Automated detection and monitoring of methane super-emitters using satellite data

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Summary

We have designed and trained a two-step machine learning approach to automatically detect methane plumes in TROPOMI data. We apply these models to all 2021 TROPOMI data and find 2974 manually-verified methane plumes. We find plumes from both known and unknown sources originating from various anthropogenic activities. Based on our detections, we then "tip-and-cue" high-resolution satellite instruments to identify the exact sources responsible for these plumes. The identification and monitoring of these super-emitters with large mitigation potential is paramount to reach the goals of the Global Methane Pledge.

Project context

A reduction in anthropogenic methane emissions is vital to limit near-term global warming and has thus been recognized as an international priority. A small number of so-called super-emitters is responsible for a disproportionally large fraction of total methane emissions. Since late 2017, the TROPOspheric Monitoring Instrument (TROPOMI) has been in orbit providing daily global coverage of methane mixing ratios at a resolution of up to 7x5.5 km^2, enabling the detection of these super-emitters. However, TROPOMI produces millions of observations each day, which makes manual inspection infeasible.

Methodology

We use two machine learning (ML) models in sequence to detect plumes in the TROPOMI methane data (Fig 2). First, we apply a Convolutional Neural Network (CNN, Fig 1) to detect plume-like structures in the methane data. We then use additional data to distinguish between genuine methane plumes and retrieval artefacts using a support vector classifier (SVC). We perform automated quantifications on all plumes using the Integrated Mass Enhancement (IME) method.

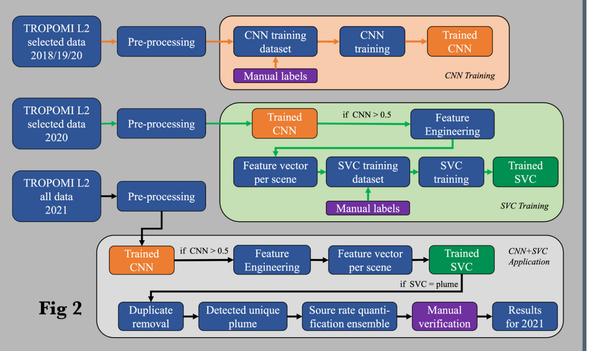


Fig 2

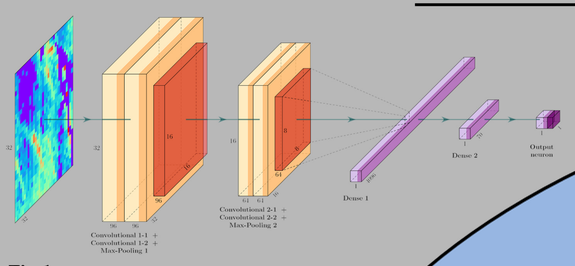
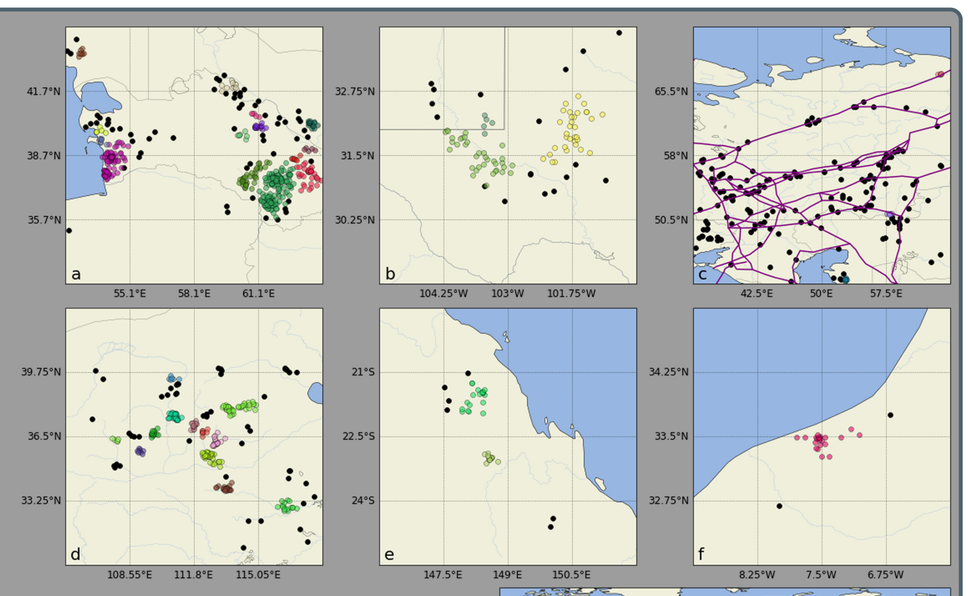


Fig 1

Results

We apply the trained ML models to all 2021 data. We detect 2974 plumes with a mean estimated source rate of 44 t h and 5-95th percentile range of 8-122 t h^{-1}. These emissions originate from 94 persistent emission clusters and hundreds of transient sources. We find that most detected plumes are related to urban areas / landfills (35%), followed by plumes from gas infrastructure (24%), oil infrastructure (21%) and coal mines (20%).

We see clusters of detections in known oil and gas exploitation regions in Turkmenistan (Fig 3a) and the Permian Basin in the US (Fig 3b). We also see many detections at coal mines in China (Fig 3d) and Australia (Fig 3e). Along the pipeline network in Russia and surrounding countries we detect many transient plumes (3c). We also find 20+ plumes over the city of Casablanca, Morocco (3f).



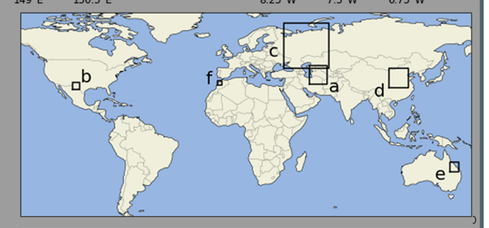


Fig 3

2974 TROPOMI detected methane super-emitters in 2021

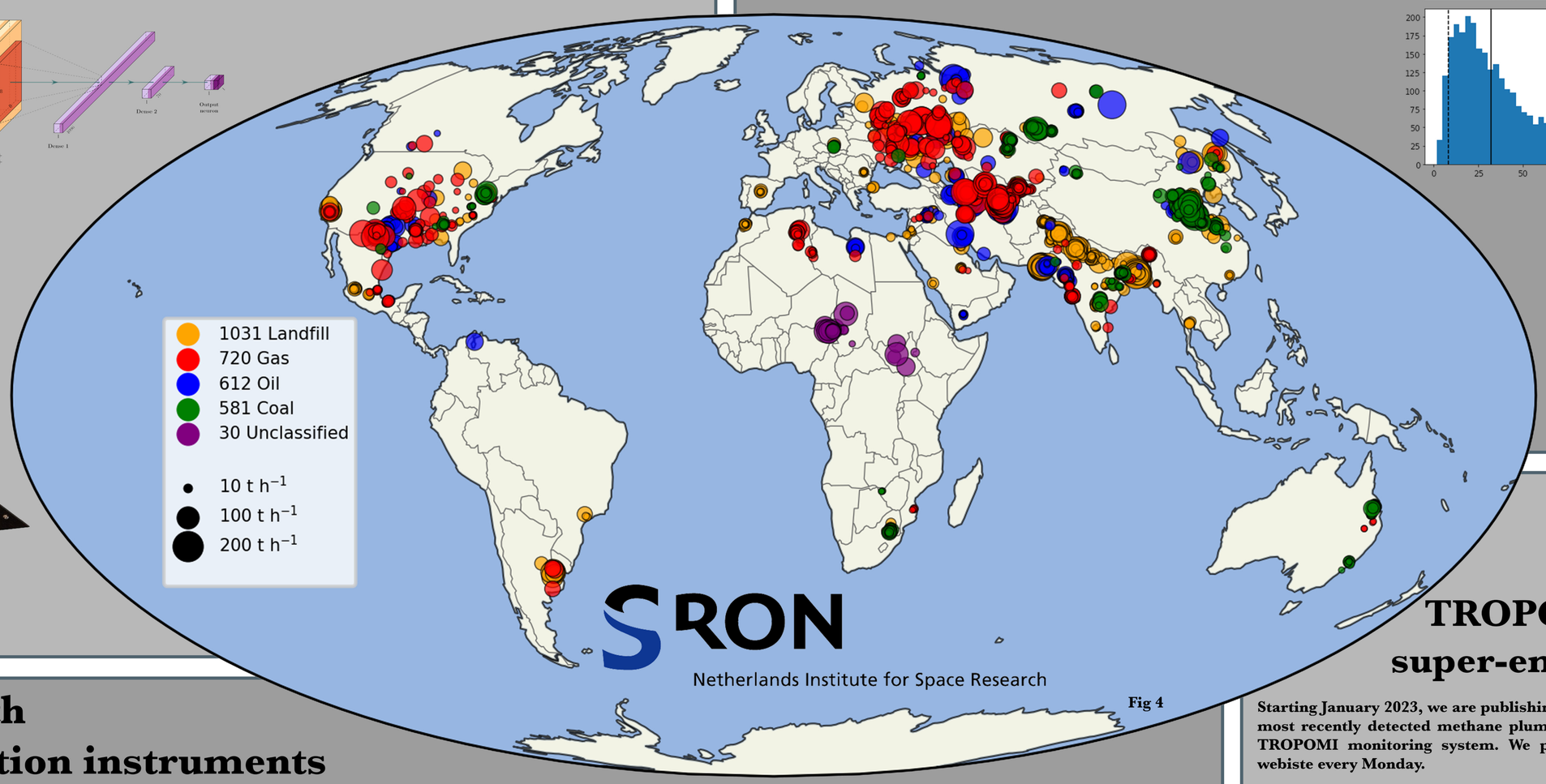
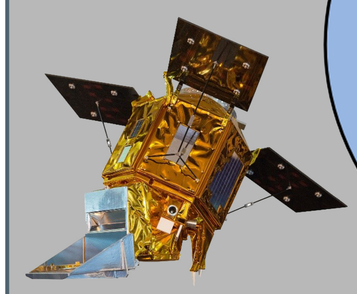


Fig 4



TROPOMI

Synergy with high-resolution instruments

Based on our TROPOMI detections, we "tip-and-cue" high-resolution instruments (GHGSat, PRISMA and Sentinel-2) to detect and analyze both persistent (e.g. Fig 5 and Fig 7) and transient (Fig 6) facility-level emissions underlying the TROPOMI plumes. We find emissions from landfills (e.g. Fig 5) and fossil fuel exploitation facilities, for the latter we find up to ten facilities contributing to one TROPOMI detection.

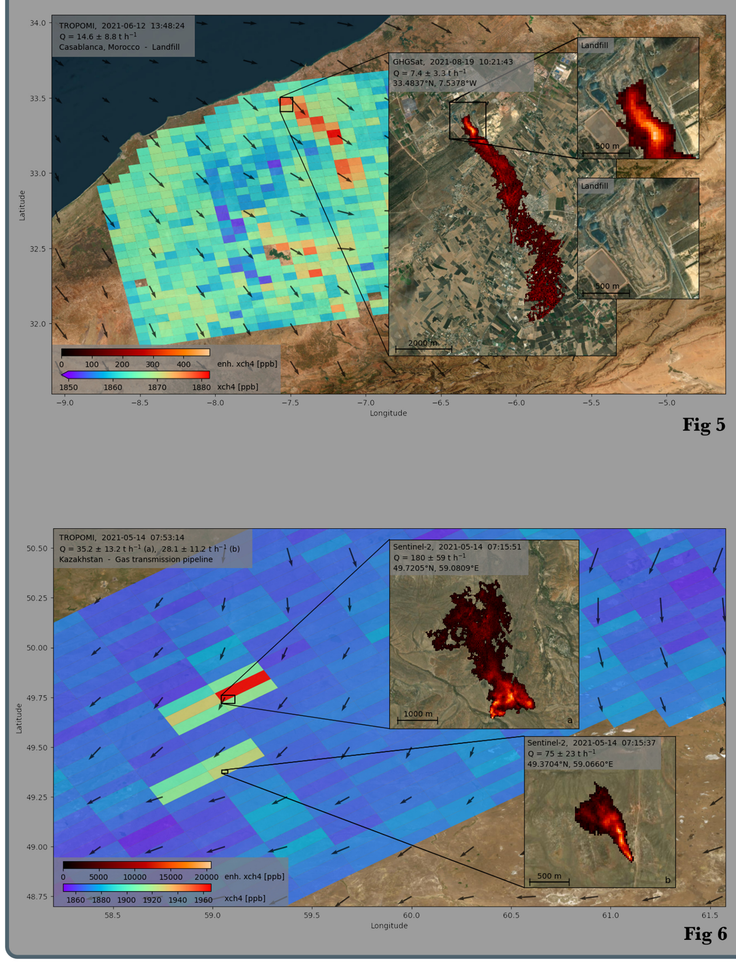


Fig 5

Fig 6

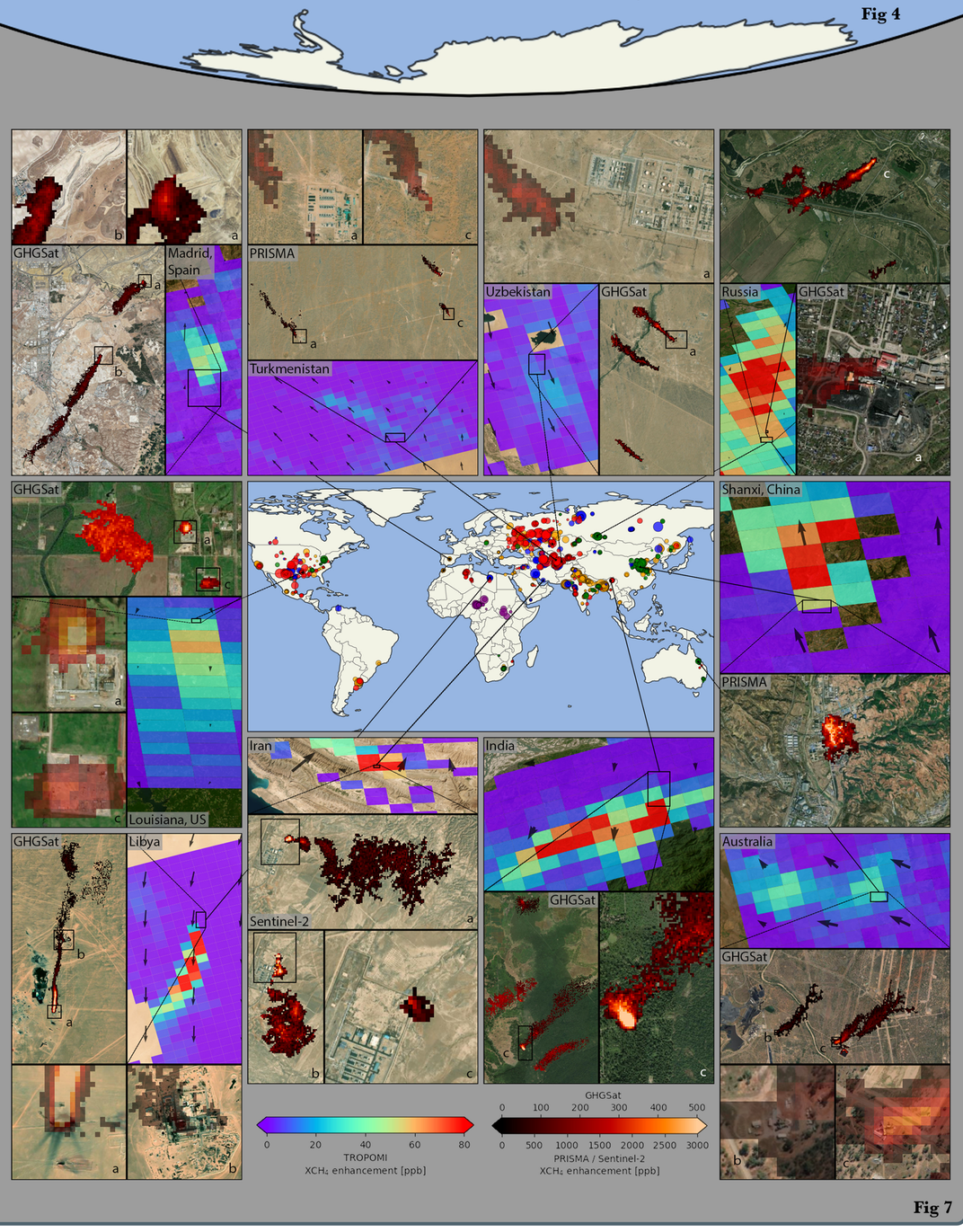


Fig 7

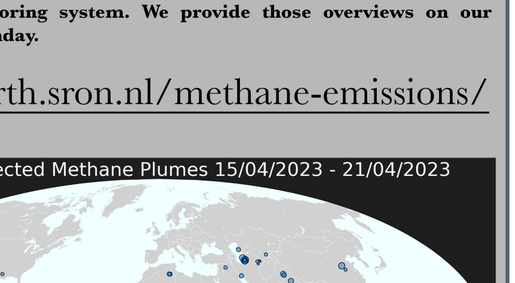


Fig 3

Weekly overviews of TROPOMI-detected super-emitter plumes

Starting January 2023, we are publishing weekly overviews (Fig 8) of the most recently detected methane plumes detected with our automated TROPOMI monitoring system. We provide those overviews on our webiste every Monday.

https://earth.sron.nl/methane-emissions/

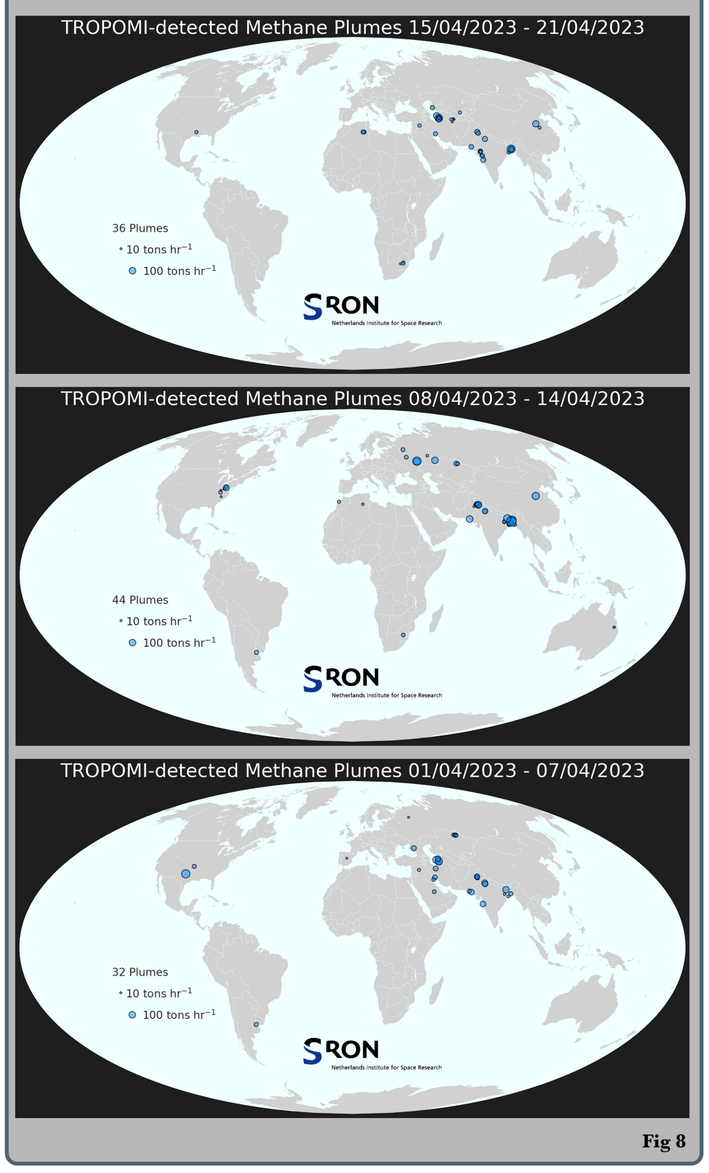


Fig 8