Investigating the potential for detecting urban methane point sources over South Korea using EMIT observations

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6. 12. 2025

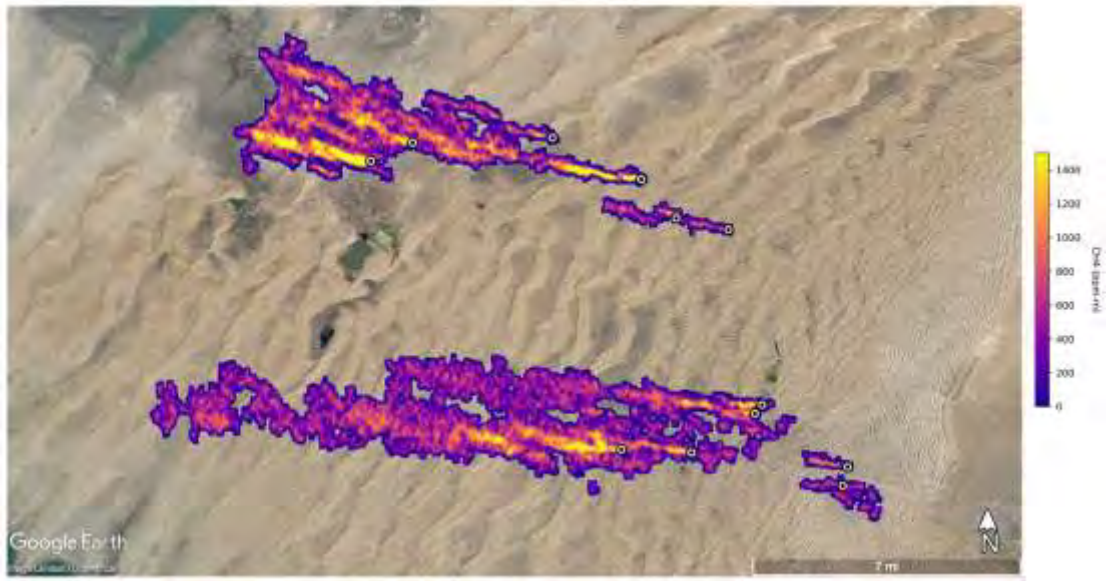
21st International Workshop on Greenhouse Gas Measurements from Space (IWGGMS-21)

IWGGMS-21
21ST INTERNATIONAL WORKSHOP ON GREENHOUSE GAS MEASUREMENTS FROM SPACE

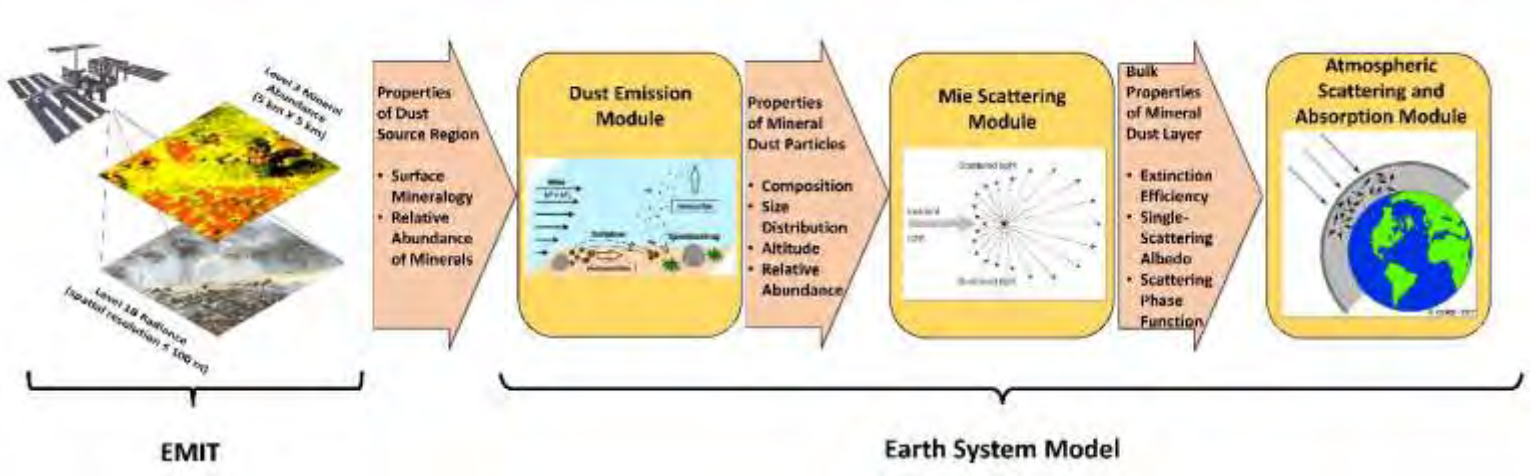
- Why focus on methane?
  - Methane is the second most abundant anthropogenic GHG after carbon dioxide. Methane is more than 28 times as potent as carbon dioxide at trapping heat in the atmosphere over 100 years.
  - Knowing exactly where methane emissions are coming from, down to the level of an individual facility or a piece of equipment, can inform the best solutions to tackle the problem.
  - Satellite remote sensing has a unique ability to monitor global methane emission: provide extensive spatial and temporal coverage

<Methane plumes detected by EMIT satellite sensor>

<Clusters of methane plumes in Turkmenistan from EMIT satellite sensor>



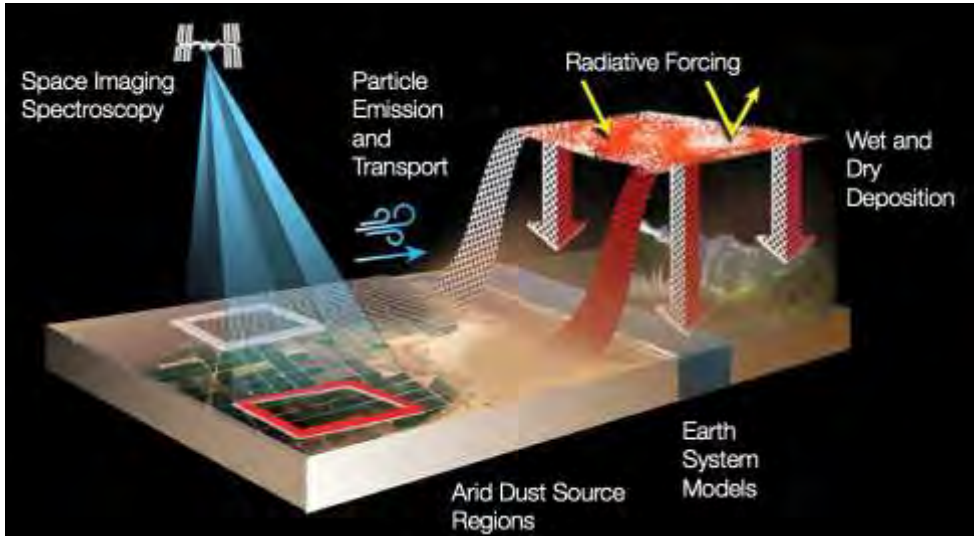
EMIT: Earth Surface Mineral Dust Source Investigation



EMIT is an instrument onboard the International Space Station (ISS)

➢ Science Goals and Objectives of EMIT

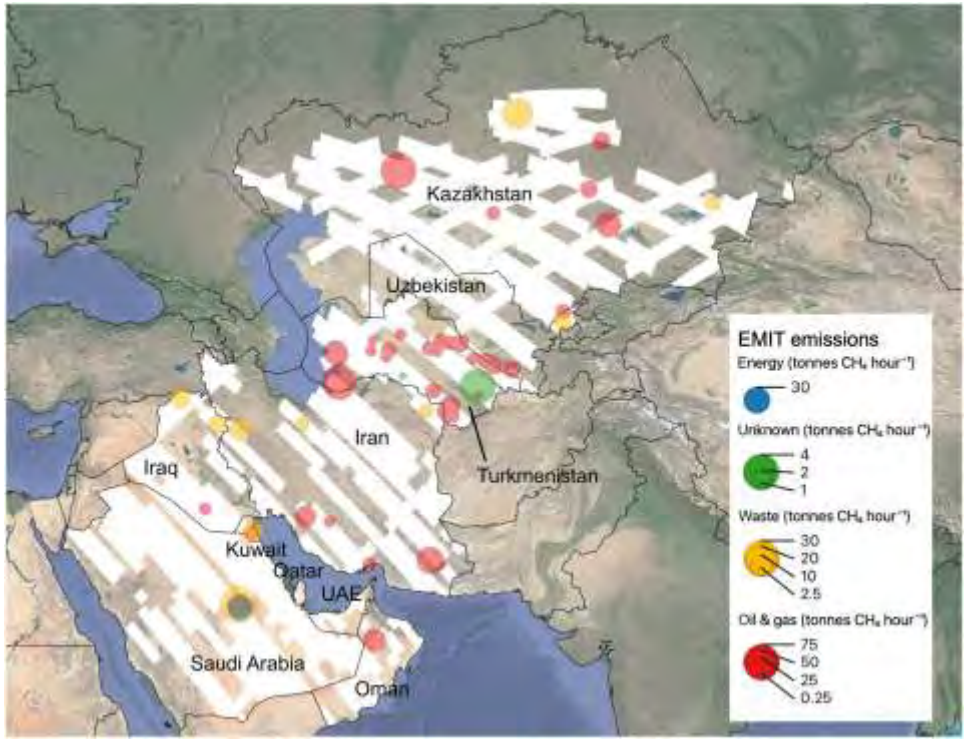
1. To acquire remote-sensing measurements of the **abundance of surface minerals** (hematite, goethite, etc) in arid regions between 50-degree south and north latitudes
2. To deliver an improved assessment of the **heating and cooling effects of mineral dust** in Earth's atmosphere
3. To improve predictions of how future climate scenarios might change the amount and type of mineral dust emitted into Earth's atmosphere

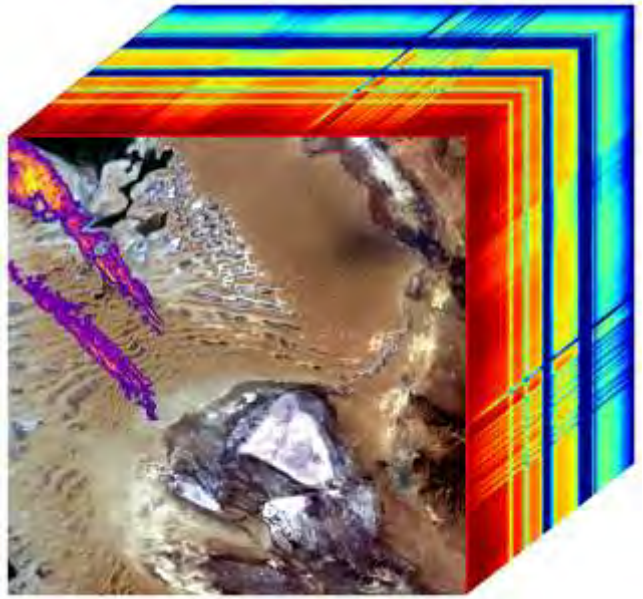


https://earth.jpl.nasa.gov/emit/science/objectives/

- Methane and carbon dioxide have distinct absorption features in the shortwave infrared (1800-2500nm) that permit the detection and mapping of point source greenhouse gas emissions with EMIT data.
- In the data EMIT has collected since being installed on the International Space Station in July, the science team has identified more than 50 “super-emitters” in Central Asia, the Middle East, and the Southwestern United States.

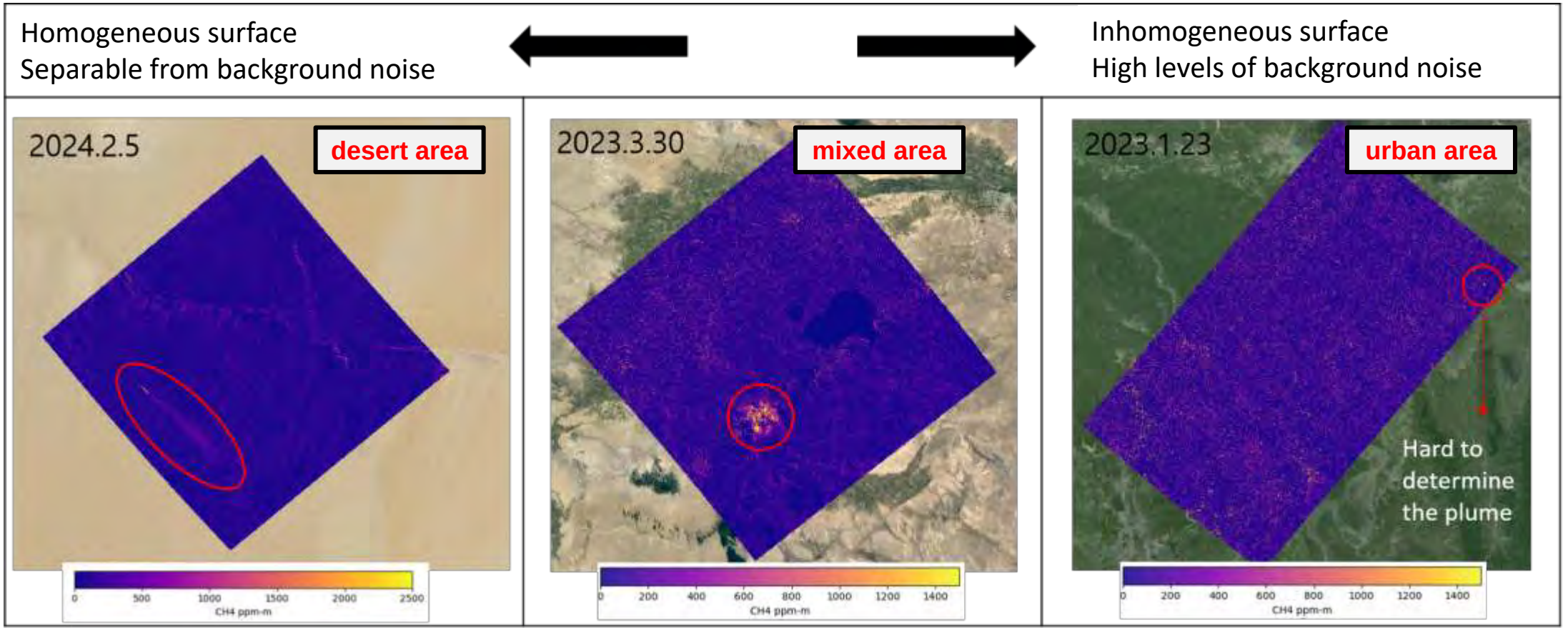
<Location, magnitude, and emission sector for methane plumes observed from EMIT>
(Thorpe et al., 2023)



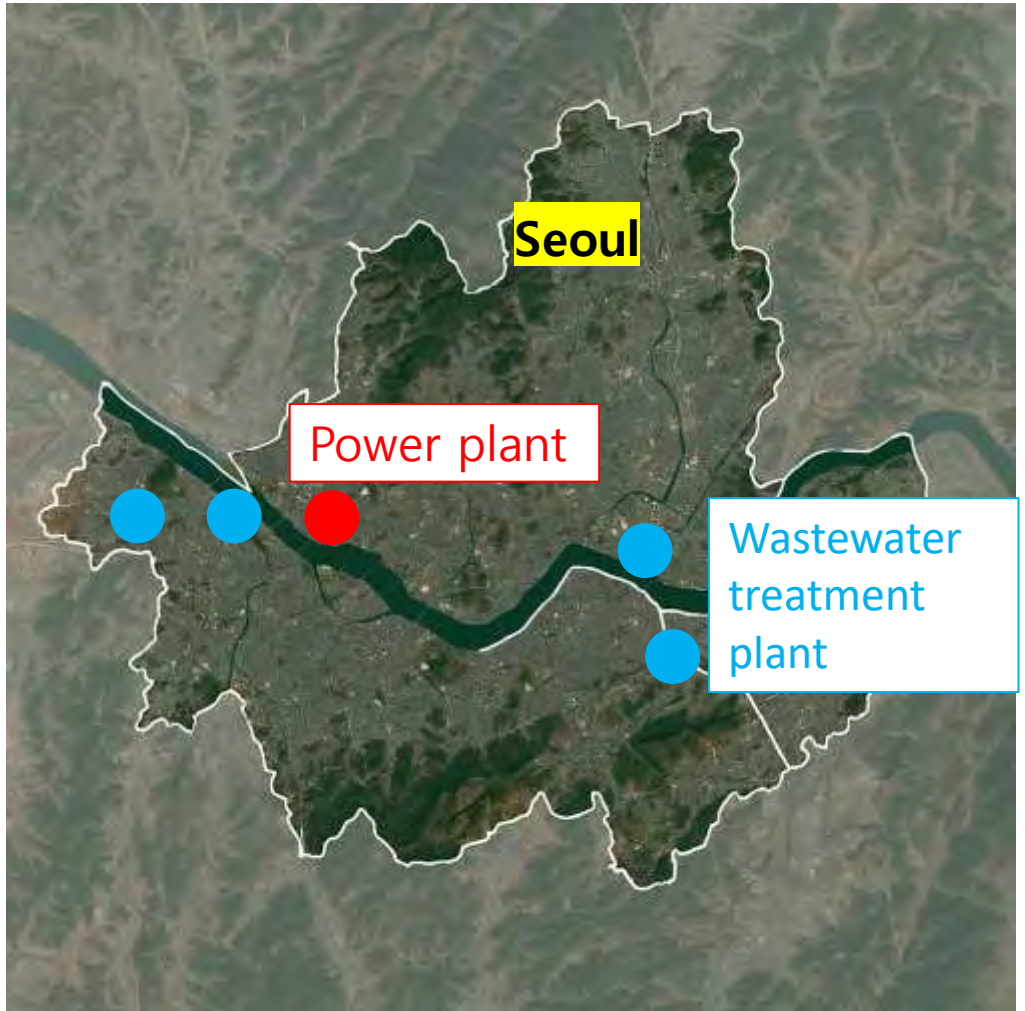


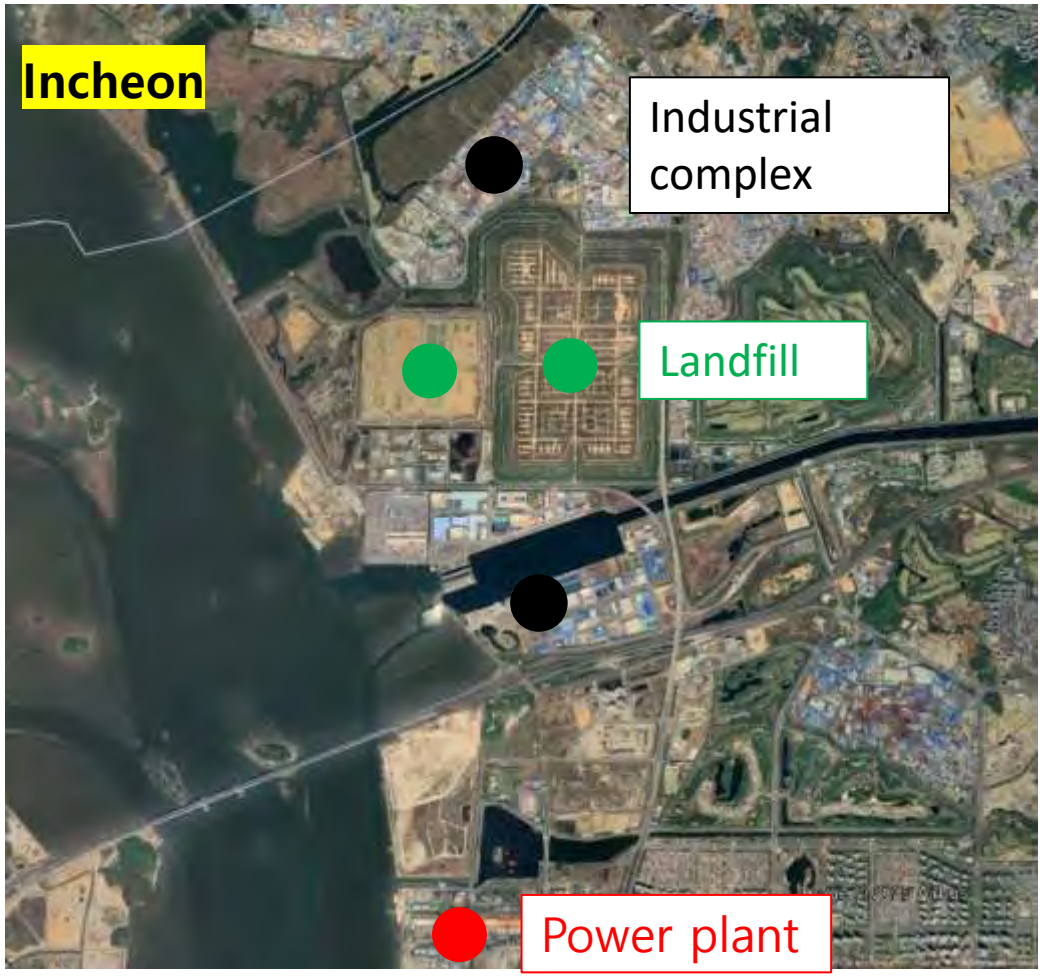
- Methane plumes (purple, orange, yellow) over Turkmenistan
- The rainbow colors are the spectral fingerprints from corresponding spots

- Methane enhancement image from the EMIT instrument (Data from https://lpdaac.usgs.gov/products/emitl2bch4enhv001)
  - ✓ Methane plume (red circle) detected by the EMIT greenhouse gas algorithm
  - ✓ The ability to determine plumes is associated with the capability to separate the noisy background and methane signal
  - ✓ Plume detection ability depends on surface type: bright and spectrally homogeneous surfaces are favorable



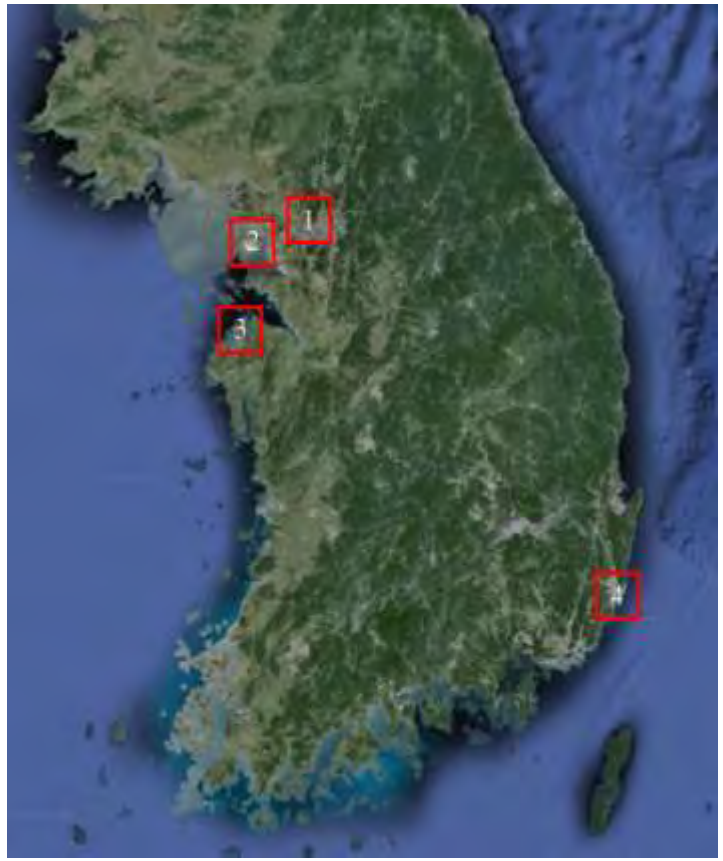
- Urban areas have numerous potential sources of methane emissions.
  - ✓ In particular, densely populated urban areas (e.g., Seoul and Incheon) are likely to contain potential methane sources, posing challenges for emission detection. (Joo et al., 2024).





- Background
  - Anthropogenic methane emissions occur due to activities such as ventilation at power plants, oil and gas production, and LNG facilities, as well as leakage from pipelines.
  - Satellites offer a capability for monitoring methane emissions due to their ability to measure reflected solar radiation in the SWIR, which can detect signals from methane absorption. Hyperspectral satellite instruments such as EMIT, PRISMA, and GHGSat utilize this ability to monitor methane emissions.
- Problem
  - However, satellites mainly detect large methane plumes emitted by super-emitters such as oil and gas companies. Estimating methane emissions from urban areas containing fossil fuel industries with inhomogeneous surfaces is very challenging because the diverse surface structures (e.g., solar panels, roads) cause retrieval artifacts (Cusworth et al., 2019; Guanter et al., 2021).
- Objective
  - In this study, methane enhancements were estimated using EMIT satellite observation data and compared with ground mobile observation to find the methane point sources in urban areas.

- Research sites: potential methane sources in urban areas were selected



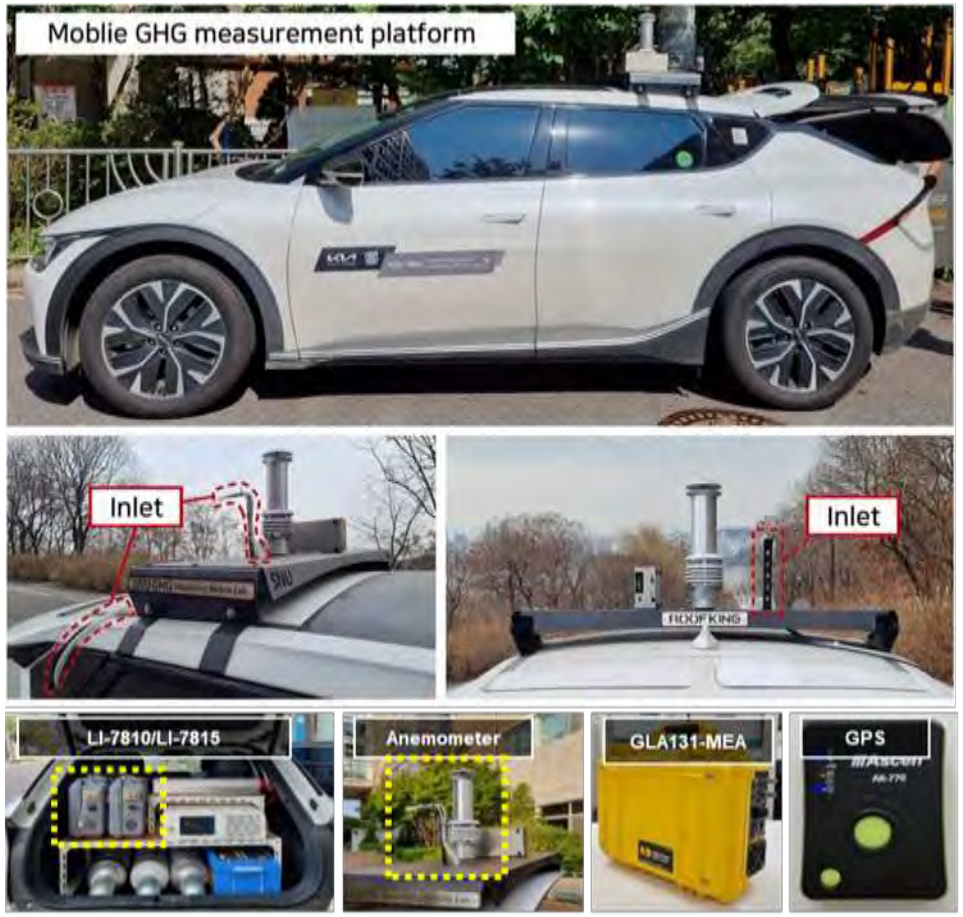
(1) Seoul power plant:

LNG gas-fired power plant

(3) Daesan and (4) Ulsan Industrial Complex:

Large petrochemical complex in South Korea

- The mobile platform employed an electric vehicle to avoid the effects of combustion from the vehicle.

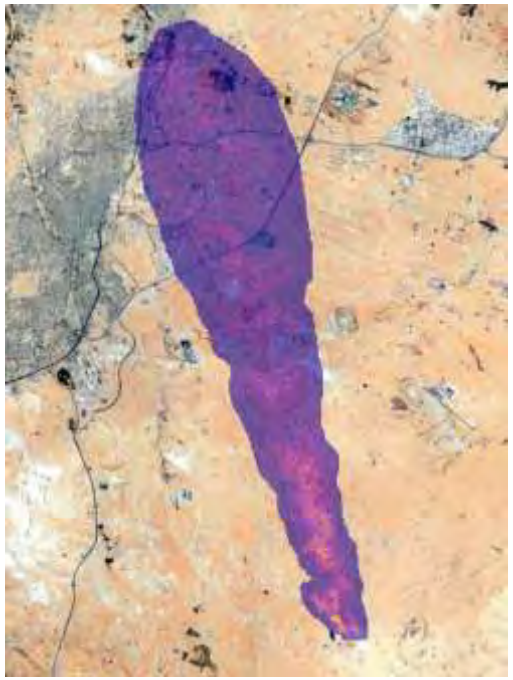


- Enhancement = Measured - background concentration
- The background concentration is defined as the median value of the observed methane concentration within ±2.5 minutes.

Instrument	Observation variables
LI-7810	CH_4, CO_2, H_2O
GLA131-MEA	CH_4, C_2H_6
WPSD-9100	Wind direction (WD), Wind speed (WS)
EOLOS-IND	Wind direction (WD), Wind speed (WS), Humidity, Temperature, Atmospheric pressure

- Methane enhancement estimated at South Korea from the EMIT observation
  - ✓ Matched filter technique (Foote et al., 2020) is used to estimate the methane enhancement.
  - ✓ The estimated methane enhancement was cropped to match the size of the methane plume provided by EMIT, revealing a similar enhancement pattern: confirming the successful retrieval of methane enhancement

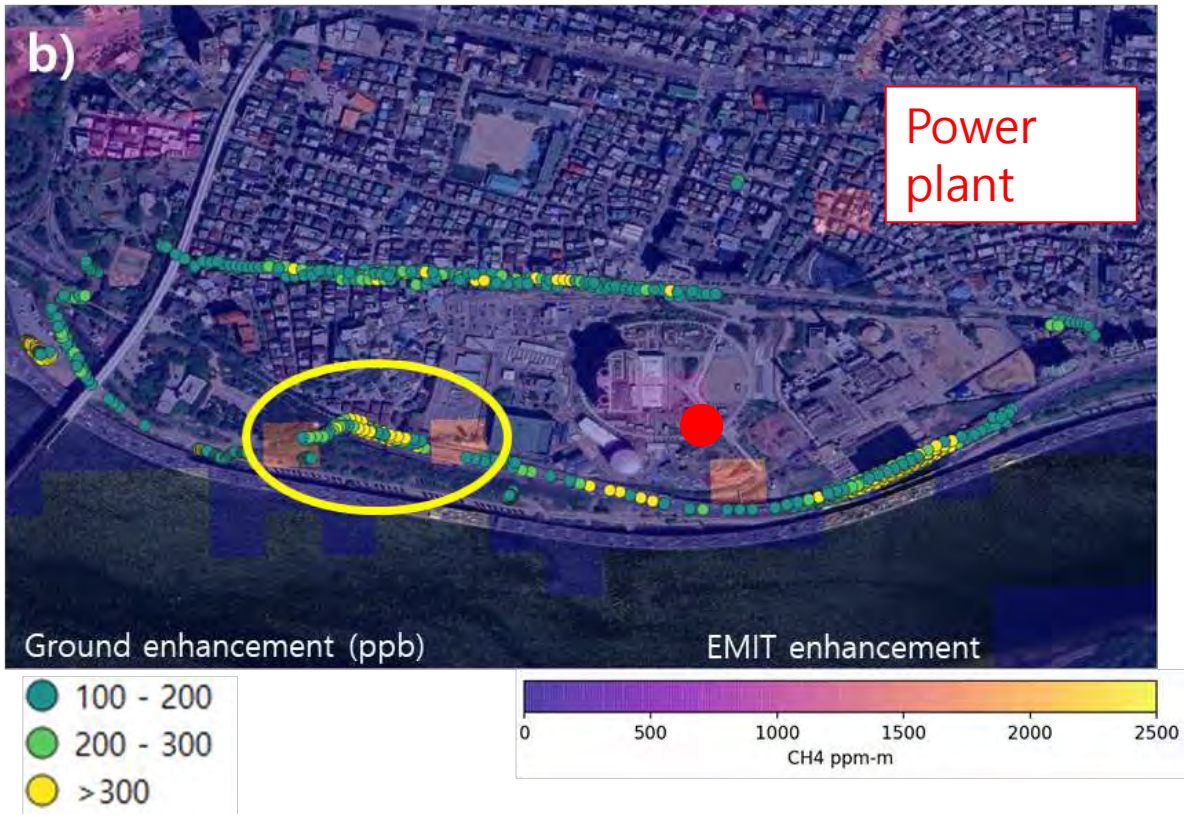
<Methane plume from EMIT L2B product>



<Methane plume from matched filter>

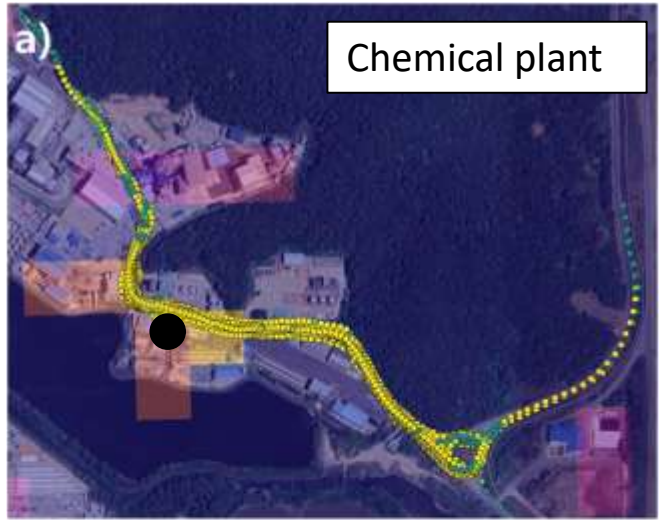
<Methane plume from EMIT L2B product>

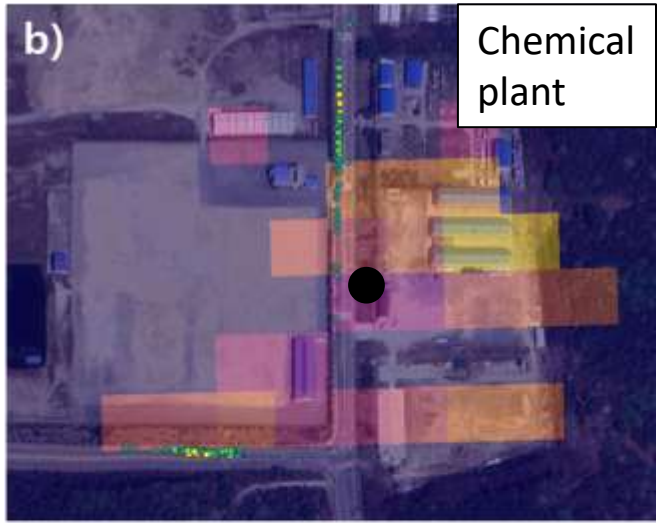
<Methane plume from matched filter>

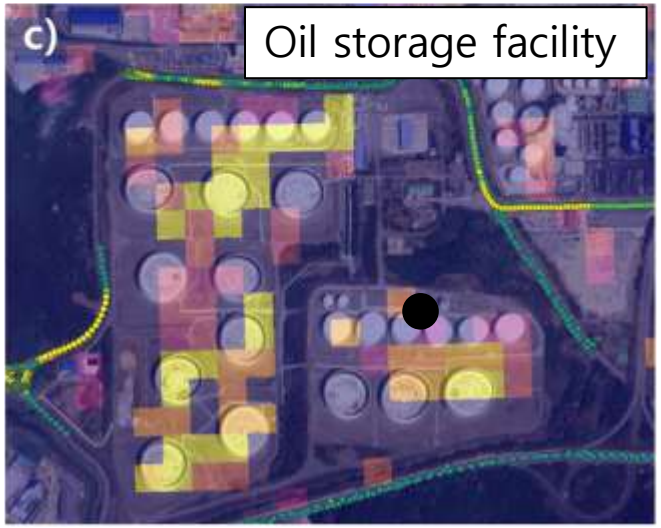


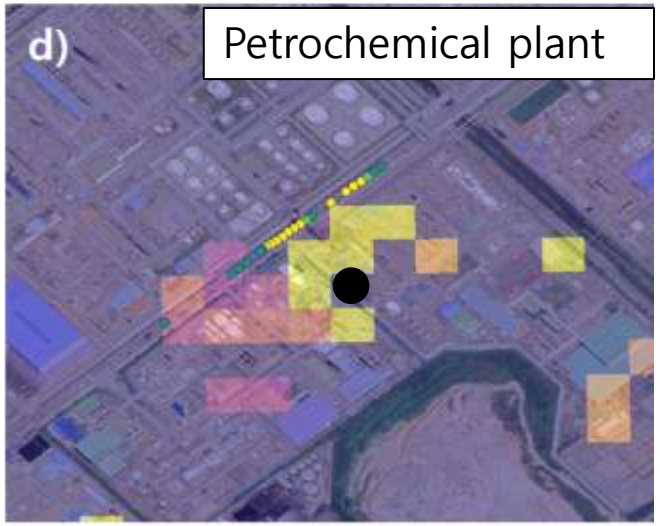
- EMIT and ground measurements detected high methane enhancement near the power plant although the observation dates are not the same.
- Since ground mobile observations and satellite enhancements are estimated using independent methods, if both observations indicate high methane concentrations in a specific area, there is a high probability that the area is an emission source.

Results – Petrochemical complex

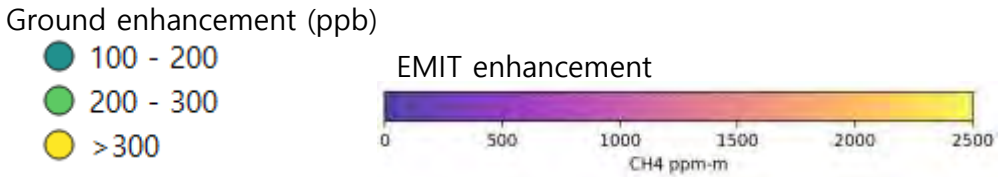




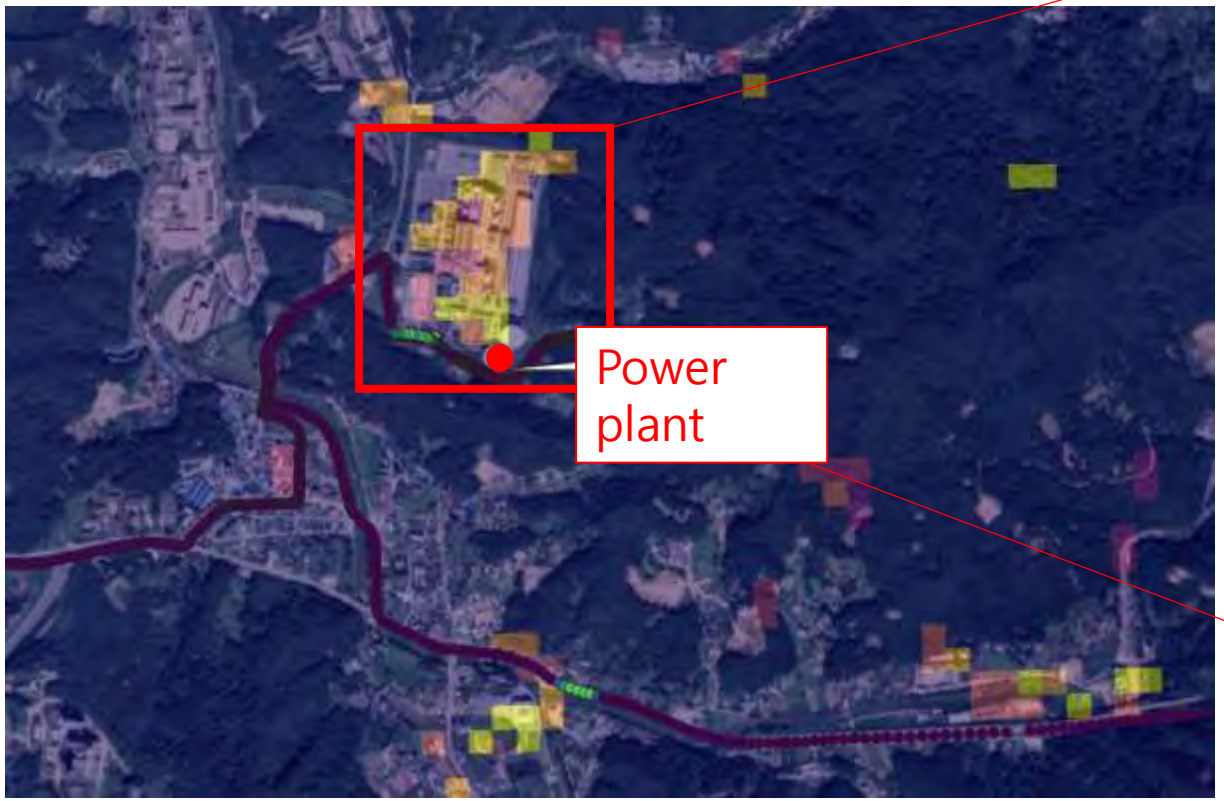


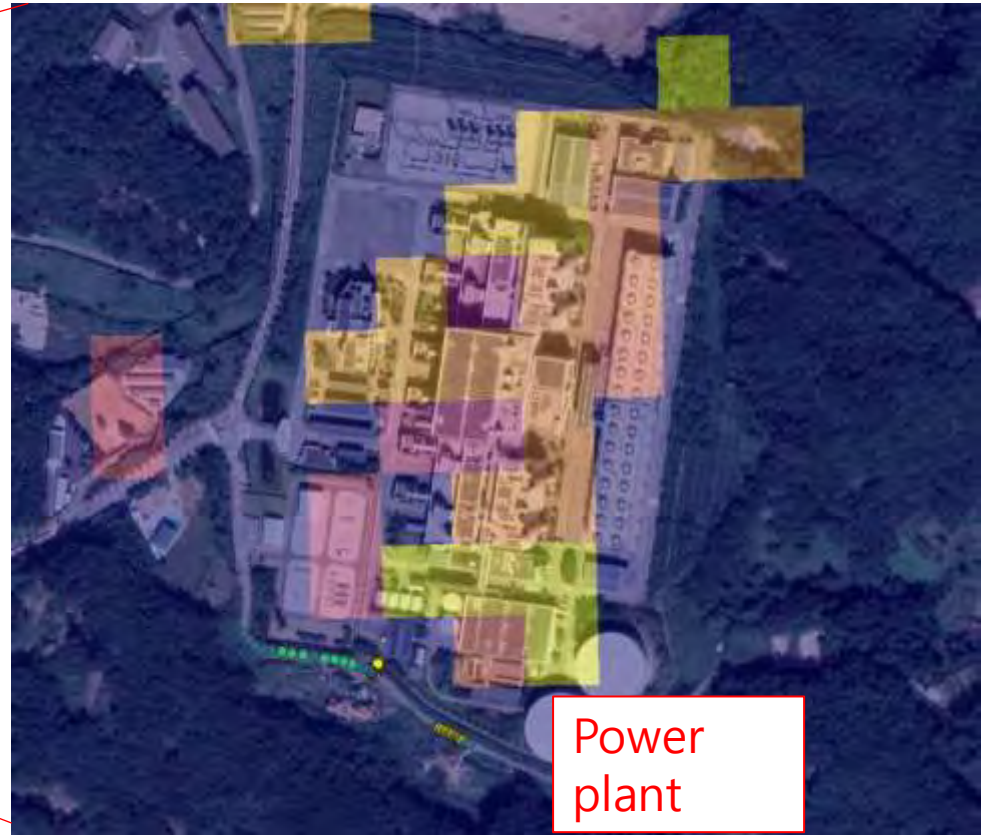


- During the entire period of ground observations, there were areas that showed a high enhancement of over 300 ppb. In these areas, EMIT also recorded high values of 2127.56 ppm-m : suggesting potential leakage or emissions
- The fact that EMIT estimated high methane enhancement in nearly the same location indicates that EMIT is capable of detecting methane point sources.



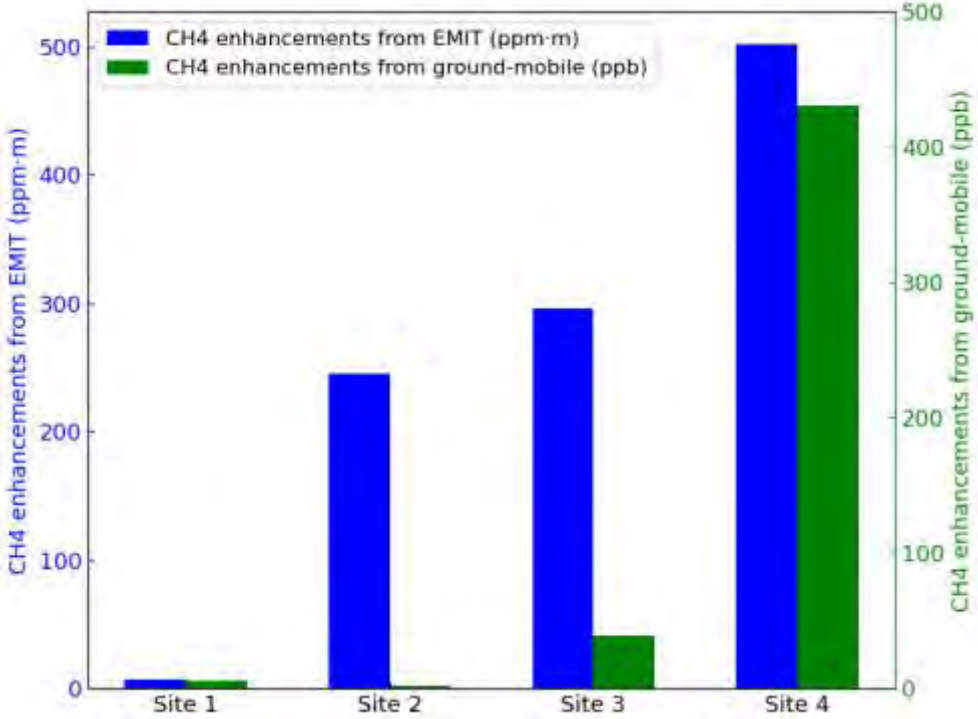
- The EMIT and ground-based mobile measurements simultaneously observed the Dongducheon Power Plant on February 14, 2025
- As in previous findings, areas in Dongducheon with high methane enhancements observed from the ground also showed elevated enhancements in the EMIT observations.





- To compare satellite and ground-based data, an area matching the size of the plume near the power plant was selected for averaging methane enhancement.
- As in previous findings, areas in Dongducheon with high methane enhancements observed from the ground also showed elevated enhancements in the EMIT observations.

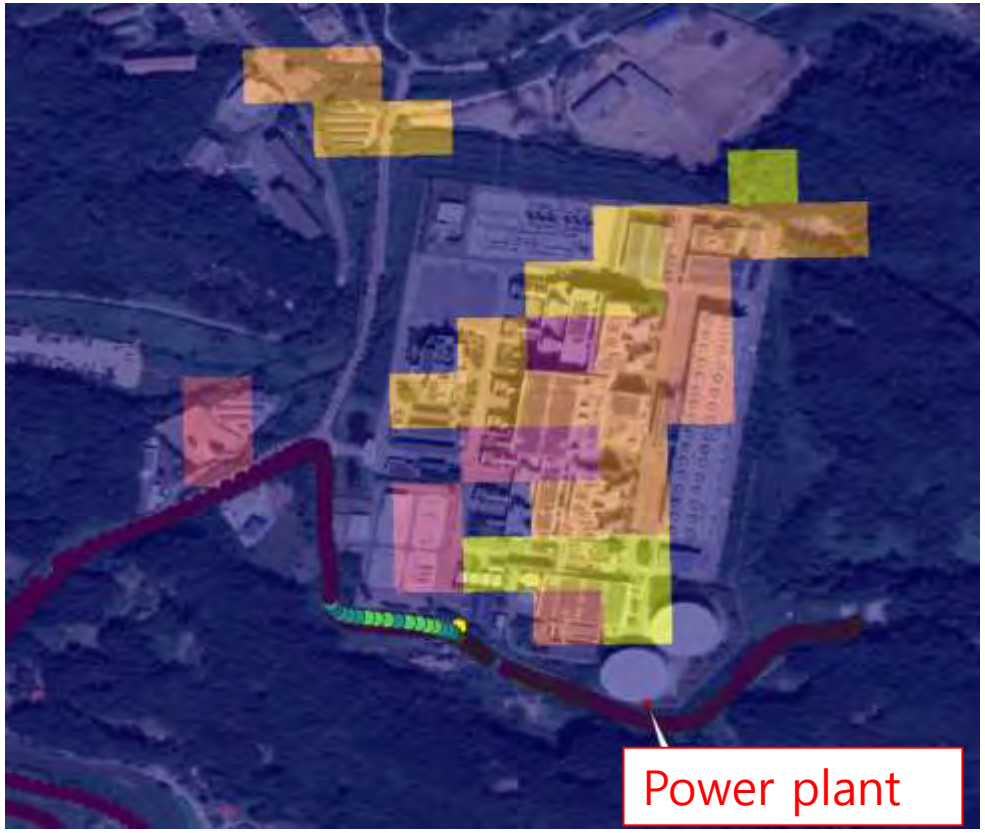
<Area-averaged methane enhancement from ground-based and EMIT observations>



➢ The average EMIT methane enhancement was calculated for each ground-based enhancement range.

✓ Only a single EMIT pixel directly matches the ground-based observation: there is a significant difference in spatial resolution between the two datasets

✓ To analyze EMIT data at a spatial scale comparable to the near-field methane plume captured by ground-based observations, a 5×5 pixel average of EMIT values was calculated around each ground observation point.



<Average EMIT methane enhancement (5×5 pixel) by ground-based enhancement range>

Obs type / Ground-based enhancement (ppb)	Ground-based enhancement (ppb)	EMIT enhancement (ppm-m)
0-100	10.152	55.440
100-200	154.687	290.112
200-300	247.996	338.040
>300	1220.971	358.533

✓ A quantitative relationship was identified, showing that higher ground-based methane enhancements tend to correspond to higher EMIT enhancement values

- **Conclusion**
  - In this study, we compared methane enhancements observed by ground-based mobile measurements in urban and industrial complex areas with those estimated by the EMIT satellite instrument, in order to assess the capability of satellites to identify methane point sources.
  - The fact that areas suspected to be methane sources based on ground observations with industrial complexes show high EMIT enhancement that demonstrates the potential of satellite observations to detect methane sources.
  - Identifying potential methane sources in the region using domain knowledge and confirming satellite methane signals with ground observations enabled the successful detection of point sources in urban areas.
  - It is necessary to develop improved algorithms to separate methane and surface feature signals and to develop next-generation satellites with high spectral and spatial resolution (e.g., the Narsha project) to identify methane emissions at the scale of specific facilities of urban point sources.