International Methane Emissions Observatory

Methane Alert and Response System (MARS)

Detection, *Notification, Mitigation*

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UN environment programme 50 1972-2022

Anthropogenic methane emissions

Methane, responsible for ~1/3 of global warming but ~20-y lifetime

"Cutting methane emissions is the best way to slow climate change over the next 25 years." Inger Andersen, Executive Director, UNEP

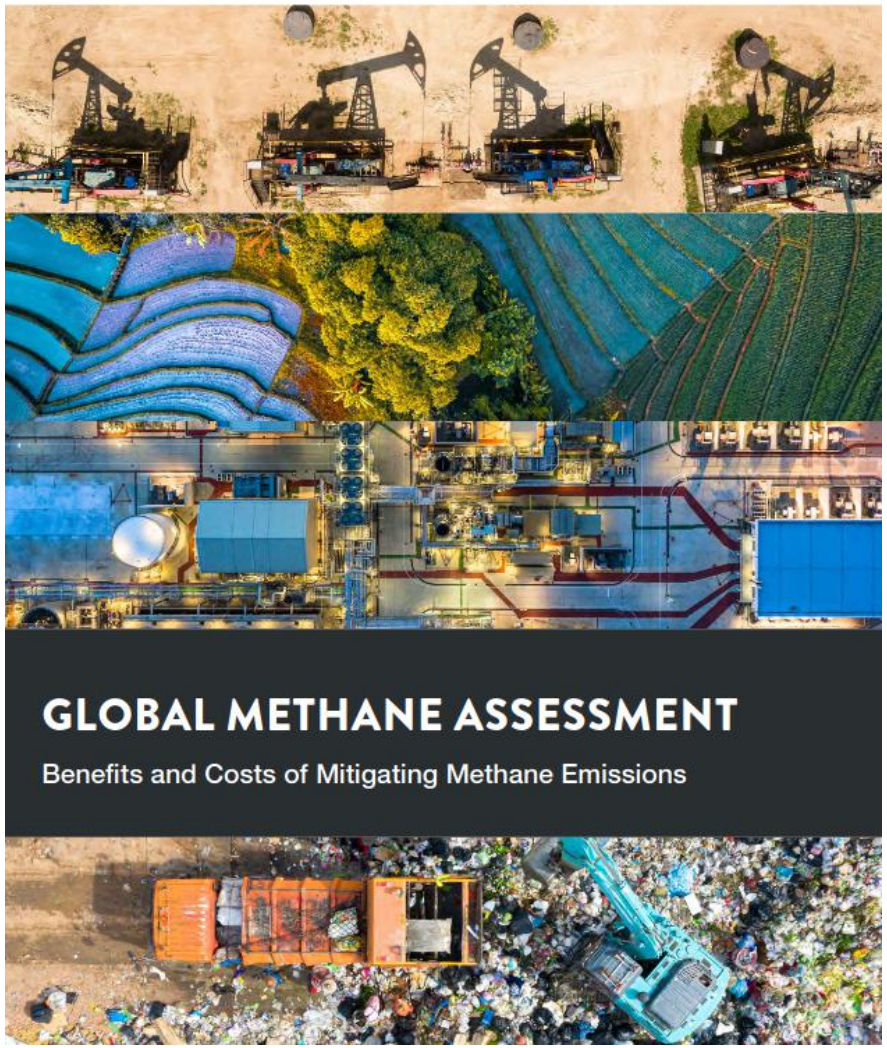
2021 report from the United Nations Environment Programme:

- **>50% of global methane emissions** stem from human activities in 3 sectors: fossil fuels (O&G+coal mining, 35%), waste (20%) and agriculture (livestock+rice, 40%)
- **The fossil fuel sector has the greatest potential** for targeted mitigation by 2030
- **Remote detection, quantification and monitoring** of human-based methane emissions is key to guide mitigation efforts

US and EU pledge 30% cut in methane emissions to limit global heating

Major commitment with deadline of 2030 is big advance towards reaching 1.5C goal set out in Paris agreement

The Guardian, 17 Sep 2021



United Nations Environment Programme (2021)

IMEO & MARS

The focus of the **International Methane Emissions Observatory (IMEO)** is to catalyze reductions of methane emissions using transparent, data-driven approaches. IMEO consists of several efforts including:

- A portfolio of **Methane Science Studies** (sub-orbital direct emission measurements)
- An innovative, transparent voluntary emissions reporting framework **(OGMP2.0)**
- **Methane Alert and Response System (MARS)** – IMEO's data product

The first phase of MARS system will use satellite remote sensing for detection and attribution of methane plumes from point-sources (energy sector) AND will also include notification and mitigation-tracking workflows.

MARS' components:

- Component 1: Detection, localization, and – where possible – attribution
- Component 2: Notification to OGMP 2.0 companies and governments
- Component 3: Mitigation and Tracking

MARS Component 1: Detection

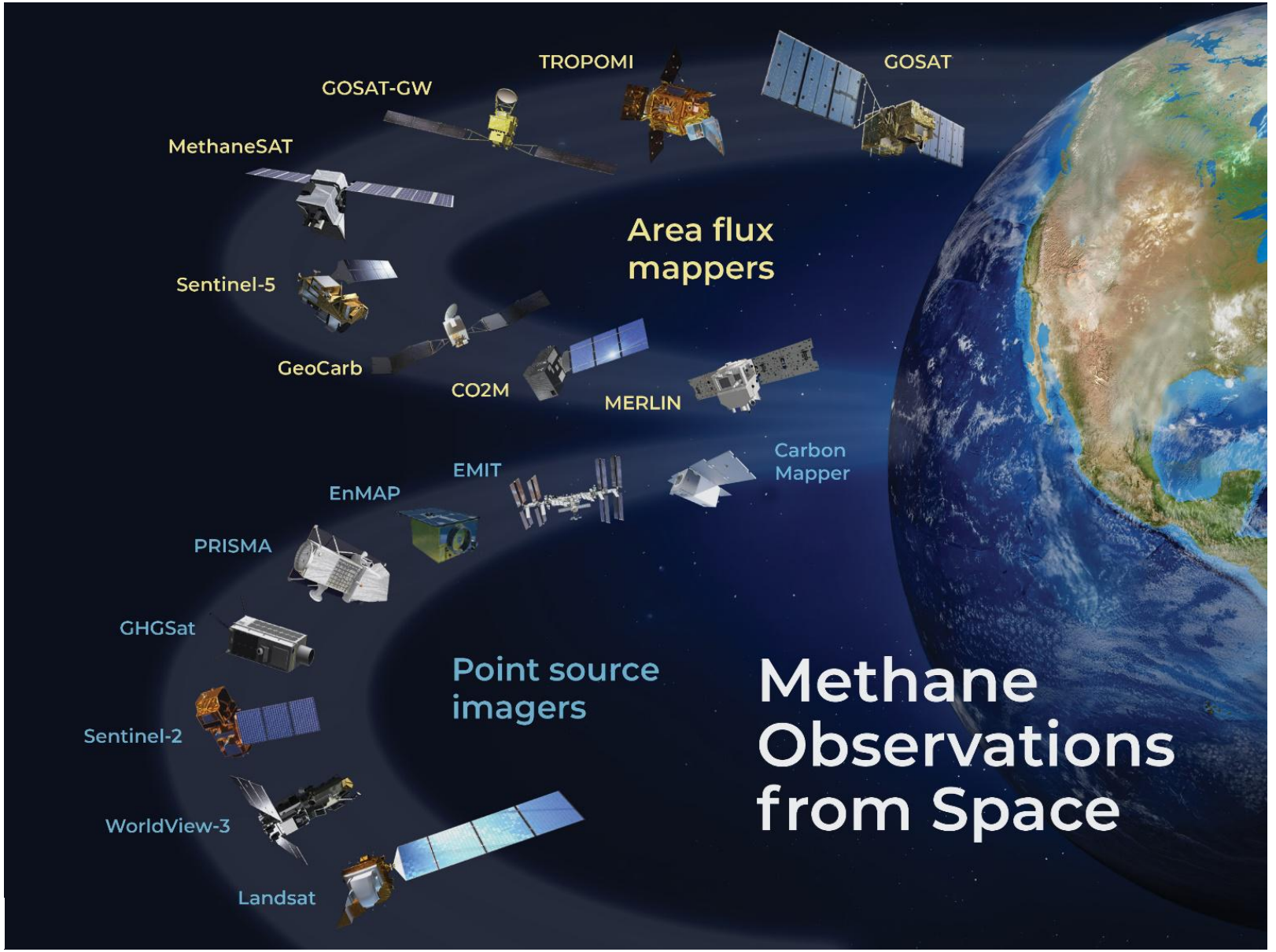
MARS-Detection, objectives:

- **First phase: use satellites to identify large point-source emissions from the energy sector**
- *Next phases (~2023-2024): improve detection limits and include area sources*
- Results will be made public through a data portal and used to guide mitigation efforts

Satellite Data:

The ecosystem of methane-sensitive satellite missions is very heterogeneous in terms of

- Detection limits
- Spatial and temporal sampling
- Availability of analysis-ready methane data products



Jacob et al., ACP, 2022

Satellites relevant to MARS – A diverse ecosystem of methane–sensitive missions

Area flux mappers:

- **TROPOMI**: 7 km/pixel, global daily coverage, >10 t/h emissions, no attribution to sources
- A number of other missions coming up in the next 2-3 years

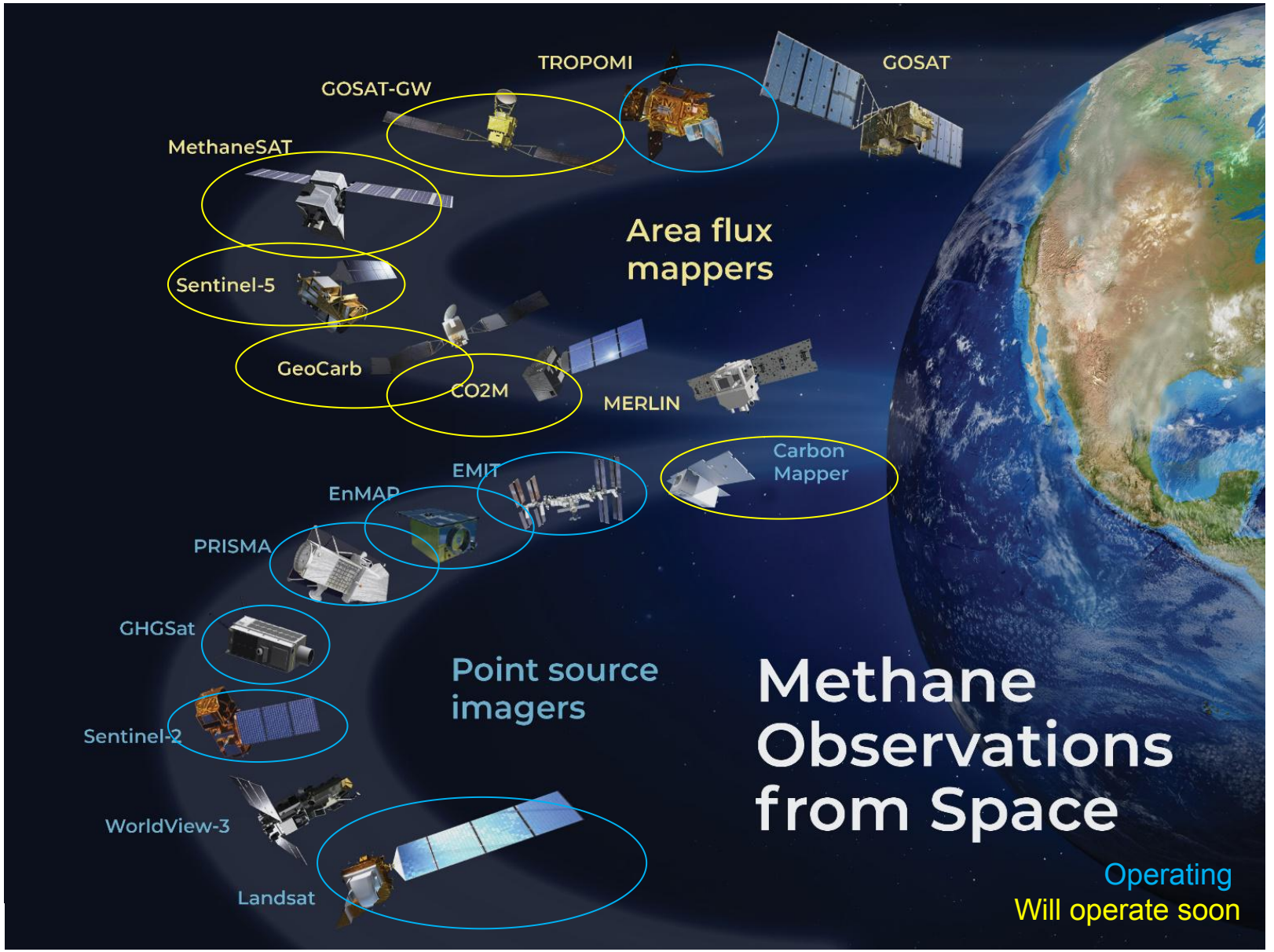
Point Source Imagers:

Hyperspectral missions:

- **GHGSat** (private): 25/50 m resolution, high sensitivity, sporadic acquisitions, 12 km coverage
- Imaging spectrometers (**PRISMA, EnMAP, EMIT, AHSI**): 30 m resolution, medium sensitivity, 30-60 km coverage, require tasking

Multispectral missions:

- **S-2/Landsat**: 20-30 m resolution, low sensitivity, but "monitoring" with frequent and global coverage

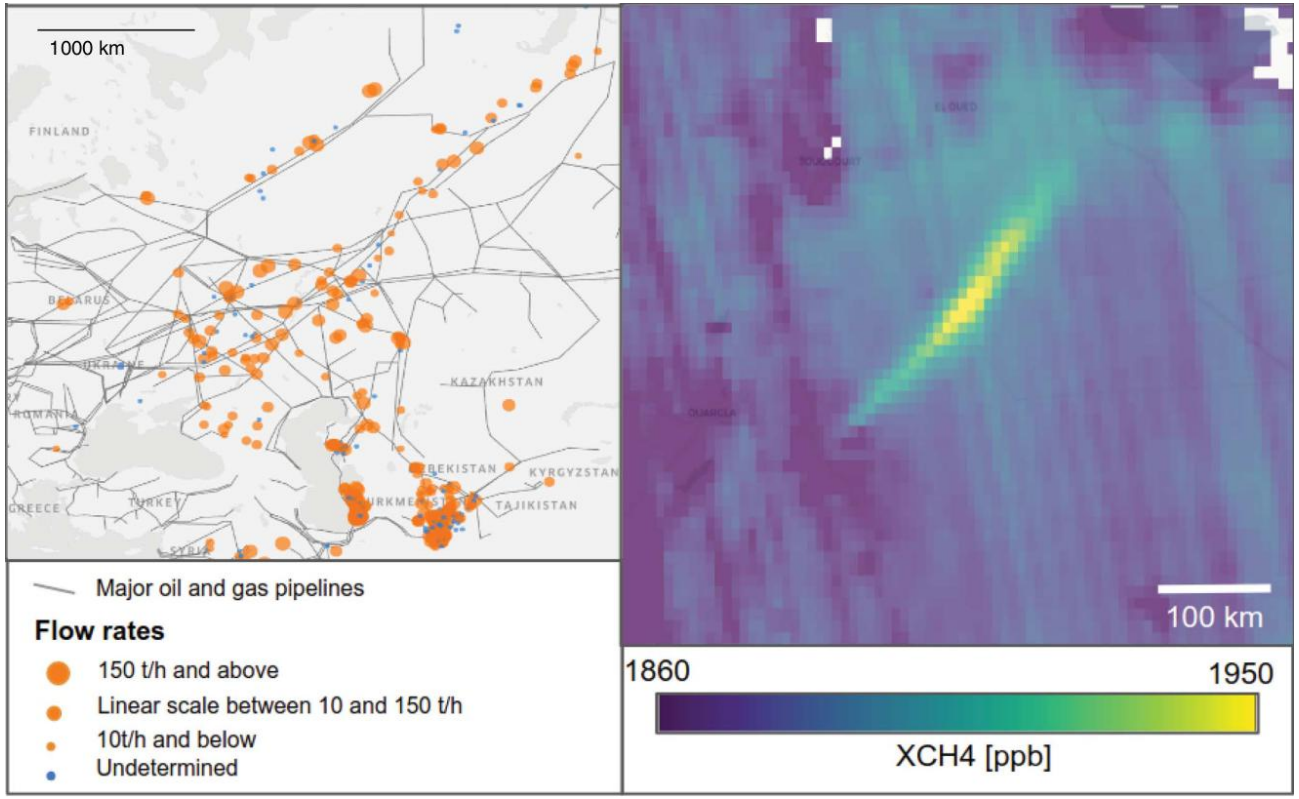


Jacob et al., ACP, 2022

ESA/EU Sentinel–5P/TROPOMI (area flux mapper)

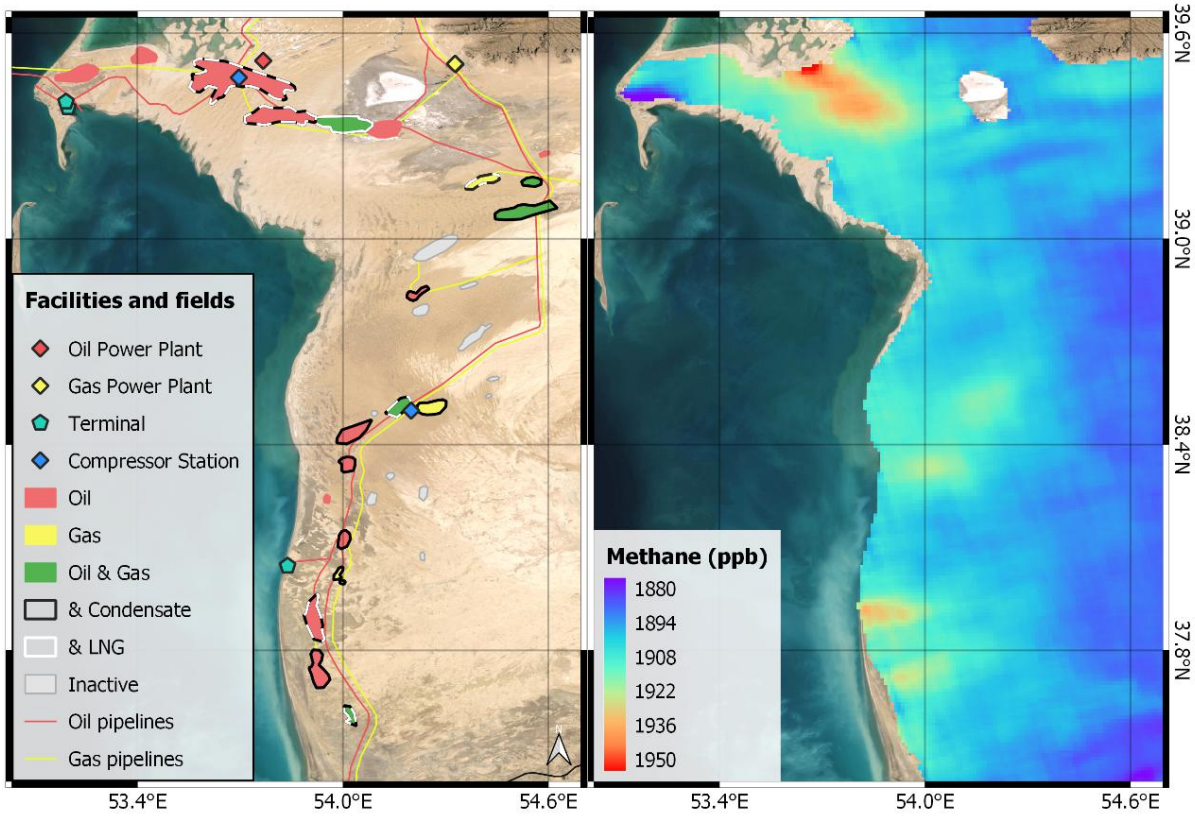
- TROPOMI - operational, global and daily sampling, but coarse resolution

Application #1
Detection of individual ultra-emission events
(daily global surveillance, very large plumes)



Lavaux et al., Science, 2022

Application #2
Determination of "hotspot" regions
(average over time, persistent emissions)



Irakulis-Loitxate et al., ES&T, 2022

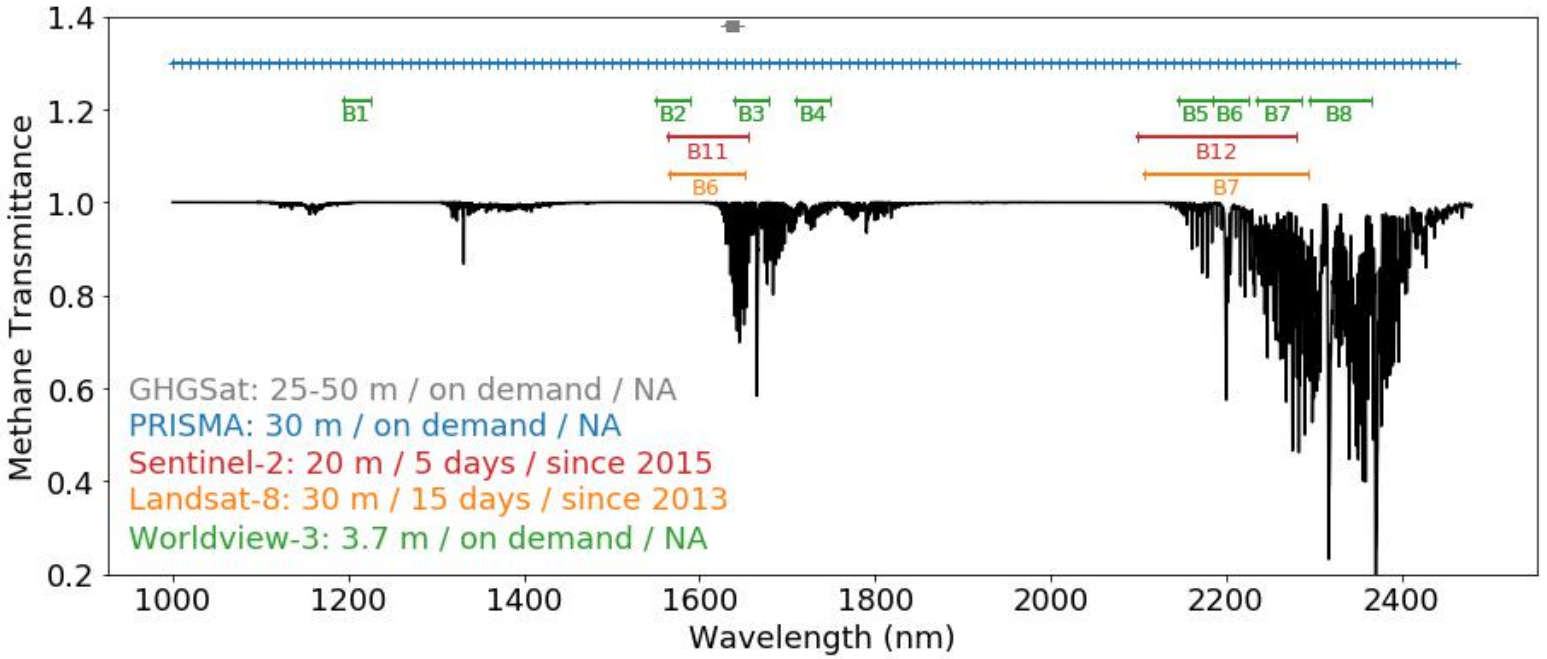
High–resolution satellites (point–source imagers)

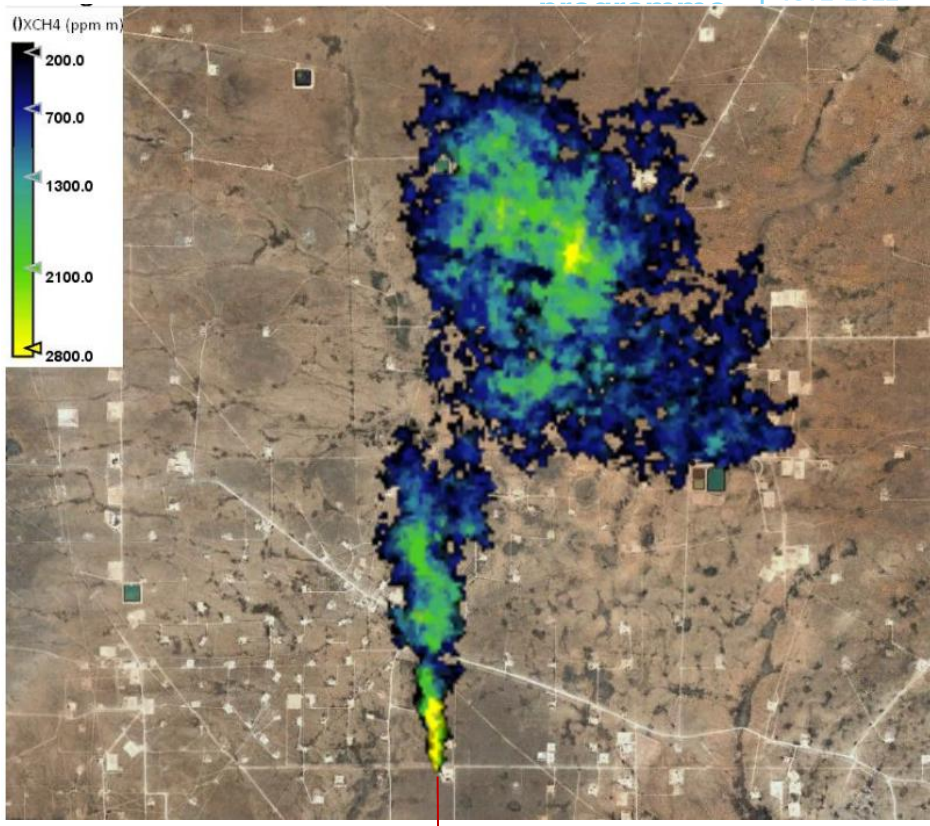
Instruments covering the methane absorption at ~2300nm

Allow attribution to sources and lower detection limits (>300 kg/h)

Two classes of missions

- Hyperspectral missions (GHGSat, PRISMA, ...): 30-m resolution, medium sensitivity, sporadic acquisitions but wide spatial coverage 30-60 km, require tasking
- Multispectral missions (S-2/Landsat): 20-30 m resolution, low sensitivity, but “monitoring” with frequent and global coverage





Malfunctioning flare, Permian Basin, NM, USA 9 Feb 2022

IMEO MARS–Detection concept

Tasks

1) Ultra-emission detection system: Rapid detection and -when possible- attribution of individual ultra-emissions (>10 t/h), with global coverage

2) Persistent point-source detection system: Identification and characterization of infrastructure elements responsible for >1 t/h. Focus on regions where strong and persistent emissions are detected

Core team

- **UNEP-EDF**: management and coordination
- **Kayrros**: TROPOMI operational and low-latency data processing (Task 1)
- **SRON**: TROPOMI data analysis for the detection of regions of interest with persistent emissions (Task 2)
- **UNEP-analysts**: attribution of plumes to sources, link to notification and data portal (Task 1 & 2)
- **In-kind data contributors**:
  - GHGSat
  - UPV (Spain): acquisition and processing of hyperspectral data
  - TBC: NASA-JPL, China Ministry of Ecology and Environment

Task 1: Ultra–emission detection system (rapid response)

Objective:

Rapid detection and -when possible- attribution of individual ultra-emissions (>10 t/h), with global coverage

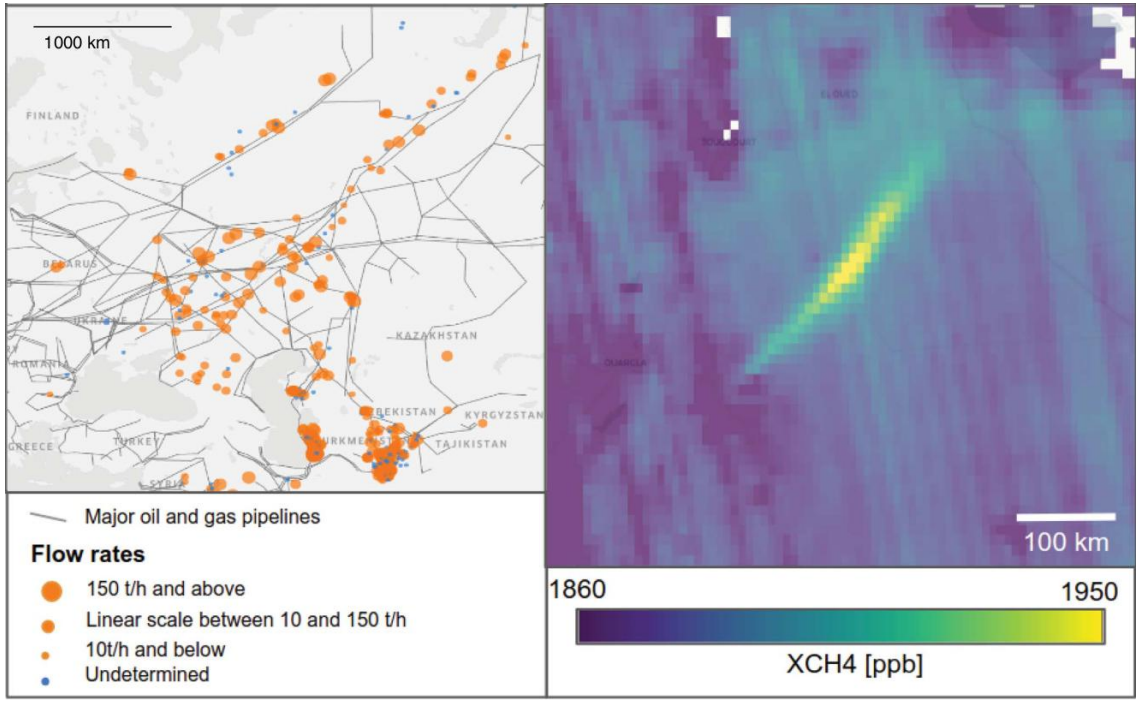
Methods:

1. Confirmed detection of "ultra-emissions" around the world with TROPOMI, with an uncertainty of ~10-50-km in the source location → notification #1
2. If no attribution possible, follow-up with PSIs:
    1. Sentinel-2/Landsat for the days around the detection
    2. Potentially GHGSat, depending on total latency of the process (time since TROP acquisition + time for GHGSat acquisition)
3. Attribution to sources achieved? → notification #2

Challenge: short latency

Main contributors: Kayrros, UNEP

Detection of individual ultra-emission events (daily global surveillance, very large plumes)



Lavaux et al., (2021)
Global Assessment of Oil and Gas Methane Ultra-Emitters

Task 2: Persistent point–source detection system

Objectives

- Identification and characterization of infrastructure elements responsible for persistent emissions (>1,000 kg/h)
- Focus on regions of interest (ROIs) where persistent emissions are detected or expected

Methods:

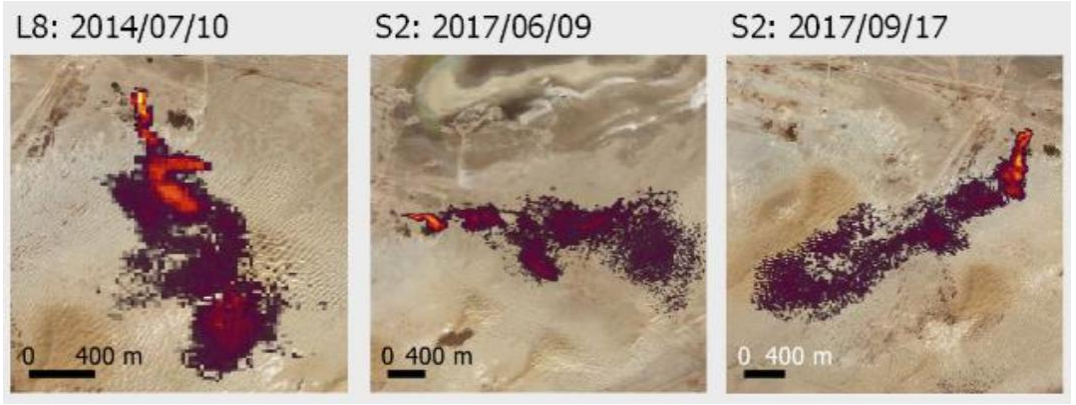
1. Definition of ROIs (or individual super-emitters) based on TROPOMI or other sources of information
2. Point source imagers to detect and characterize sources inside those ROIs

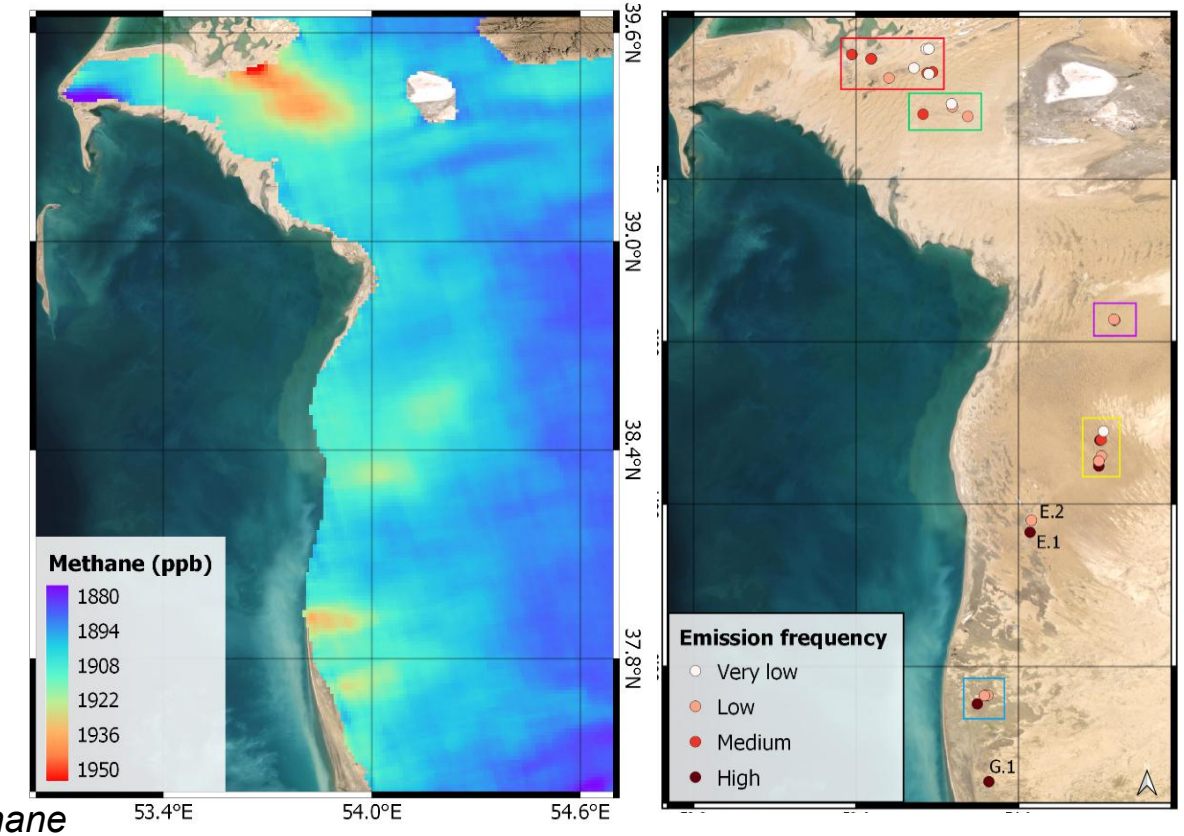
❖ Tasking needed for GHGSat, EnMAP and PRISMA

❖ EMIT and AHSI contribution under discussion

Detections from targeted hi-res acquisitions (GHGSat, EnMAP, PRISMA) can be reported with low latency (Task 1)

Main contributors: SRON, UNEP, UPV





Detection of persistent methane point sources in Turkmenistan

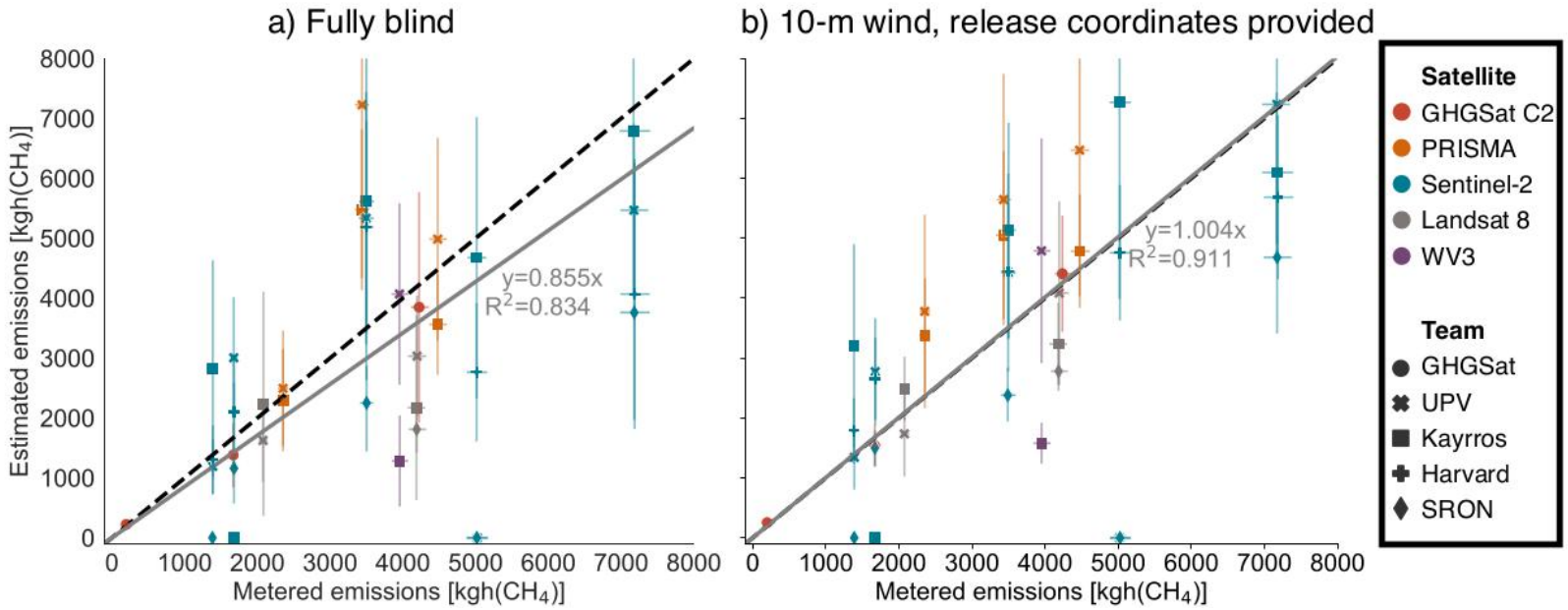
Irakulis-Loitxate et al., ES&T, 2022

Validation

- **MARS' main objective: detection of methane plumes and attribution to sources**; flux-rate estimates (quantification) to be included as ancillary information for each detection.
- The validation concept is under discussion - possibilities:
  - Plume detection algorithms: inter-comparison of the "operational" MARS algorithms used in Task 1 (Kayrros) and 2 (SRON) (focus on TROPOMI, but also hi-res, ...)
  - Performance of the different satellites for point-source detection: inter-comparison of concurrent acquisitions by different satellites
  - Plume quantification & (to some extent) detection limits: controlled methane release experiments (Stanford)

Satellite results from the "Stanford" release experiment

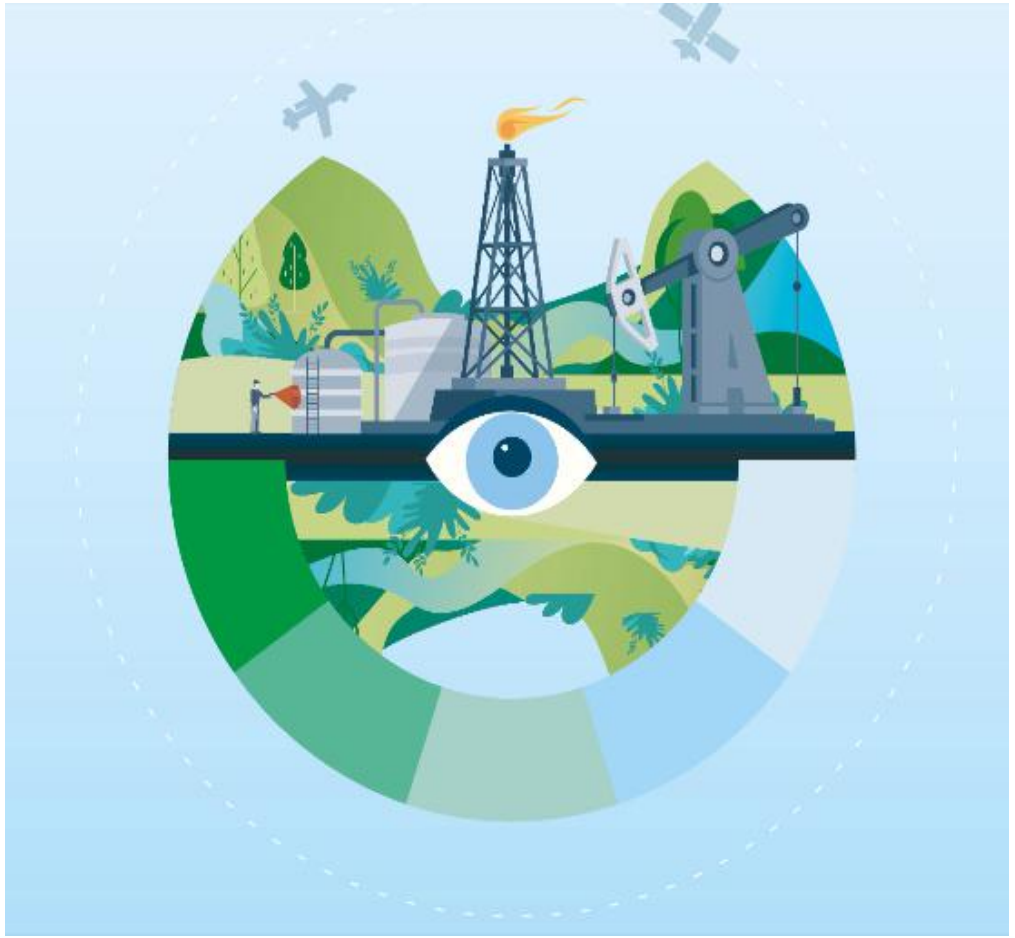
Sherwin et al. (preprint, 2022)



MARS – Concluding remarks

- A diverse ecosystem of methane-sensitive missions already operating; a number of powerful missions to operate soon
- MARS-Detection: a satellite-based system for the detection, quantification, and attribution of methane emissions from point sources (energy sector)
- The project team and an initial concept based on two tasks (rapid reponse and persistent sources) have been implemented - first results expected by COP27

- Potential contribution by CEOS:
  1. Facilitate access to satellite data, esp. targeted imagers such as PRISMA (ASI), EnMAP (DLR), EMIT (NASA), AHSI (MEE) and GHGSat (Canada)
  2. Help coordinate the development and consolidation of data processing methods (e.g. retrieval algorithms)
  3. Help coordinate validation efforts



Thank you for your attention!