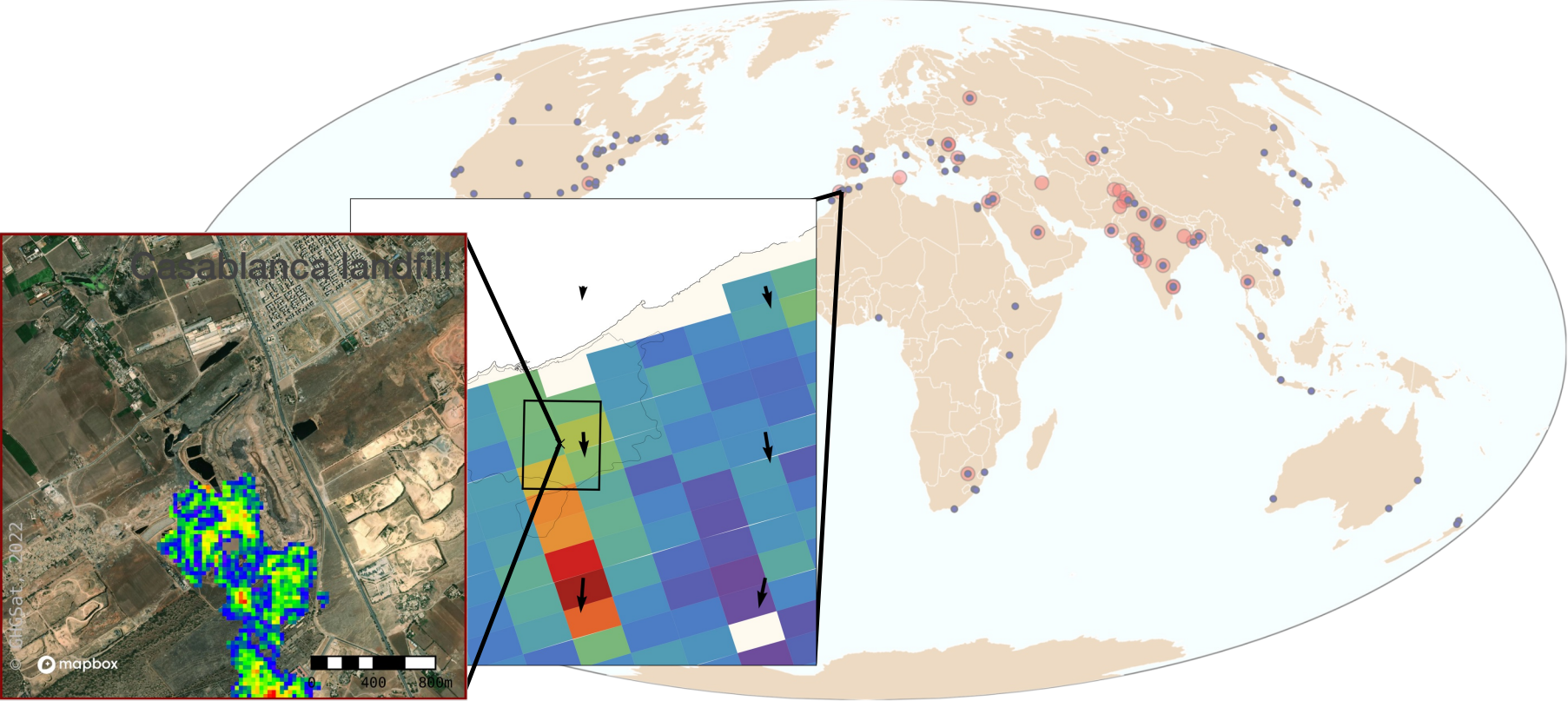
Satellite-detected urban and landfill methane emissions



# Global Methane Hub – landfill emissions

Global Methane Hub, SRON and GHGSat started new project to characterize, study and monitor landfills globally, working with NGOs and local partners on mitigation

Satellite-detected urban and landfill methane emissions



## Concluding :

- **TROPOMI** is a real **game changer** wrt detection of methane (non-)persistent super emitters globally (but limited to large emissions  $\sim 5\text{-}10\text{ t CH}_4/\text{hr}$ )
- Combination with high spatial resolution satellites (e.g. GHGSat, but also PRISMA, S2, etc) is VERY POWERFUL to identify the super emitting facilities
- Can support verification and prioritising climate mitigation action. Provide the information super emitters with **MARS** (IMEO under UN) to support countries & industry etc. to reduce their emissions and meet the **Methane Pledge** goals
- Also support GMH to address methane emissions from landfills/waste dumps in Global South



The methane hunters

Using satellites to spot industry's methane leaks

To help combat climate change