Methane Discrete Source Detection and Quantification Using MethaneSAT

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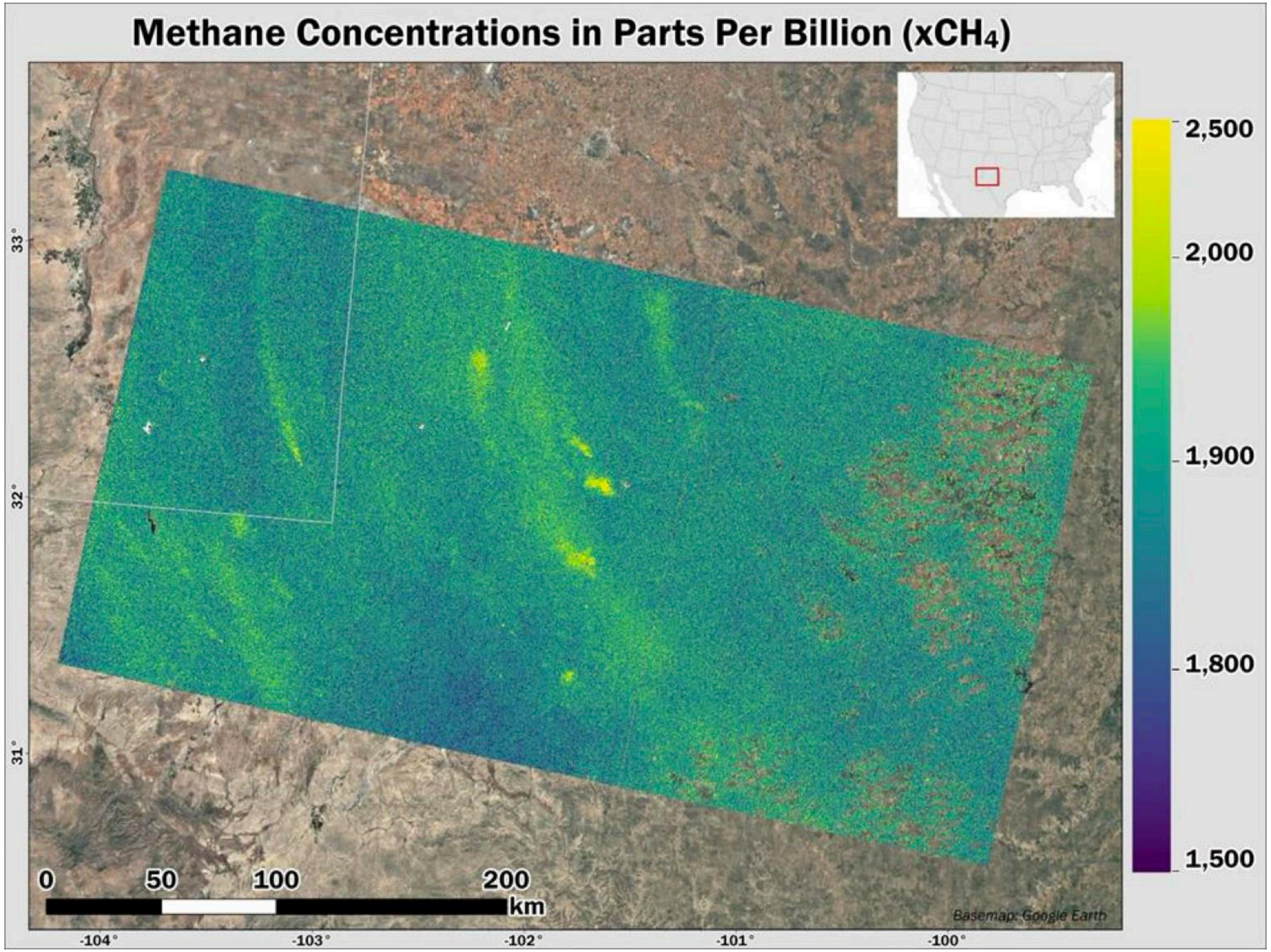
MethaneSAT Methodology Overview



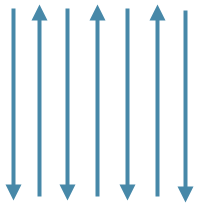
Permian Basin, 09/11/2024. Plot by Ritesh Gautam

- Retrieval:
  - CO_2 proxy method
- Discrete sources:
  - Large enough to produce a visible plume
  - Detection & Quantification
- Dispersed sources:
  - All other sources that produce XCH_4 enhancements
  - Inverse modeling

Detection of Discrete Sources

Divergence Integral (DI)

Calculate flux divergence and produce a flux map



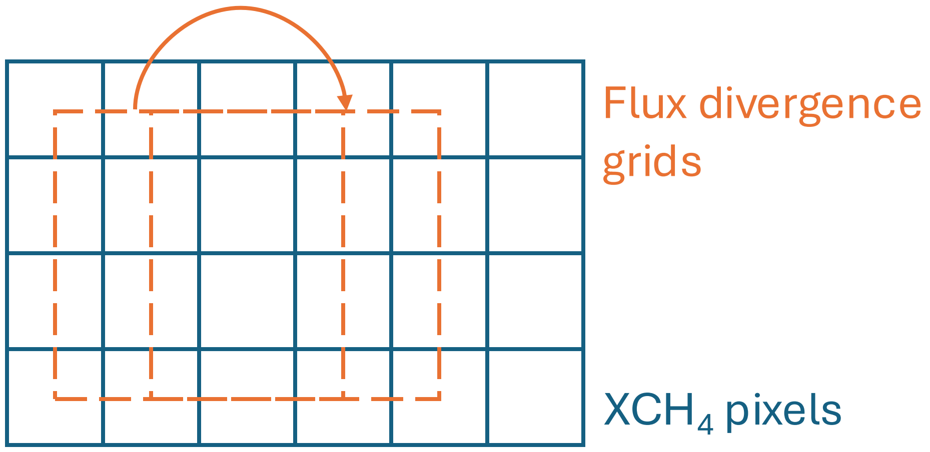
Wavelet

Denoise image using a 2D discrete wavelet transform

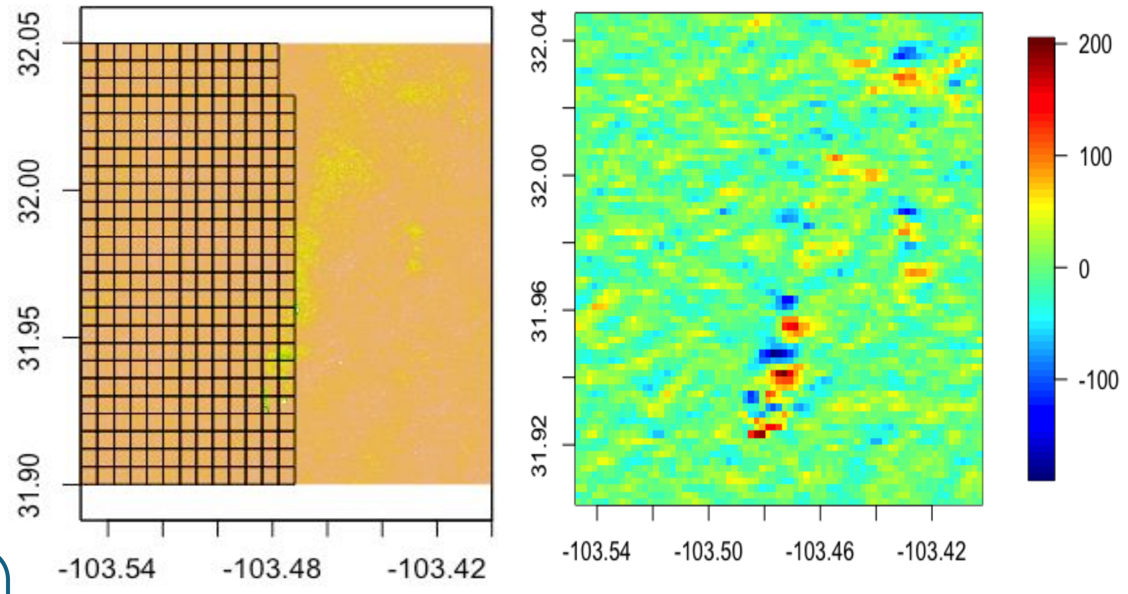
- Plume masks are generated by thresholding and filtering
- Plume source is determined as the farthest upwind end of the plume
- Wind direction is either inferred from the plume shape or based on meteorological data

Divergence Integral Method

- Apply Gauss's theorem to calculate integral of flux divergence over tiled grids across the scene (oversampled)
- Produce a flux map with hot spots at plume origins
- Absolute value of gridded flux map used for plume finding
- Plume masks generated using thresholding of both the flux map and XCH_4



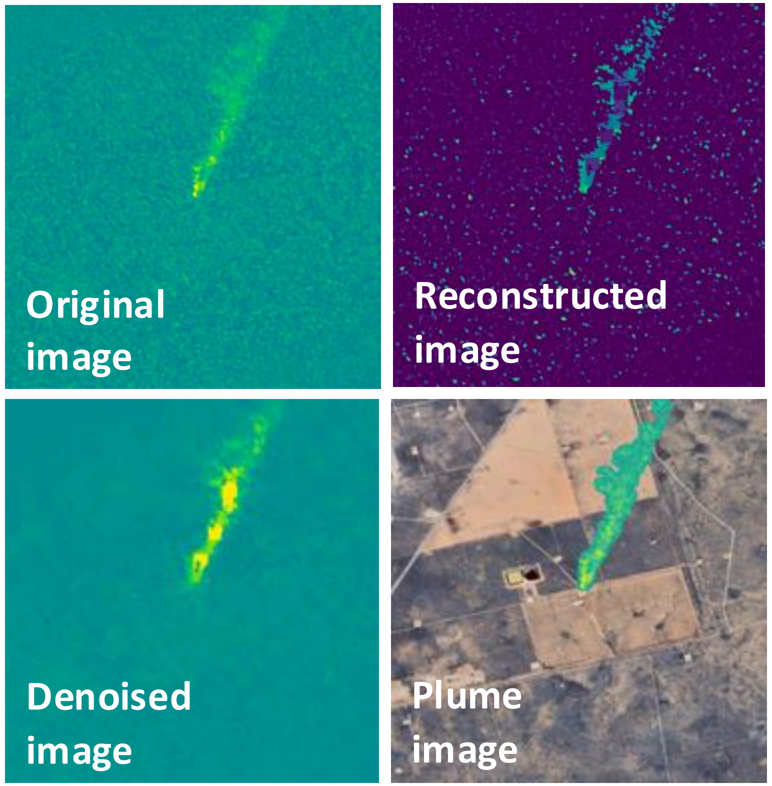
$$Q_{surf} = \sum^{around\ grid} \left(XCH4_i - \langle XCH4 \rangle_{grid}\right) \cdot n_{column} \cdot wind_{\perp} \cdot \triangle l$$



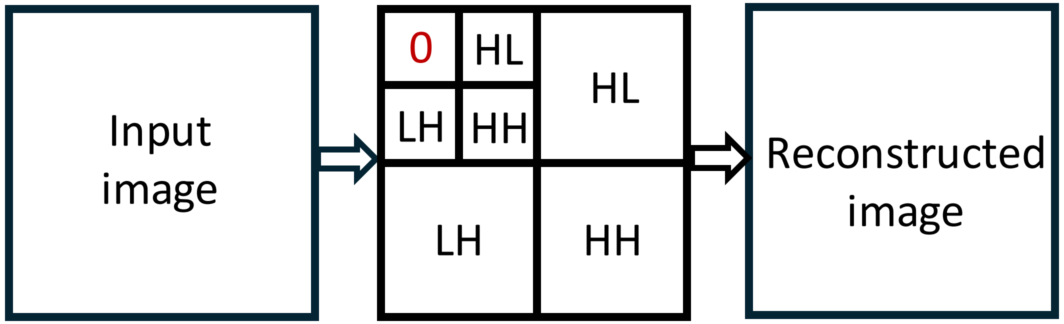
oversampling not shown for clarity

Wavelet Method

- Image denoising
  - Apply wavelet transform to generate approximation and detail coefficients
  - Set approximations to zero, followed by inverse wavelet transform
  - The resulting "reconstructed image" retains only high frequencies
  - Subtract reconstructed image from input image
- Plume mask generation and filtering
  - Thresholding to pixel value, plume shape, wind direction

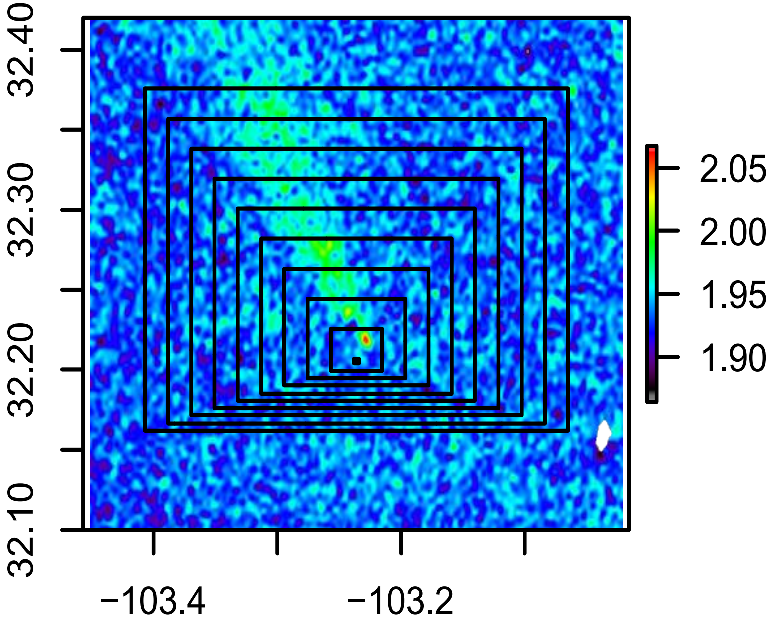


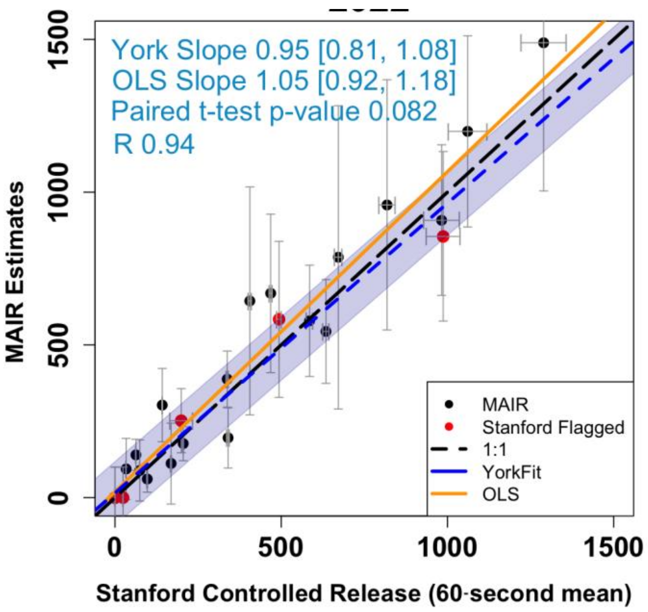
Multi-level 2D discrete wavelet transform



Quantification of Discrete Sources

- Determine the source as the farthest upwind end of the plume
- Draw a series of rectangles (“growing boxes”) surrounding the source
- Aggregate the concentration enhancements along each rectangle to calculate DI
- Final flux rate is the average of valid fluxes derived from the growing boxes





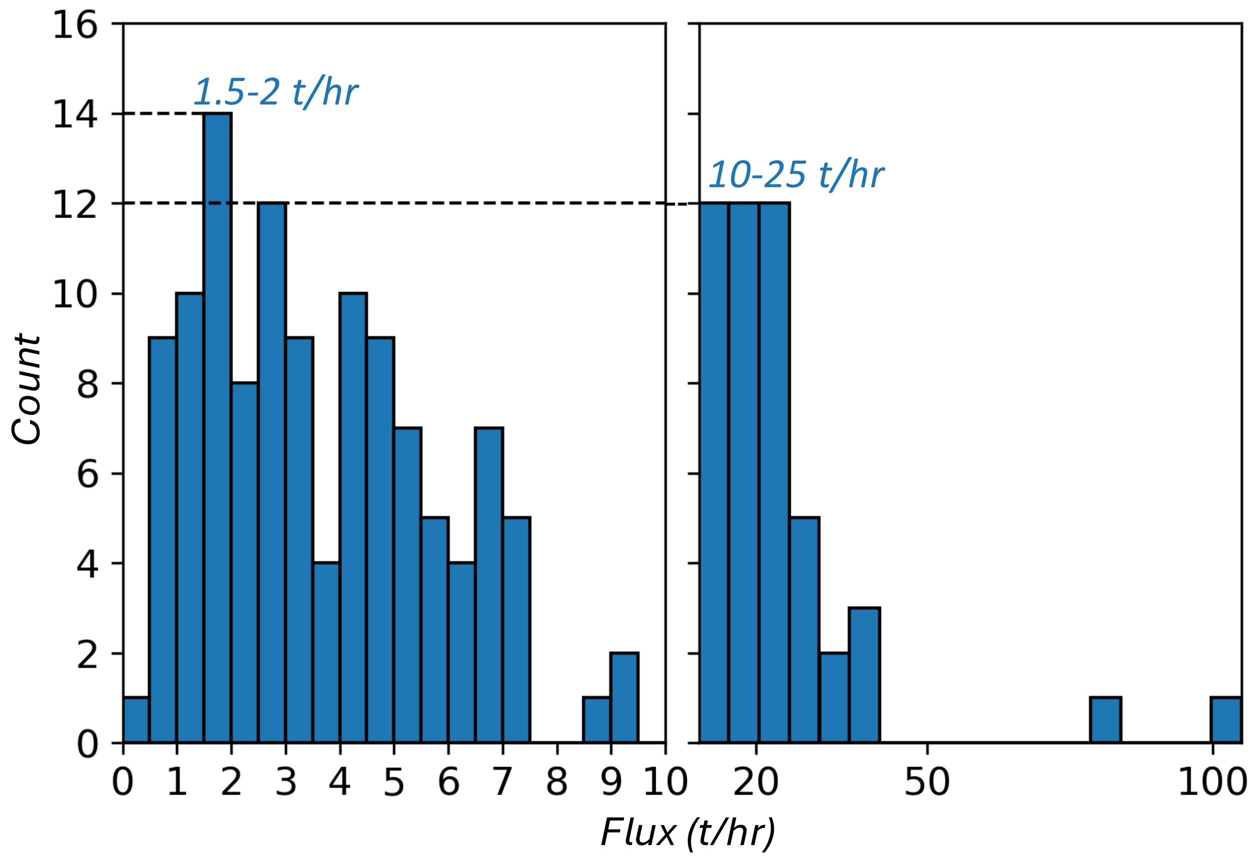
Performance validated in controlled release tests on MethaneAIR data

Chulakadabba et al., Methane point source quantification using MethaneAIR: a new airborne imaging spectrometer, Atmospheric Measurement Techniques, 16 (23), 5771–5785.
El Abbadi, S. H., et al., Technological maturity of aircraft-based methane sensing for greenhouse gas mitigation, Environmental Science & Technology, 58 (22), 9591-9600.

MethaneSAT Plume Results So Far

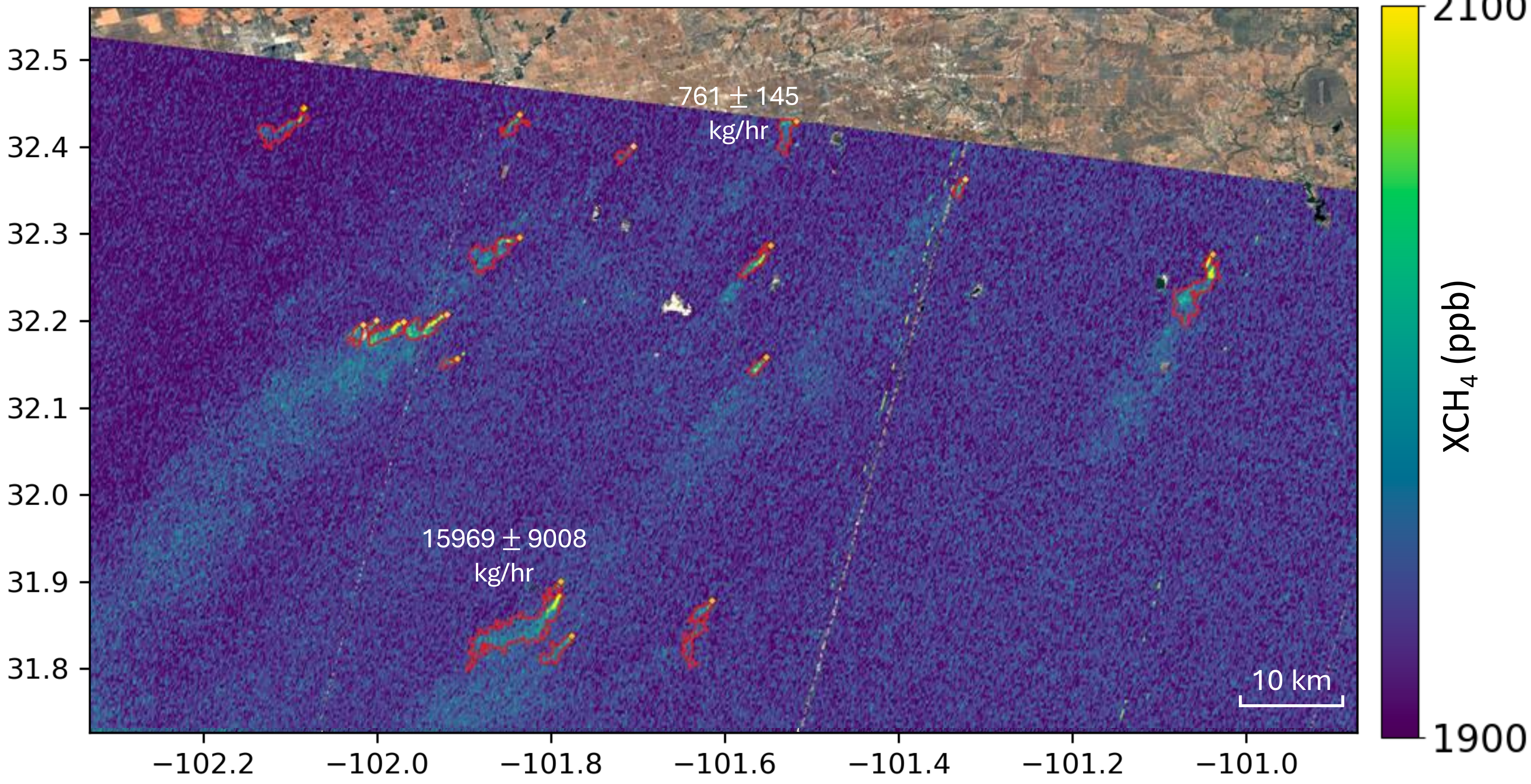
MethaneSAT can capture not only large point sources, but also potentially small point sources under good observing conditions

- 172 plumes in 75 collections with the flux magnitude range of 0.5-100 t/hr
  - Target processing priority affects flux distribution
  - Future routine processing will greatly increase plume counts
- Probability of detecting low-volume plumes needs further quantitative evaluation
- Controlled release studies are underway to validate the accuracy and assess the detection limit of our methods
- Combining two detection methods maximizes detection capabilities



MethaneSAT Plume Results So Far

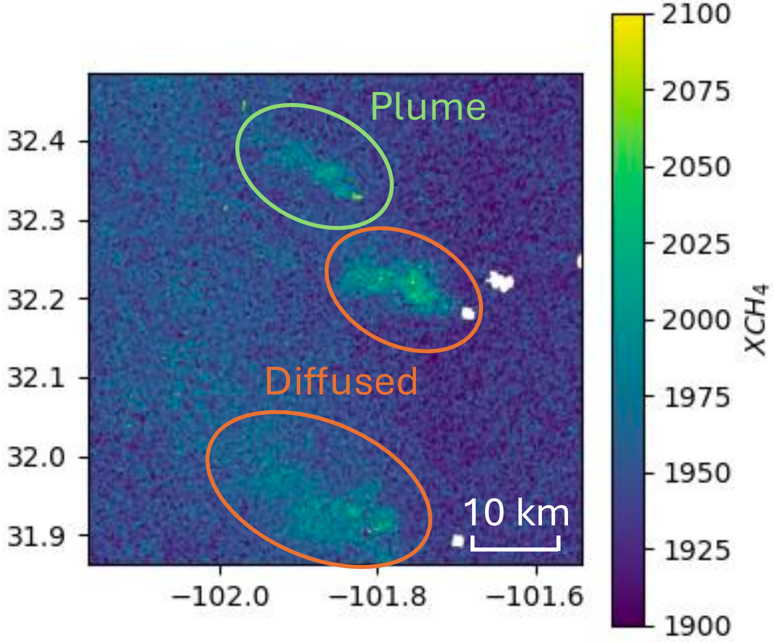
Check out our data portal!



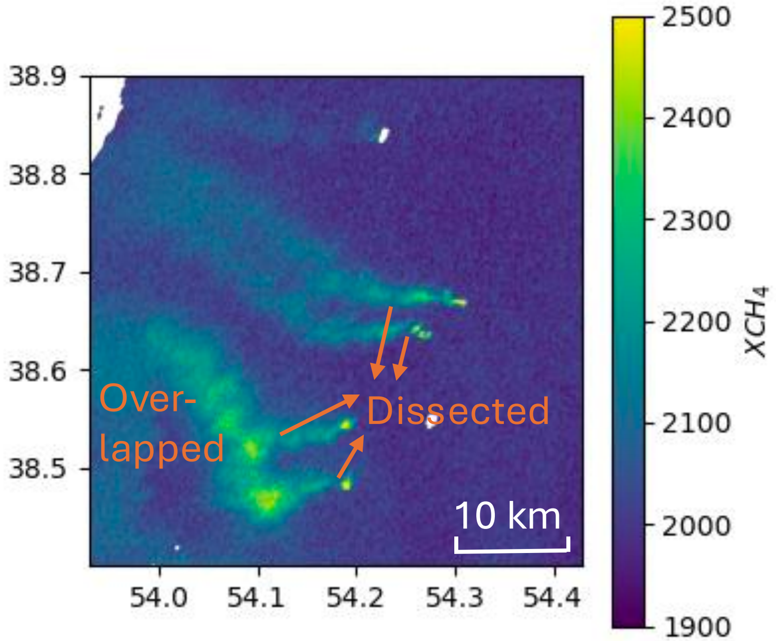
Permian Basin, 09/28/2024

Unique Challenges

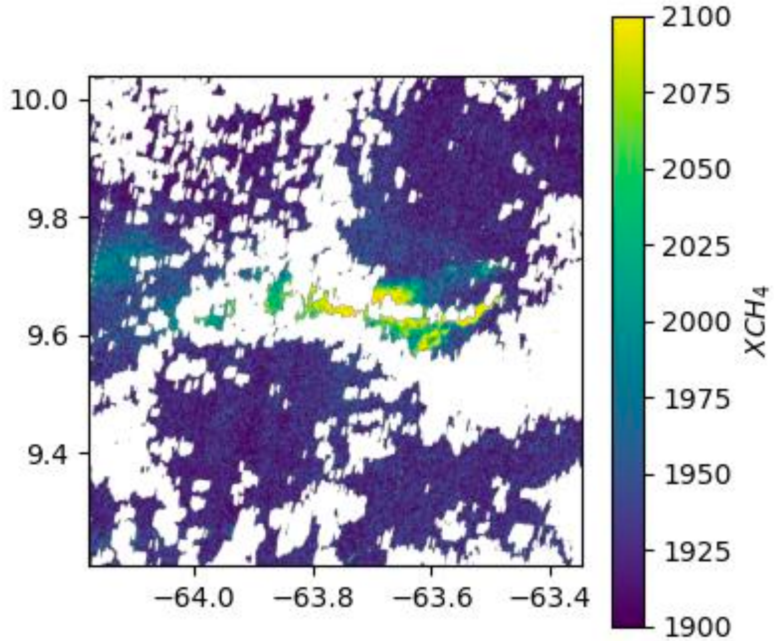
MethaneSAT's high sensitivity enables observations of diffused emissions, whose lower enhancements make it harder to attribute them to certain source infrastructure.



MethaneSAT's large spatial coverage provides traces of long plume tails, increasing the probability of dissected or overlapped plume masks.



Cloud screening corrupts plume shape, increasing the difficulty of source localization and quantification.



Discrete Point Sources Emissions

❑ Other improvements:

- Machine learning plume segmentation
- Matched filter retrieval

❑ Other ongoing efforts:

- Ground experiments validation
- Data cross-checking with other platforms

Thank you!

MethaneSAT – this machine fights climate change

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