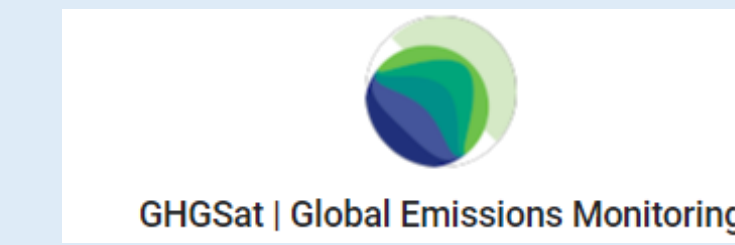


Evaluation of GHGSat Methane Emission Estimations of South Side Landfill in Indianapolis, Indiana



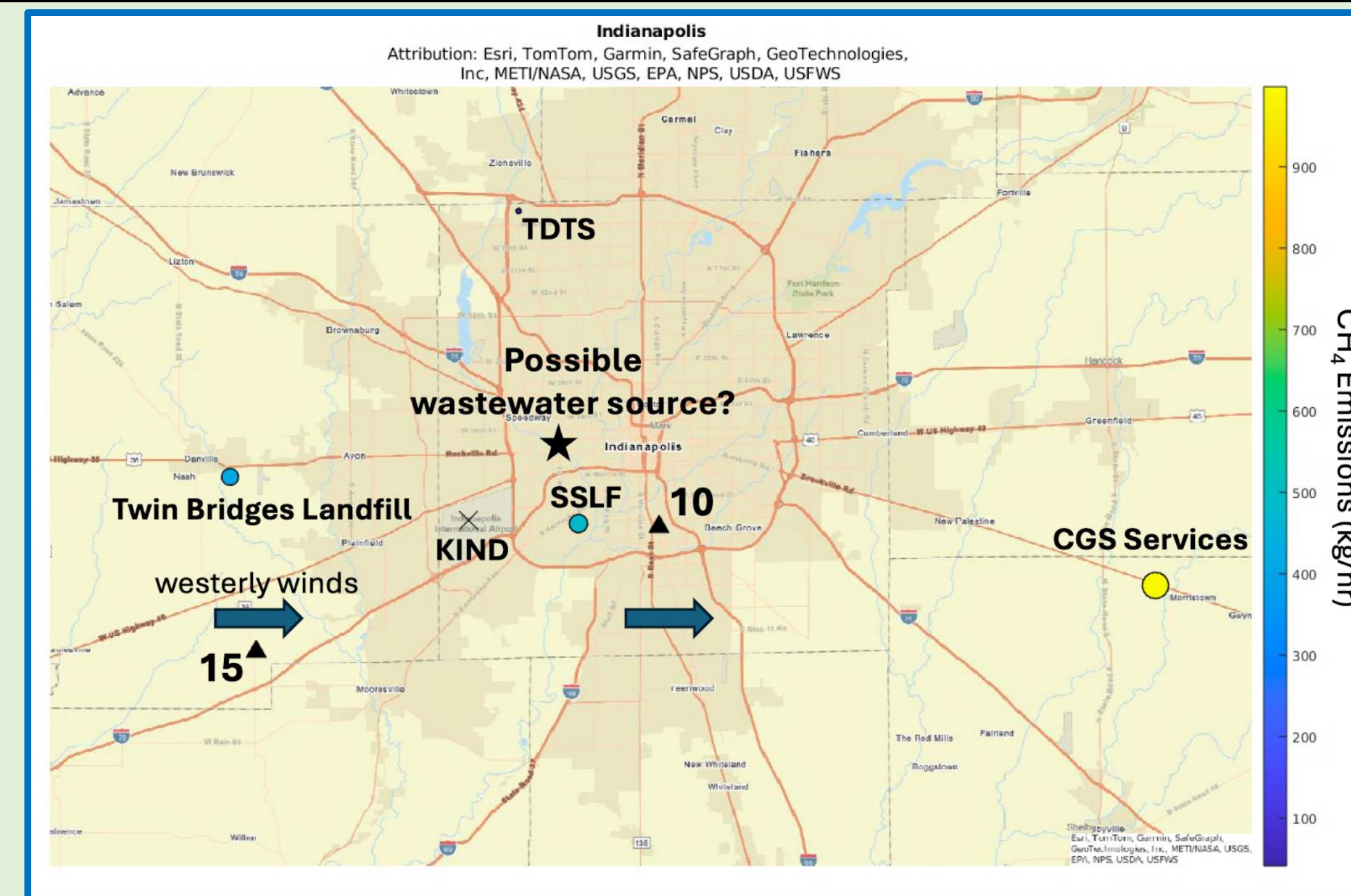
Nikolay Balasov (1,2), Yunsong Liu (3), Ying Pan (3), Zachary Barkley (3), Kenneth Davis (3), Lesley Ott (1)

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MOTIVATION

GHGSat Constellation and Evaluation

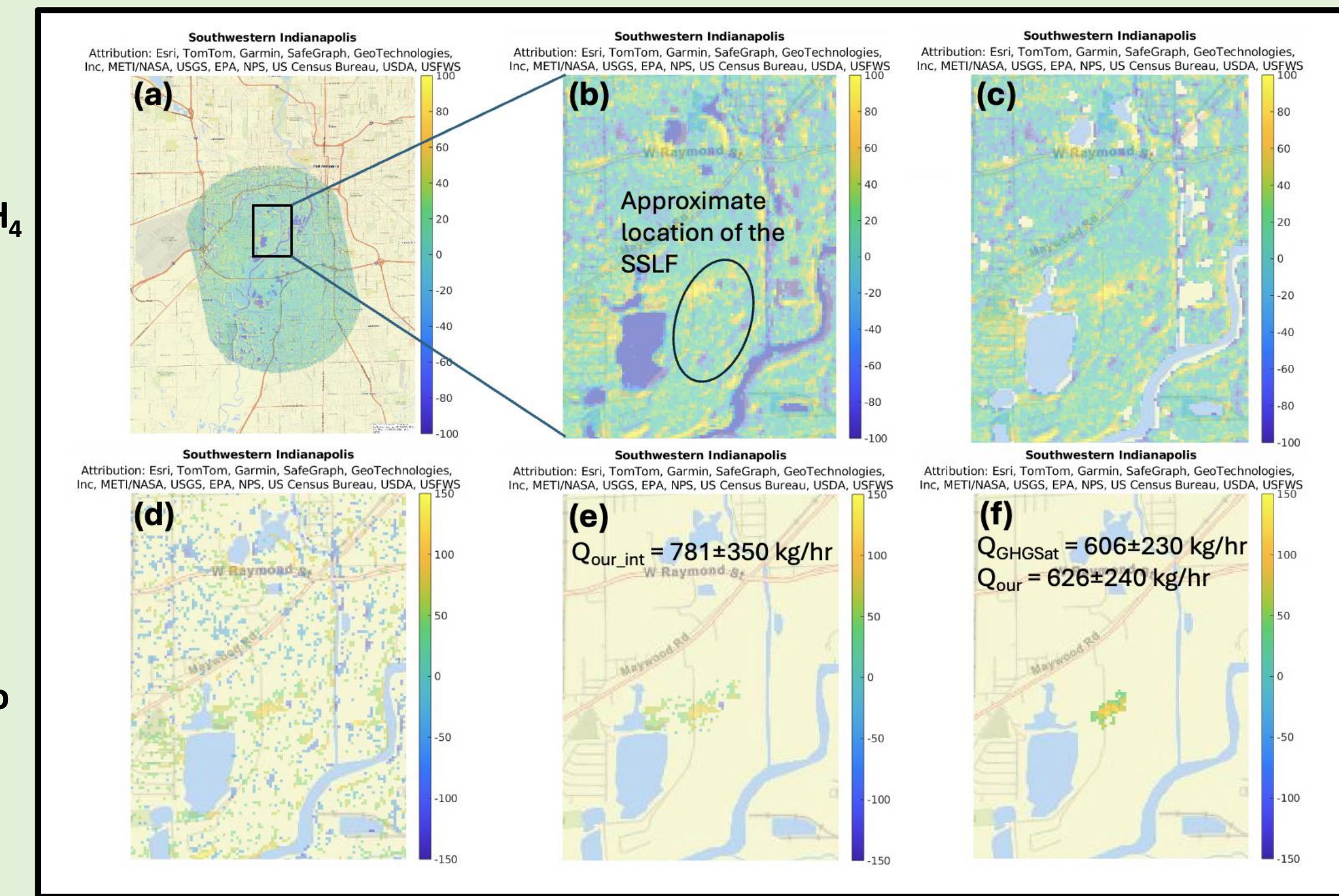
- This work is a part of the NASA's Commercial Smallsat Data Acquisition (CSDA) program to assess an ability of a private company, GHGSat, to estimate urban methane (CH₄) point source (or small area source) emissions using a fleet of satellites.
- We evaluate a year (05/2023-05/2024) of GHGSat scans over South Side Landfill (SSLF) in downtown Indianapolis, Indiana and assess the instruments' accuracy and precision with respect to prior estimations.
- As of 2024 GHGSat has 12 satellites containing a payload of imaging Wide Angle Fabry-Perot spectrometers with spectral region of 1.6 μm and spatial resolution of about 30 m on the domain size of 12 km x 12 km; their sun-synchronous orbit of about 500 km allow for an average of 15 targeted observations per day and an average site revisit time of 14 days (per satellite).



(Figure above) Map of Indianapolis, Indiana, where GHGSat was evaluated on gas transmission station (TDTs) and SSLF. A few other notable objects are also shown on the map.

Interpreting GHGSat Products

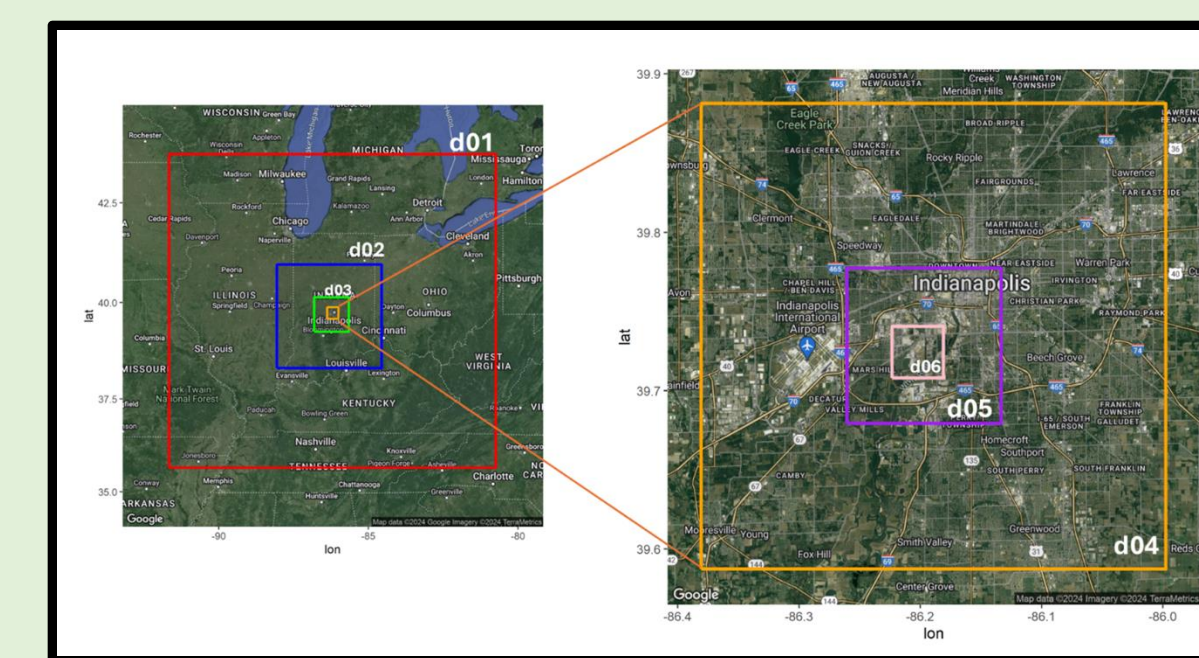
- (Figure to the right) GHGSat products and their processing for 05/26/2023 at about 16 UTC:
- GHGSat level 2 abundance enhancement product (per-pixel CH₄ excess column-averaged concentration in ppb).
 - As in (a) but zoomed in on SSLF.
 - A process of eliminating artifacts from level 2 GHGSat product by first applying the error flag.
 - Estimating signal-to-noise ratio above 1.
 - Our partially subjective interpretation of the processed data to outline a plume originating from the SSLF (units are in ppb).
 - GHGSat Level 3 product of a plume can be seen (units are in ppb) as derived by a GHGSat operator.



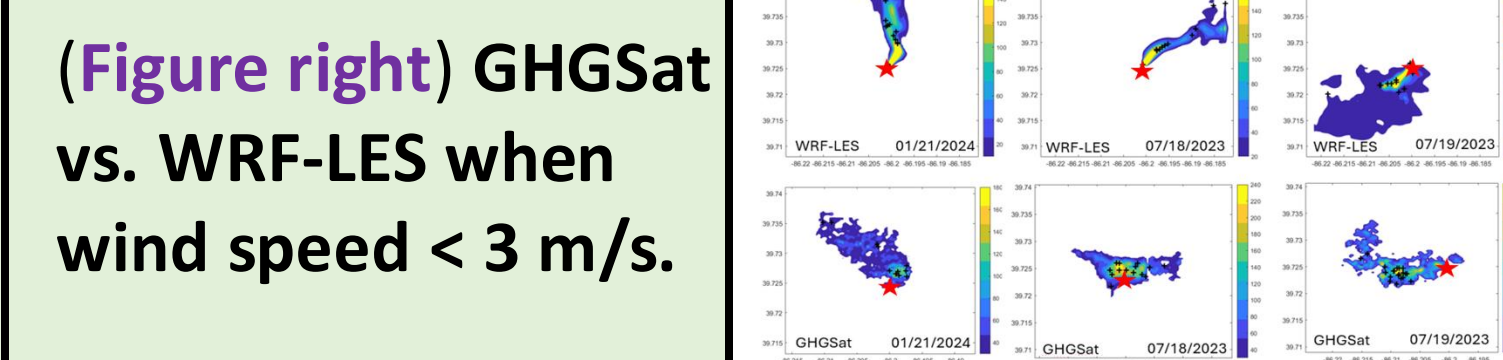
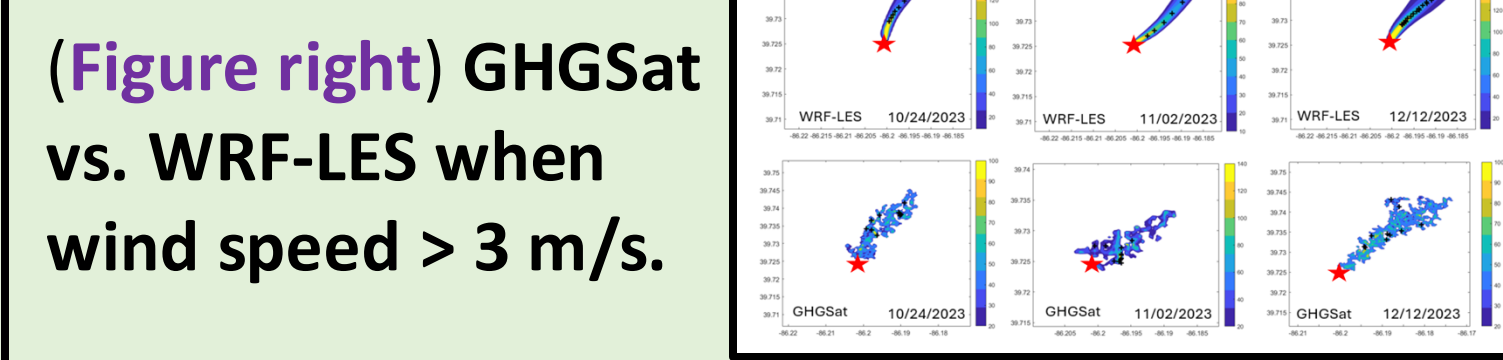
MODELING

WRF-LES v4.4 Set Up

- The Weather Research and Forecasting model combined with Large-Eddy Simulation (WRF-LES) is utilized to see if GHGSat-detected plumes are realistic and to establish relationship between U₁₀ and U_{eff}.
- Contains turbulence resolving dispersion with realistic mesoscale forcing (ERA5 Reanalysis at 0.25 degree latitude-longitude grid data).
- One-way nesting defining six nested domains.
- External domain 1: 900x900 km² with a resolution of 9x9 km².
- Inner domain 6: 3.7x3.7 km² with a resolution of 37x37 m².
- Total 87 vertical levels up to 1.6 km with ~15 m a resolution near the surface.
- Spin-up time: 24 hours.

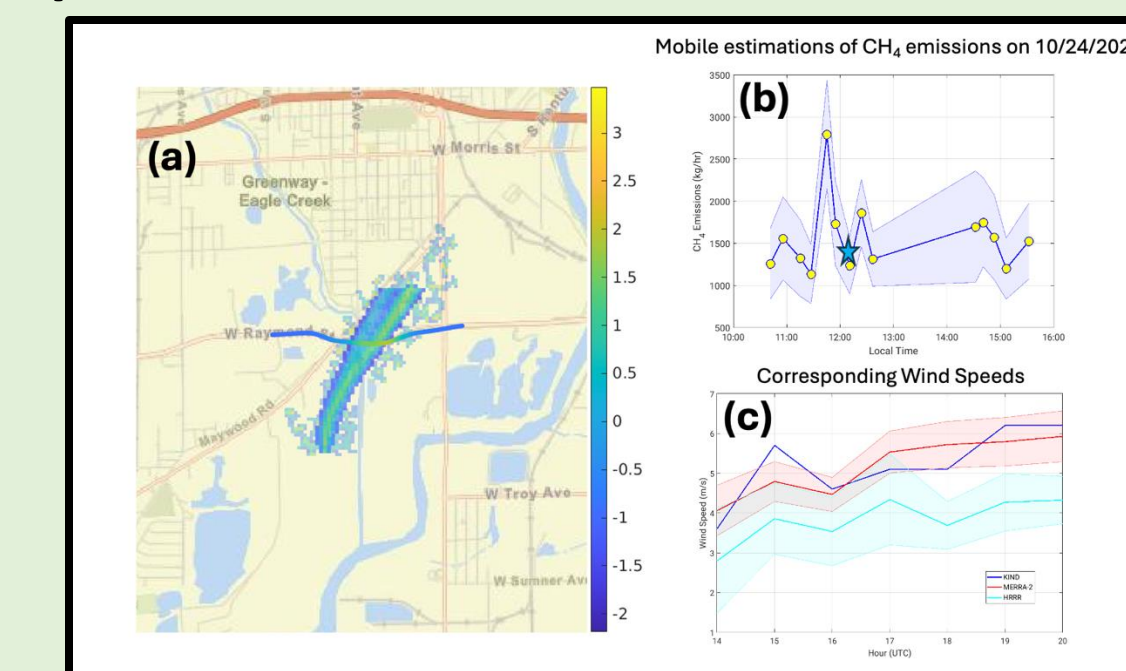


(Figure above) WRF-LES domains set-up.



Mobile SSLF Mini-Campaign

- (Figure below):
- Normalized values of SSLF CH₄ from WRF-LES, GHGSat (transparent), and drive-by at about 16 UTC.
 - CH₄ emissions derived from mobile measurements using Gaussian plume model; star is a value from GHGSat.
 - Wind speeds used to derive stability classes for Gaussian plume model.



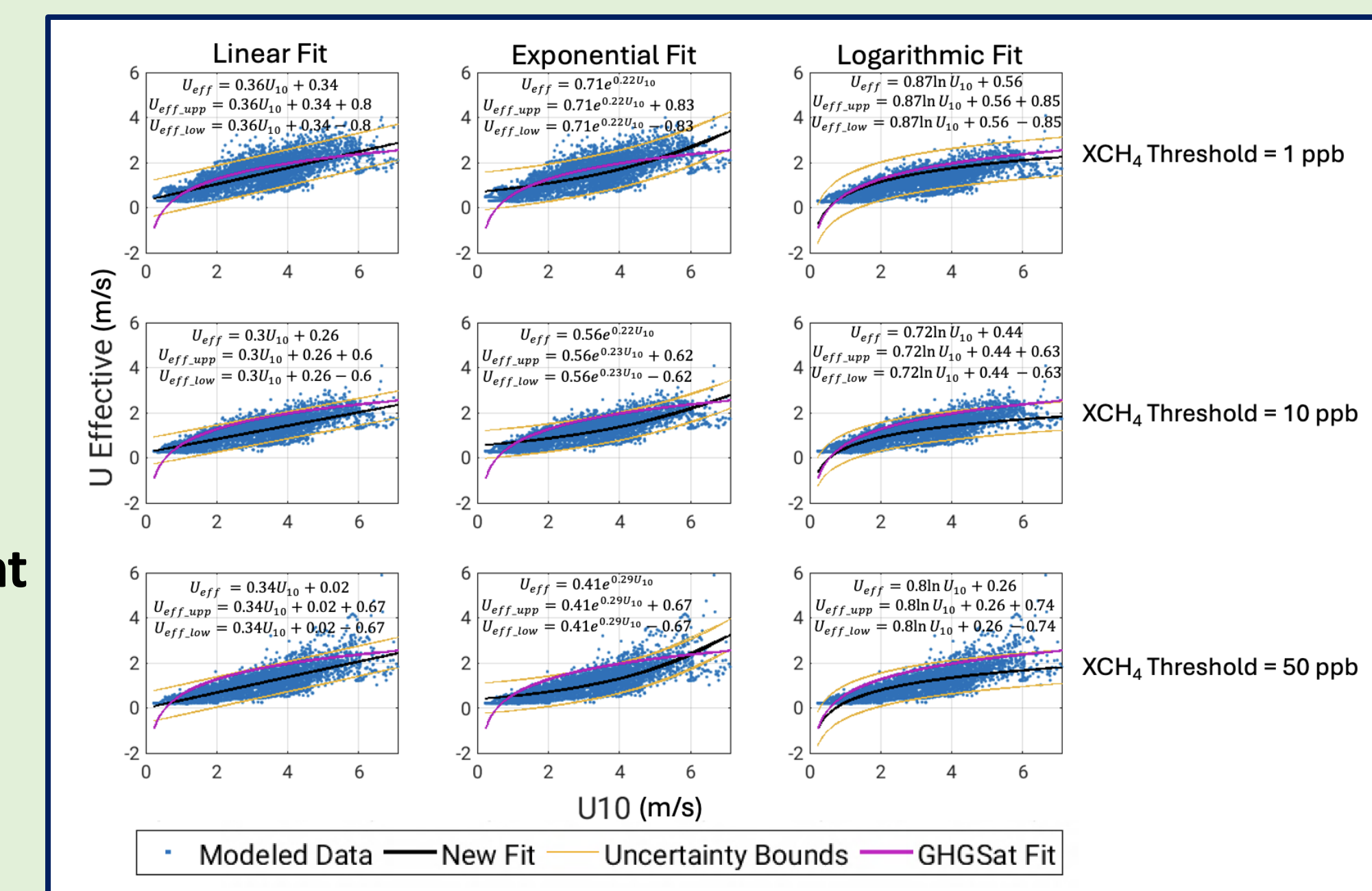
Calibrating Integrated Mass Enhancement (IME) Method

$$Q_{IME} = \frac{U_{eff}}{L} \sum_{i=1}^N \Delta\Omega_i A_i$$

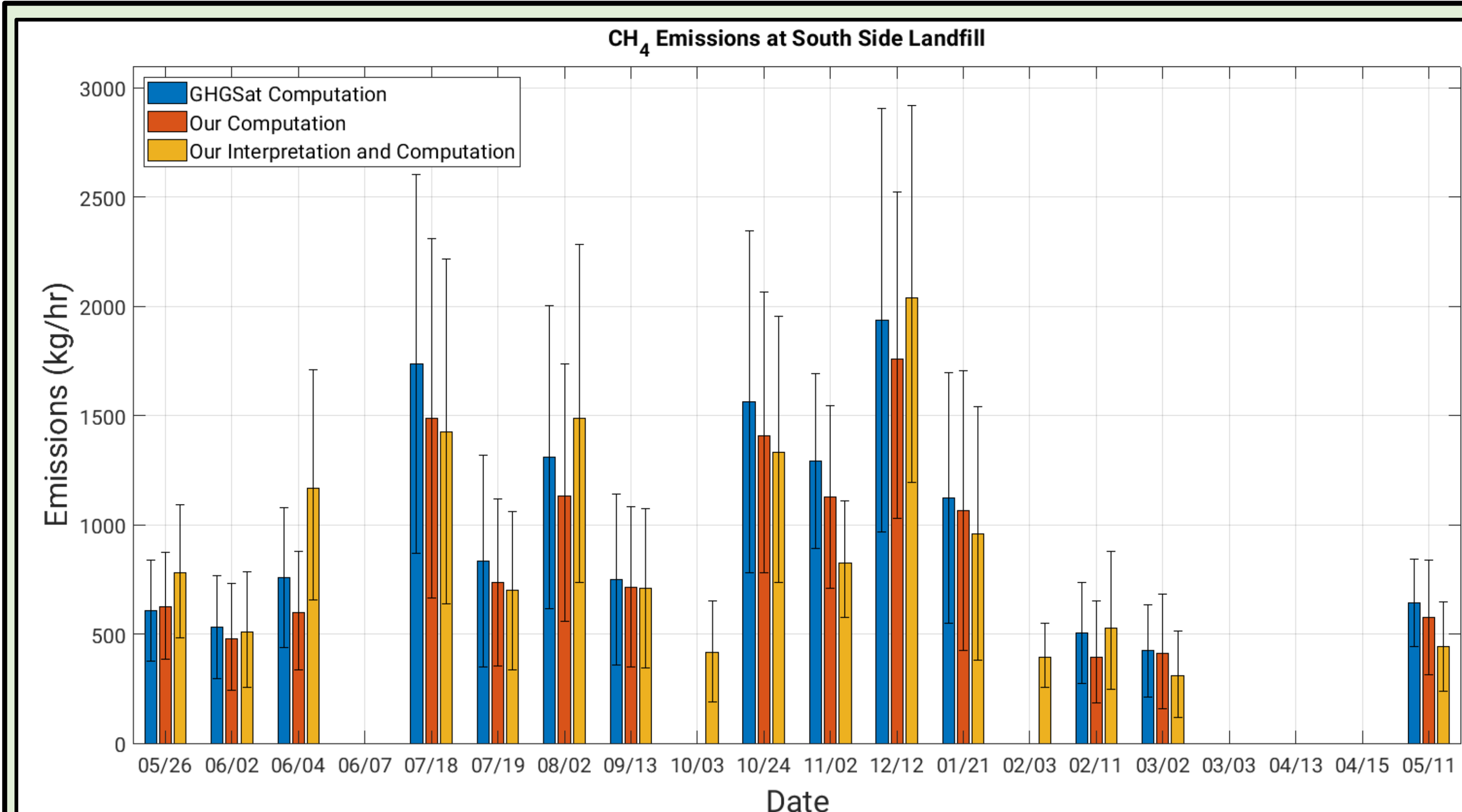
U_{eff} is effective wind speed derived from U₁₀ (Figure to the right).

ΔΩ_i is XCH₄ plume enhancement at a pixel i comprised of total N pixels with area A.

L = √A is a plume length parameter.

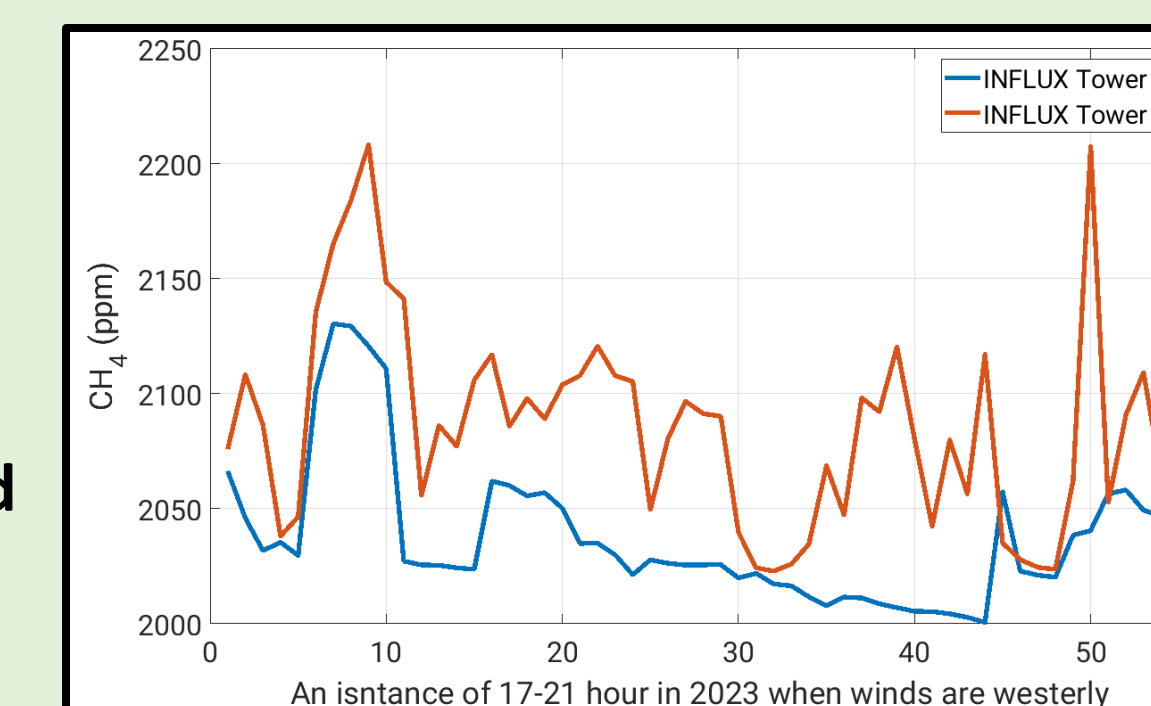


CH₄ EMISSIONS

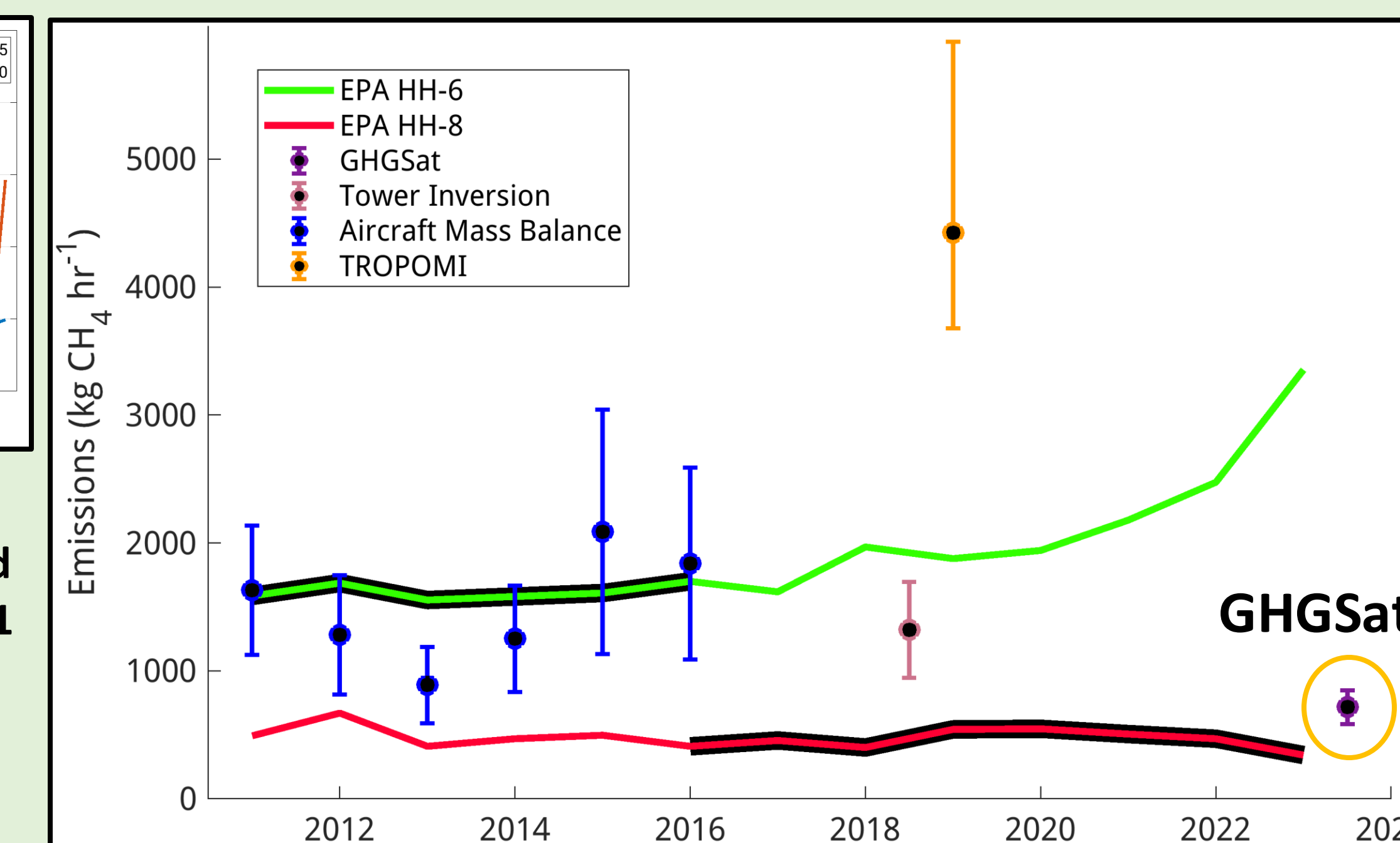


Estimation of SSLF CH₄ Emissions

- (Figure to the left). GHGSat's CH₄ emission estimations from GHGSat images at SSLF starting on 05/26/2023 and ending on 05/11/2024.
- Blue bars indicate emissions estimated by GHGSat using the plume images (level 3 product) and red bars indicate calculations completed by our team using the same images.
- Yellow bars represent emissions estimated from our own filtering of GHGSat's level 2 raw product.
- The error bars correspond to 95% confidence intervals based on the scenes provided by GHGSat.
- GHGSat gives a detection limit of about 120 kg/hr when wind speeds are equal or more than 3 m/s (GHGSat Algorithm Theoretical Doc., 2023).
- Results indicate that GHGSat emission detections in an urban environment are noisy, but still useful when providing annual average.



(Figure above) Measurements from INFLUX towers 15 (background) and 10 (downwind of SSLF) during 17-21 UTC hours and when winds are westerly (see the map for tower positions). Data indicates that SSLF consistently emits enhanced CH₄ indicating that times when GHGSat sees no emissions are likely due to detection limitations.



(Figure above) Comparison of different CH₄ emission estimations at SSLF. GHGSat annual average lies a bit on a lower side, but generally consistent with other top-down estimates. TROPOMI study is likely biased high due to its resolution limitations.

