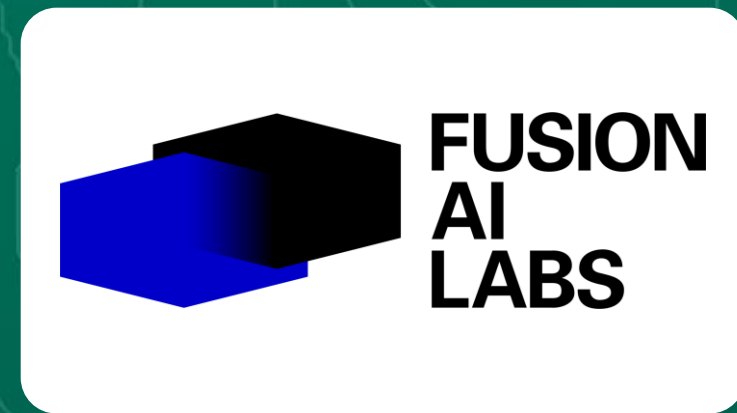




GoPilot-MethaneMapper: A Physics-Informed Platform for Sentinel-2 Methane Emission Quantification

Ali Ghandour¹, Hasan Nasrallah², Cristiano Nattero³, Nicolò Ginatta³, Andrea Pescino³

¹ National Center for Remote Sensing, CNRS, Beirut, Lebanon ² RASID SAS, Paris, France ³ FusionAILabs, Genova, Italy



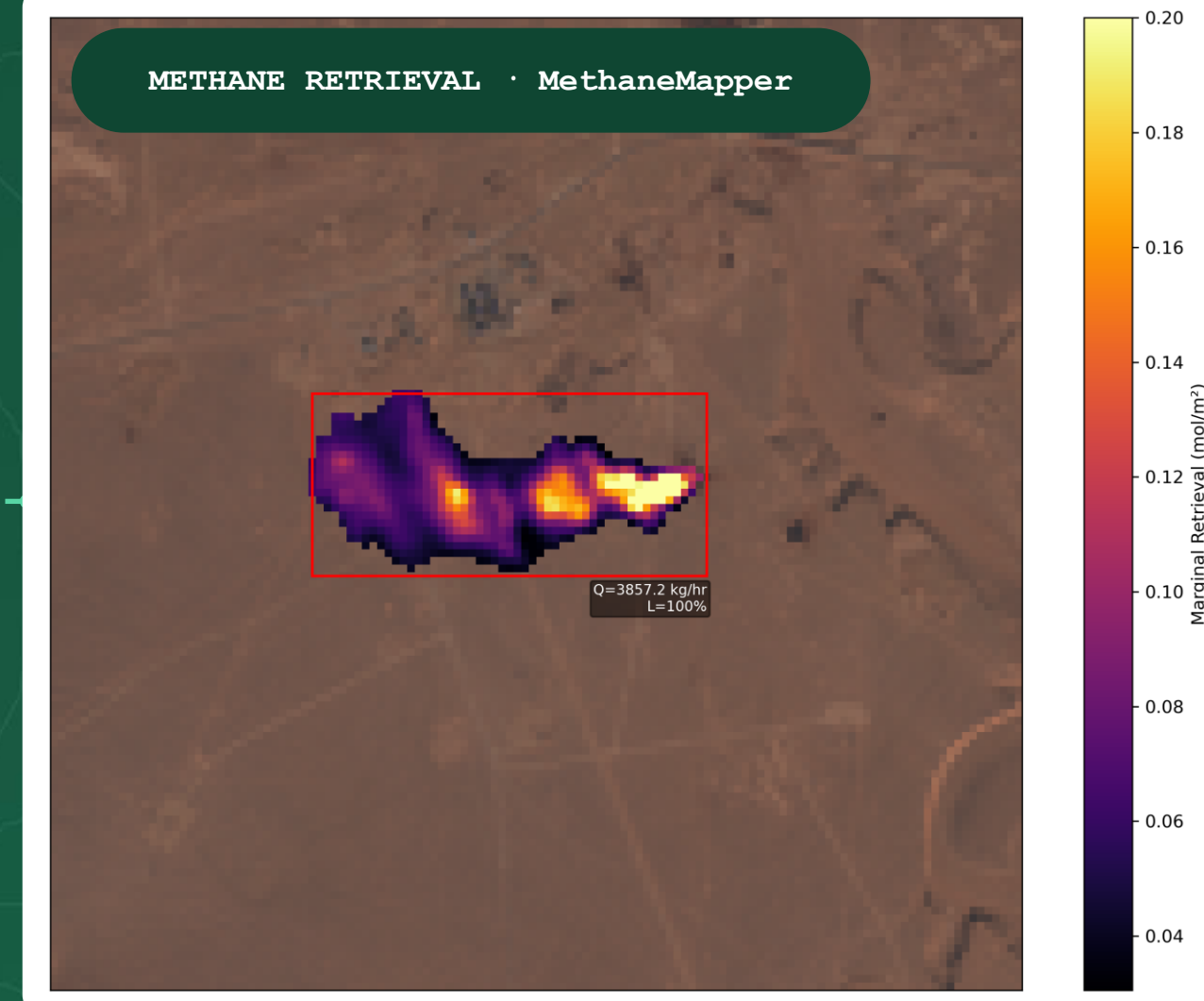
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USE CASE · UTGA — TABANKOURT, ALGERIA

One sentence in.
A plume, its flux and a map out.

PROMPT

"Check the UTGA gas treatment facility at Tabankourt, Algeria, for methane plumes on 3 January 2024."



3,857 kg/hr

PLUME FLUX · Q

L = 100%

DETECTION SCORE

3 Jan 2024

S2 ACQUISITION

28.64°N 7.62°E

SITE LOCATION

UNDER THE HOOD

USER Web app · QGIS plugin · API

AGENT GoPilot · Claude on Amazon Bedrock AgentCore

TOOLS GoServer MCP · 150+ geospatial tools

MODEL MethaneMapper v1.2 · serverless GPU, scales to zero

OUTPUT GeoJSON plume · COG rasters · PNG · analyst note

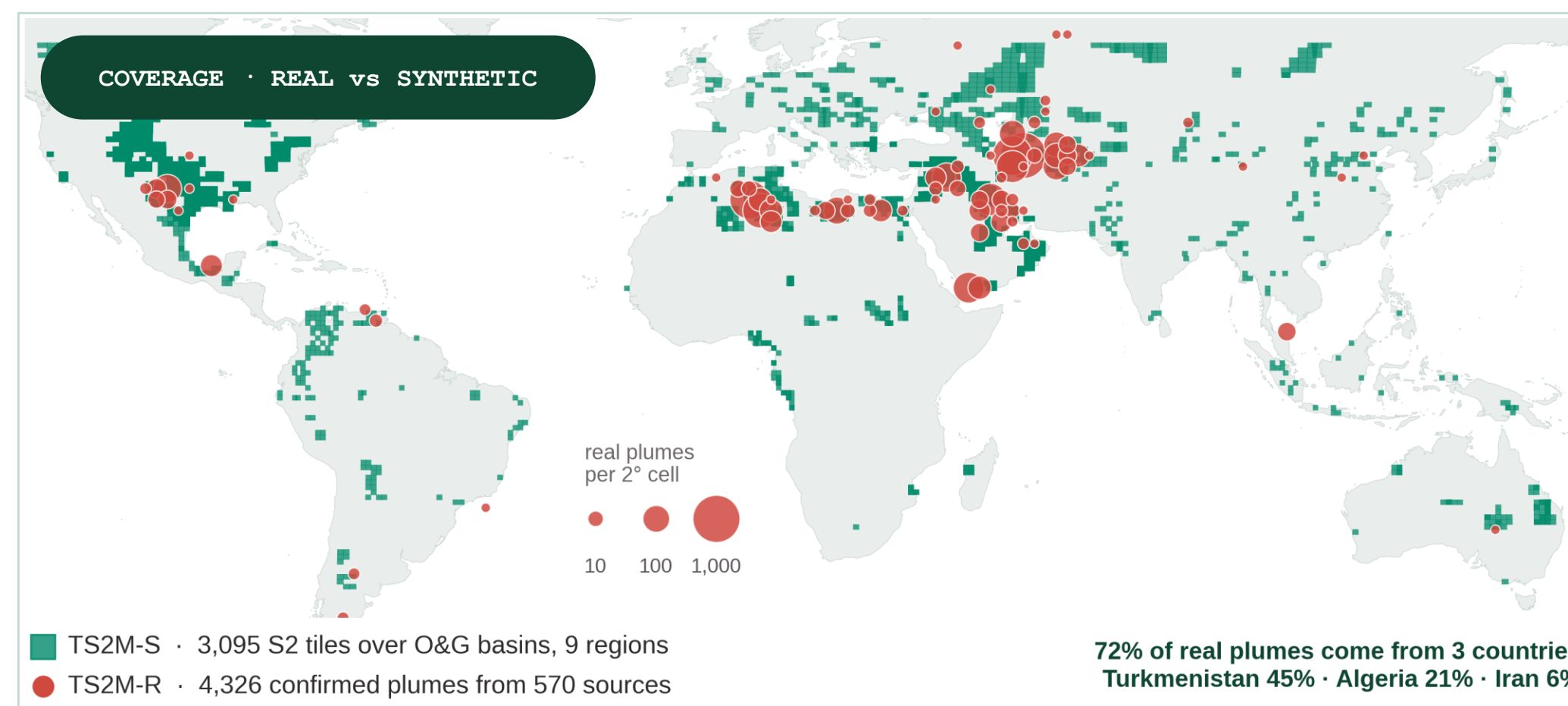
01 Motivation

Methane causes ~80× the warming of CO₂ over 20 years, and a small number of oil & gas point sources emit a large share of it. Sentinel-2 sees many of them: global, every 5 days, 20 m SWIR, free.

The bottleneck is training data, not the satellite.

02 Why Synthetic Data?

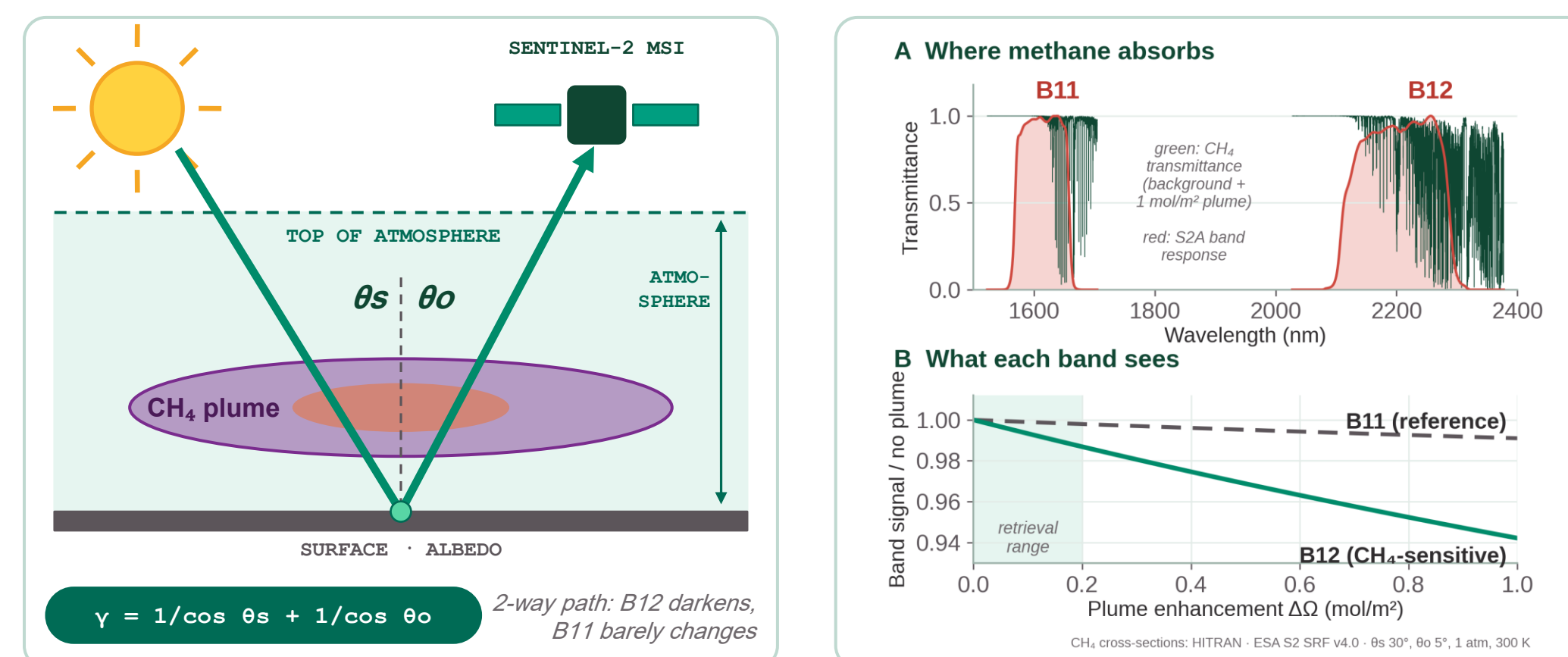
REAL DATA	SYNTHETIC DATA (TS2M-S)
Noisy labels: plumes have no crisp edge	Exact labels: the inserted concentration is known
Scale: 4,000+ confirmed S2 plumes	~[550k] samples, generated on demand
Bias: a few hotspots dominate	Backgrounds from 3,095 tiles worldwide
Flux is back-calculated	Emission rate is a controlled input



03 The Physics

CH₄ absorbs strongly in B12 (~2190 nm) and only weakly in B11 (~1610 nm), so a plume darkens B12 relative to B11. We measure the fractional change of the band ratio:

$$\text{frac} = 1 - (B12'/B11') / (B12/B11) \quad \text{frac} > 0 \Rightarrow \text{CH}_4$$



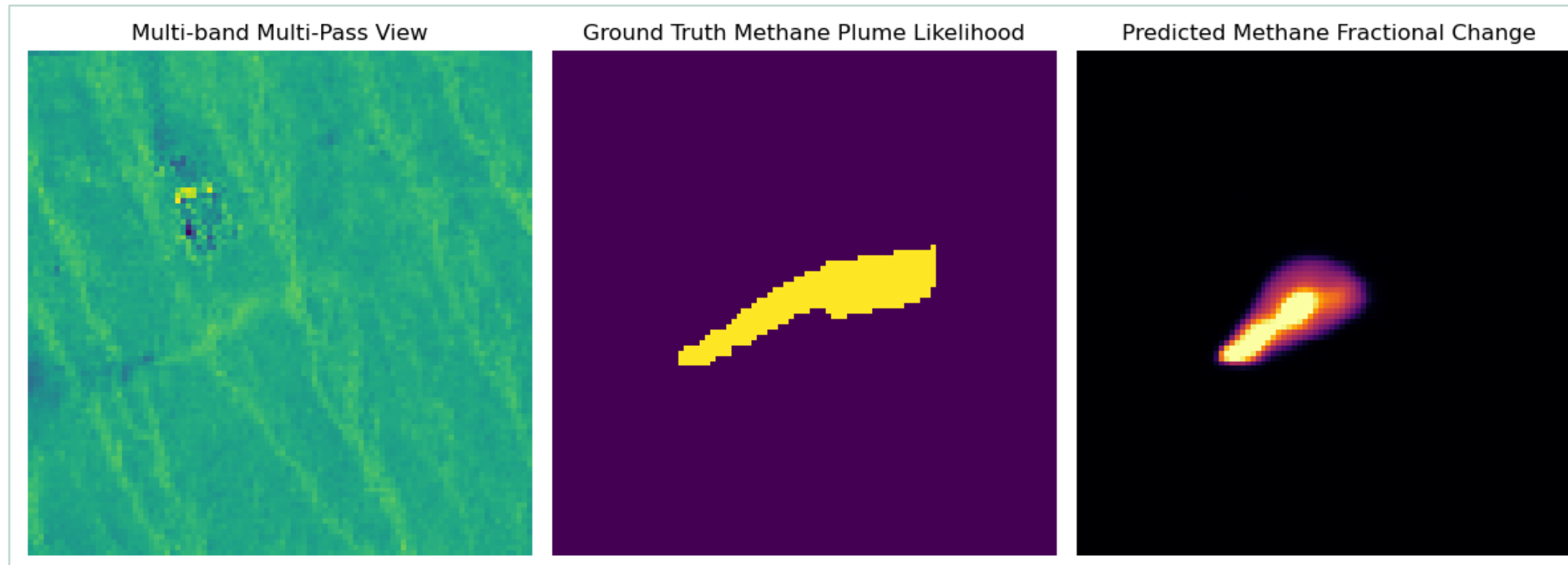
04 TS2M-S Pipeline

- Radiative transfer** ESA SRFs + HITRAN → 57 lookup tables (3 satellites × 19 sun angles)
- Plume simulation** Gaussian puff + turbulent wind → 25k shapes at 1000 kg/hr
- Scene sampling** Element84 STAC → S2 L1C target, T-90 ×2, T-365 + SCL, 2021–2025
- Plume insertion** Rescale to 500–50,000 kg/hr, rotate, place on valid surface; B11/B12 only
- Labels** Synthetic image · frac map · plume mask · source point · exact flux

DIFFICULTY 30% weak · 50% moderate · 20% strong

05 Datasets at a Glance

	TS2M-S (TRAIN)	TS2M-R (REAL VALIDATION)
Samples	~[550k] generated · [100k] used	4,000+ plumes
Source	Synthetic plumes in real S2 scenes	UNEP Eye on Methane, S2-confirmed
Per sample	Target + 3 refs, 13 bands, 128×128 @ 20 m	Target + 3 refs, 13 bands
Labels	frac + mask + exact flux	Rasterised plume polygon
Test split	TS2M-Synt 6K (held out)	TS2M-V2



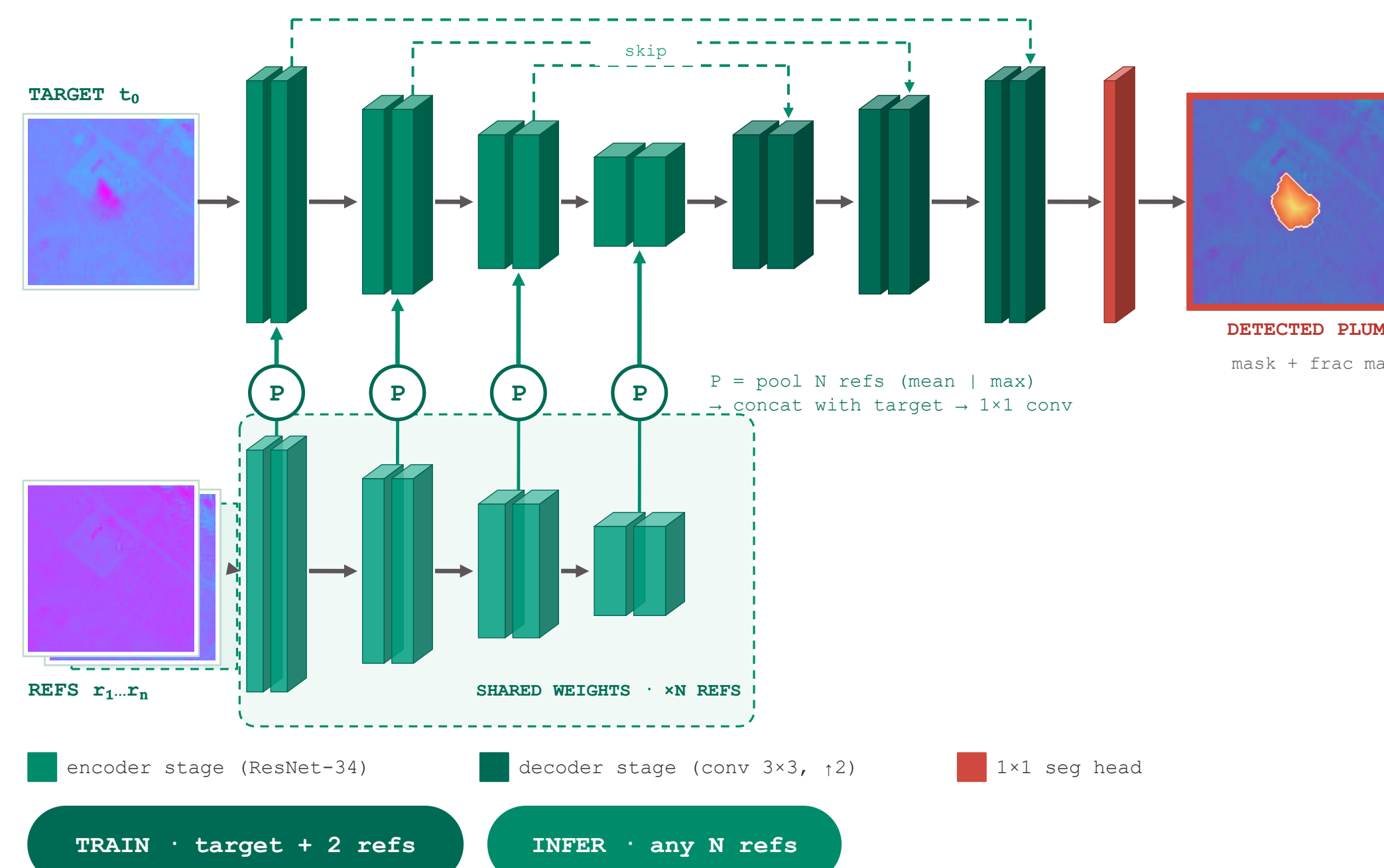
Held-out synthetic sample: multi-pass input · ground-truth plume · predicted fractional change.

Key Takeaways

- Physics-based synthetic data removes the label, scale and bias limits of real methane data.
- Trained only on synthetic data, MethaneMapper recovers 75%+ of confirmed real plumes.
- Inside GoPilot, detection and flux estimation become a single question.

06 Model: CompUNet

One shared encoder reads the target and every reference image. Reference features are pooled per scale (mean or max), concatenated with the target's and projected back by a 1×1 conv, then decoded by a U-Net.



07 Detection on Real Plumes

MODEL · TS2M-R	RECALL	PREC.	F1	IoU
MethaneMapper (synthetic only)	82%	73%	75%	70%
Same model, trained on real only	42%	35%	38%	30%

75%+ of confirmed real Sentinel-2 plume events recovered, with no real data in training.

10 GoPilot in Action

PROMPT
"Check the gas facility at Wa'ad Al Shamal, Saudi Arabia, for a methane plume on 23 August 2025."

- RETURNED IN ONE TURN
- Plume polygon (GeoJSON layer)
 - MBMP / MBSP index cross-check
 - True-colour composite + previews
 - Written analyst note

One chat turn: MethaneMapper detection, independent spectral-index cross-check and an analyst note, delivered as map layers and files.

08 Detections in the Wild



MethaneMapper retrievals over oil & gas sites in five countries, 2023–2025; flux Q per detected plume.

09 Emission Quantification

Each plume gets a flux Q from its retrieved column enhancement (mol/m²) and wind: [method, e.g. IME]. Estimates span 200 kg/hr to 35 t/hr.

