

Supplemental Information

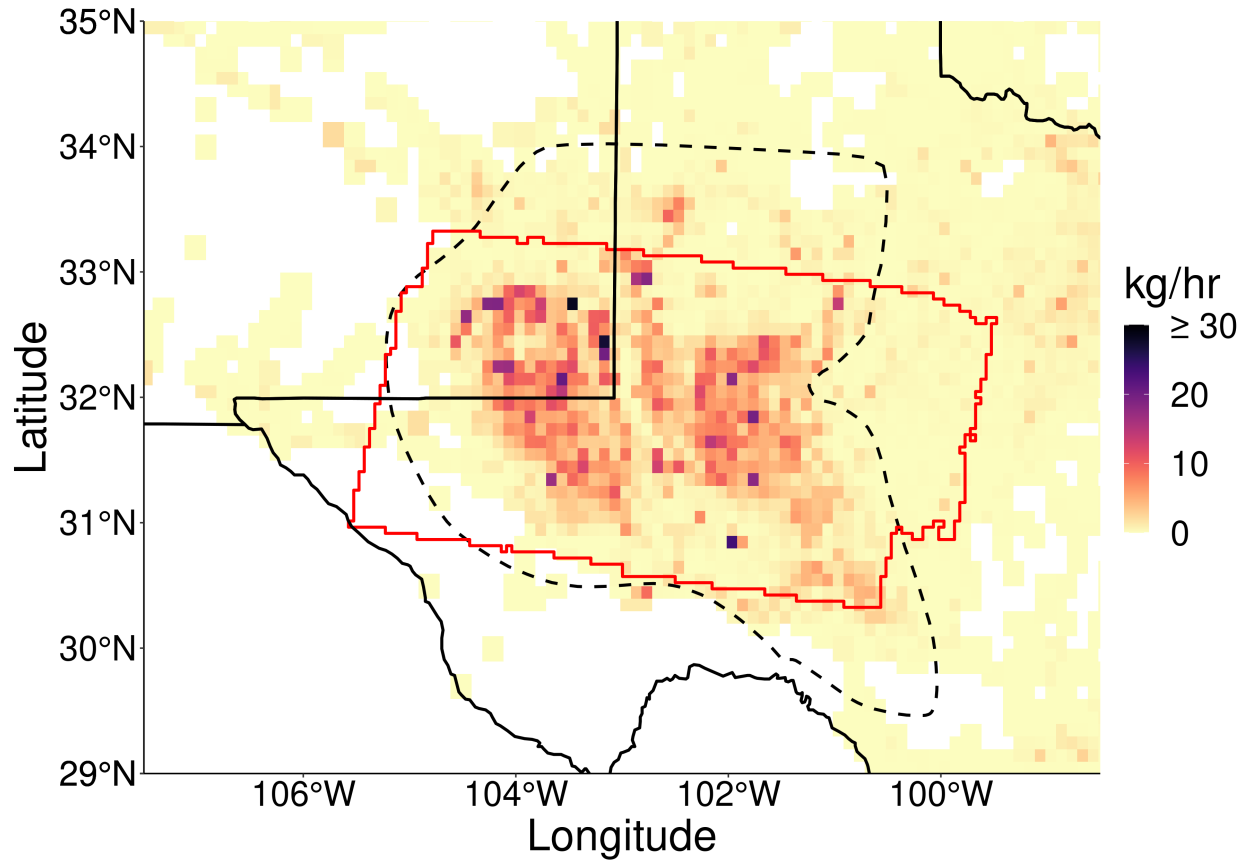


Figure S1. The composite of 9 MethaneSAT scenes (red line) over the Permian Basin covers ~70% of the geographic extent of the basin (dashed black line), and ~96% of emissions according to the EI-ME (Omara et al., 2024), shown here. This makes the data well suited to quantify the average emission rate during the period of observation. Solid black lines are state and country borders.

Figures S2-S10 give summaries of the inversion results for each scene. In each 4 paneled figures, the panels are as follows (top to bottom, left column then right column).

- Observed XCH_4
- Background concentration
- Enhancements (observed XCH_4 – background)
- Posterior enhancements recovered by the model
- The contribution to the enhancements attributed to inflow (external emitters) by the model
- Gridded emissions estimates for the scene
- Residual between observations and posterior concentrations for the scene
- A binned scatterplot of the posterior enhancements compared to observations
- A histogram of the observations (blue) and modeled concentrations (orange)

Solid black lines are political boundaries, the dashed black line is the outline of the Permian Basin from the EI-ME.

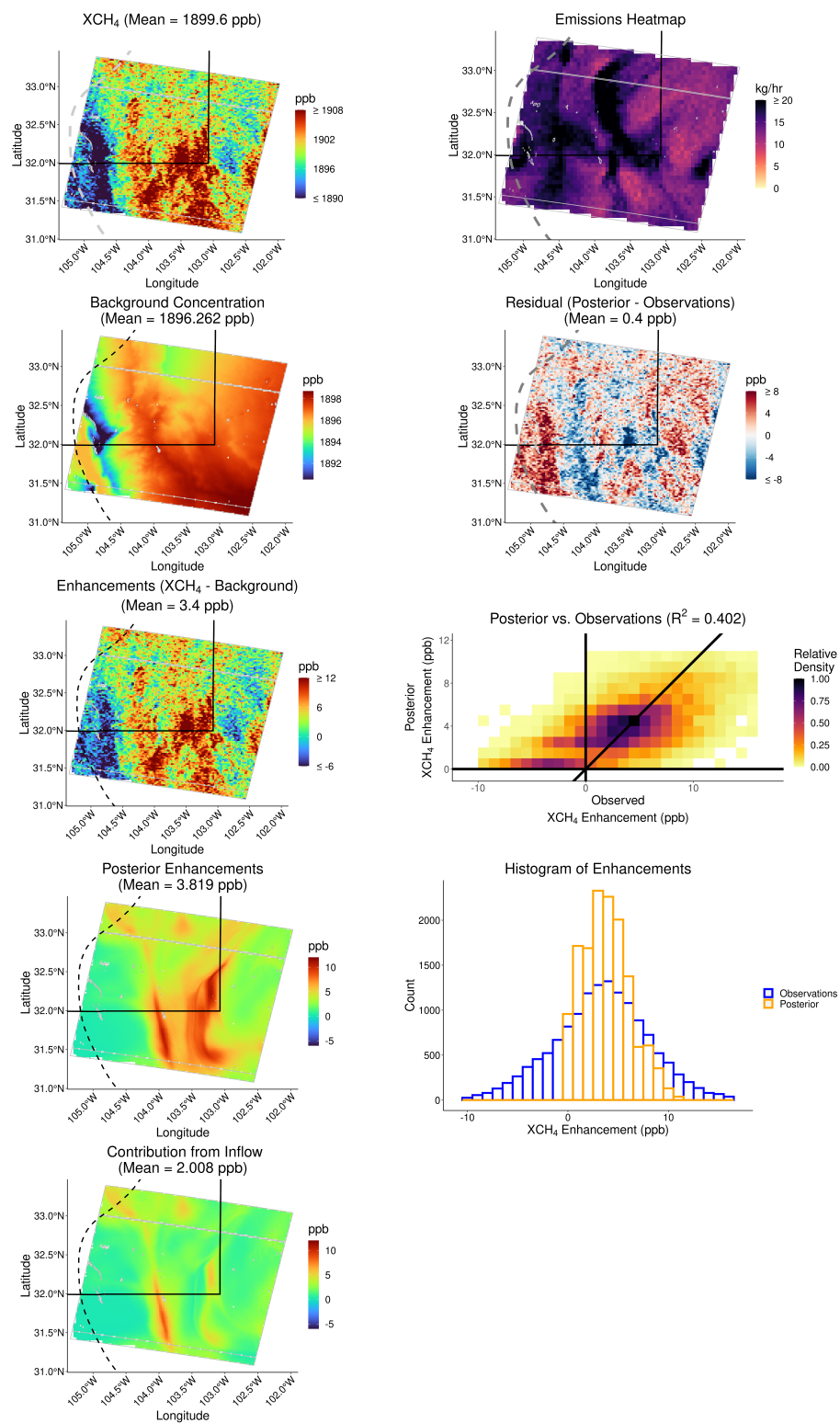


Figure S2. Summary figures for data from target 006, collect 00040060, observations from 22 May 2024.

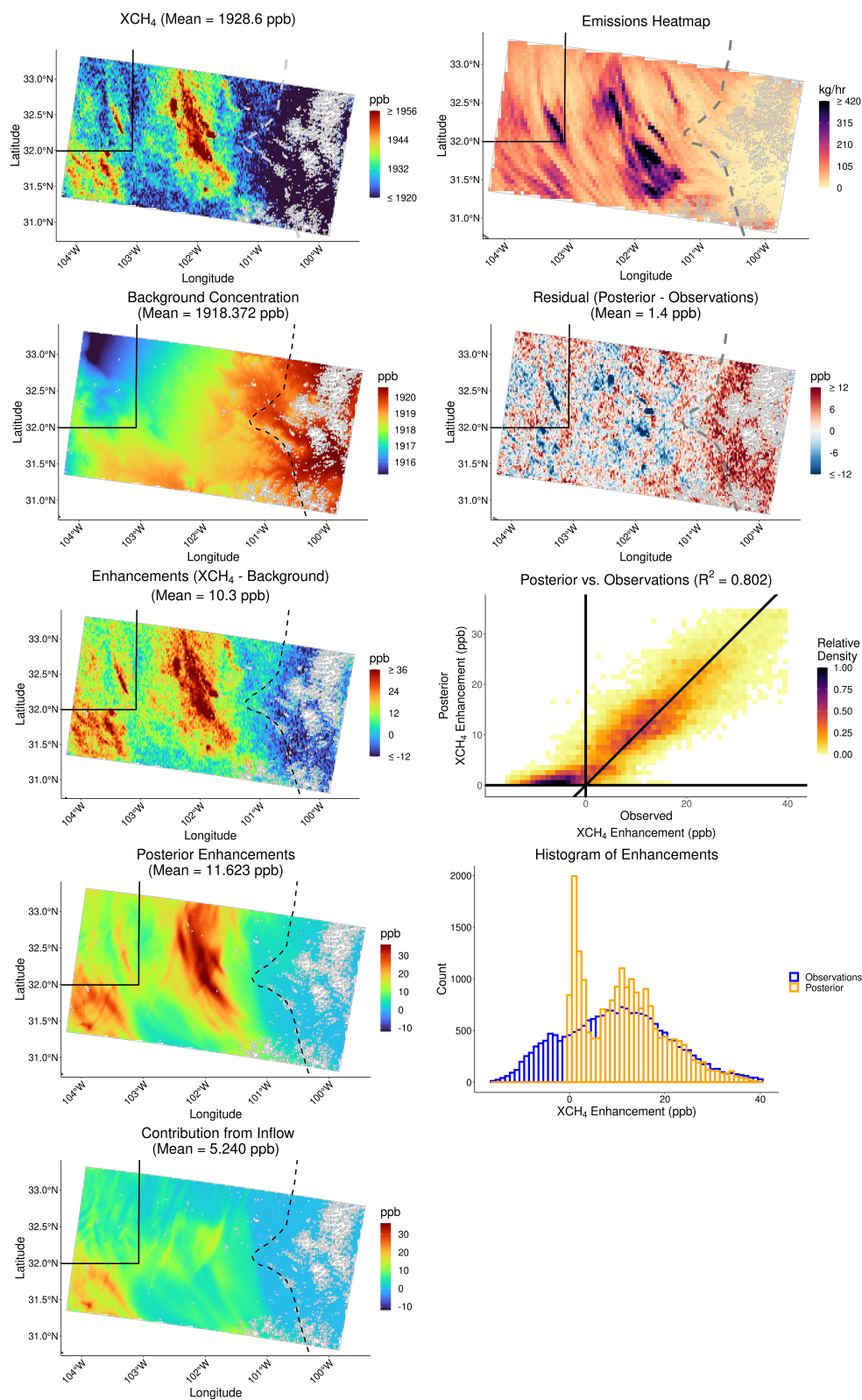


Figure S3. Summary figures for data from target 005, collect 01430050, observations from 11 Sept. 2024.

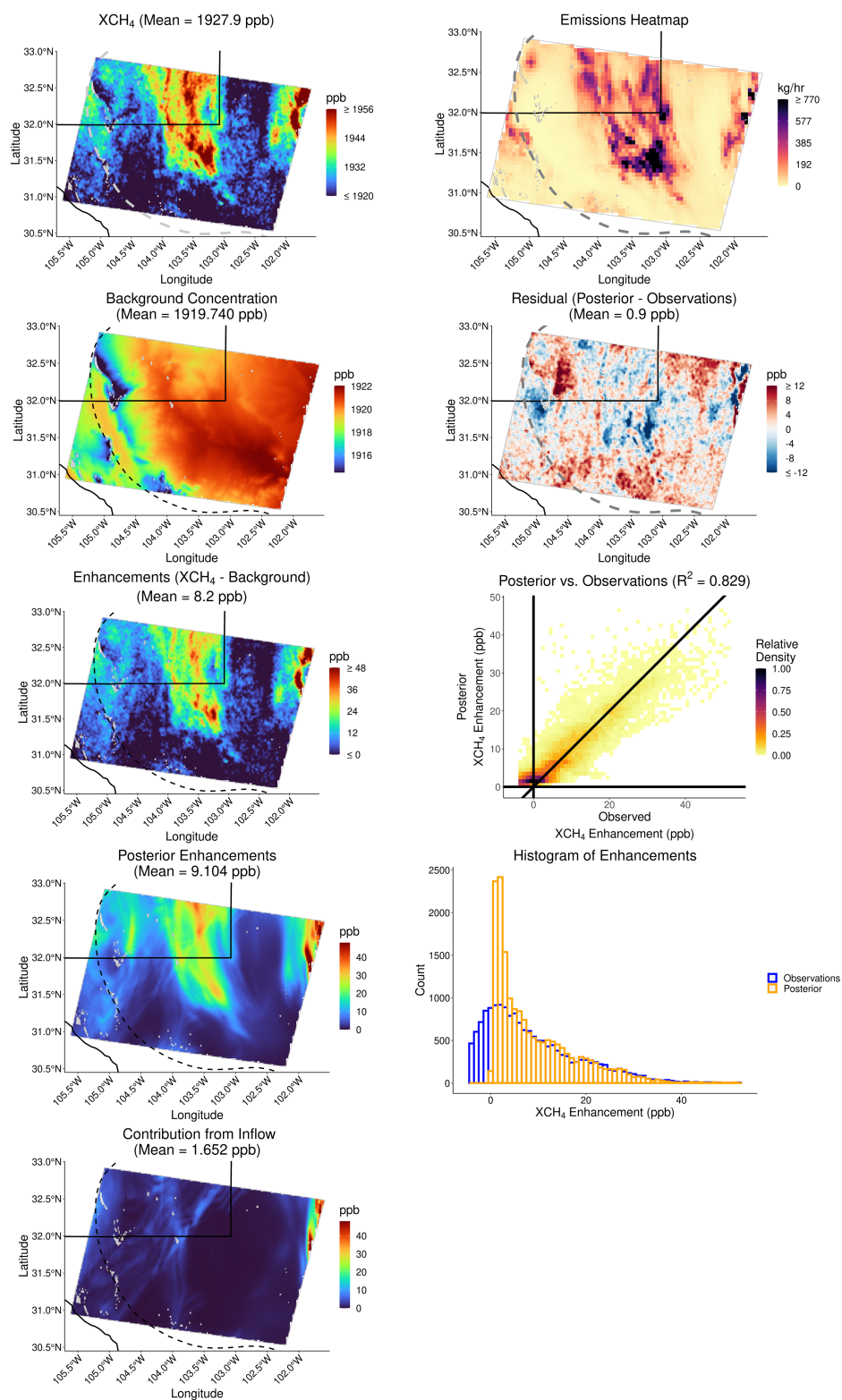


Figure S4. Summary figures for data from target 057, collect 01DF0390, observations from 30 Sept. 2024.

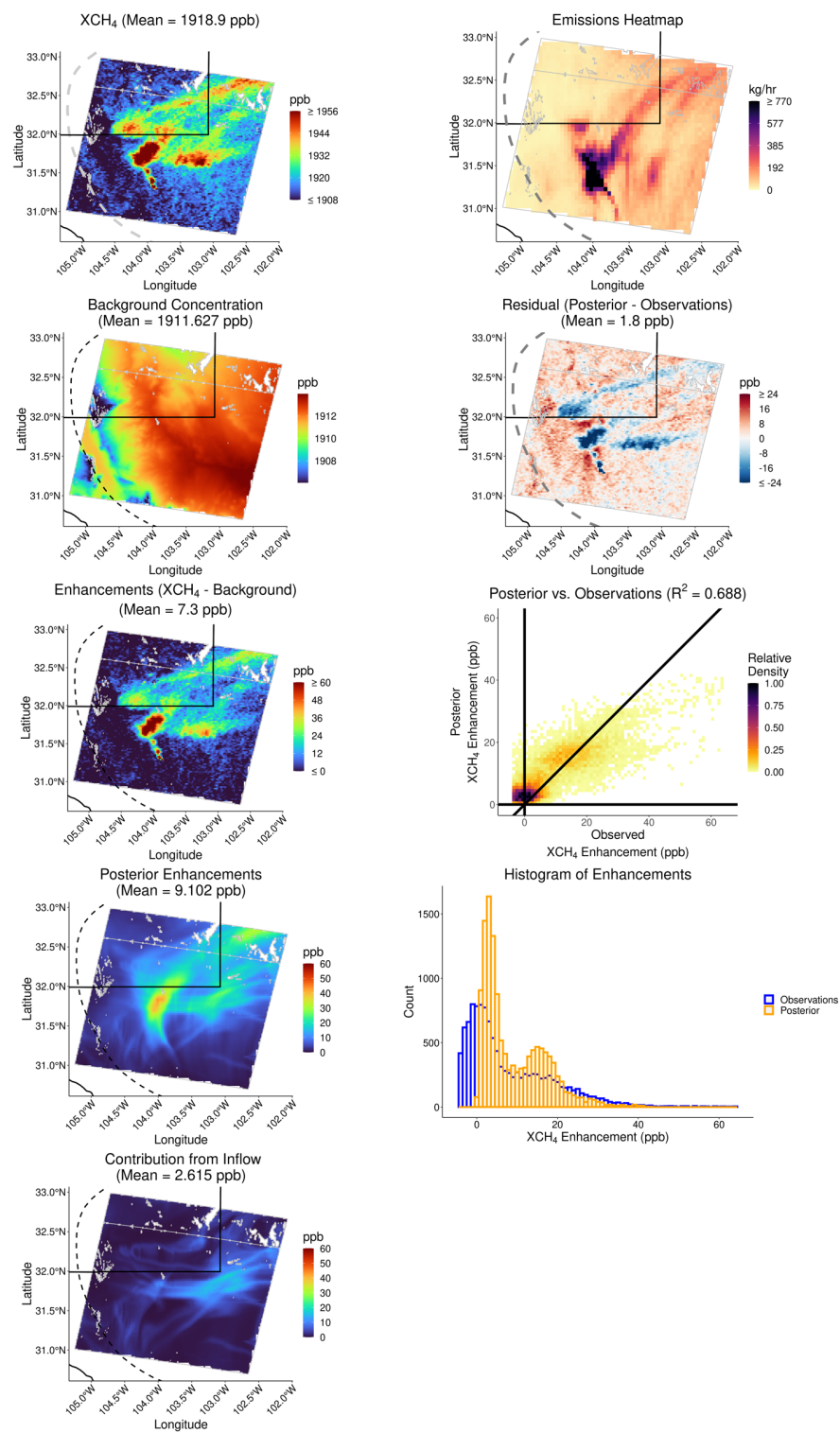


Figure S5. Summary figures for data from target 057, collect 02710390, observations from 13 Oct. 2024.

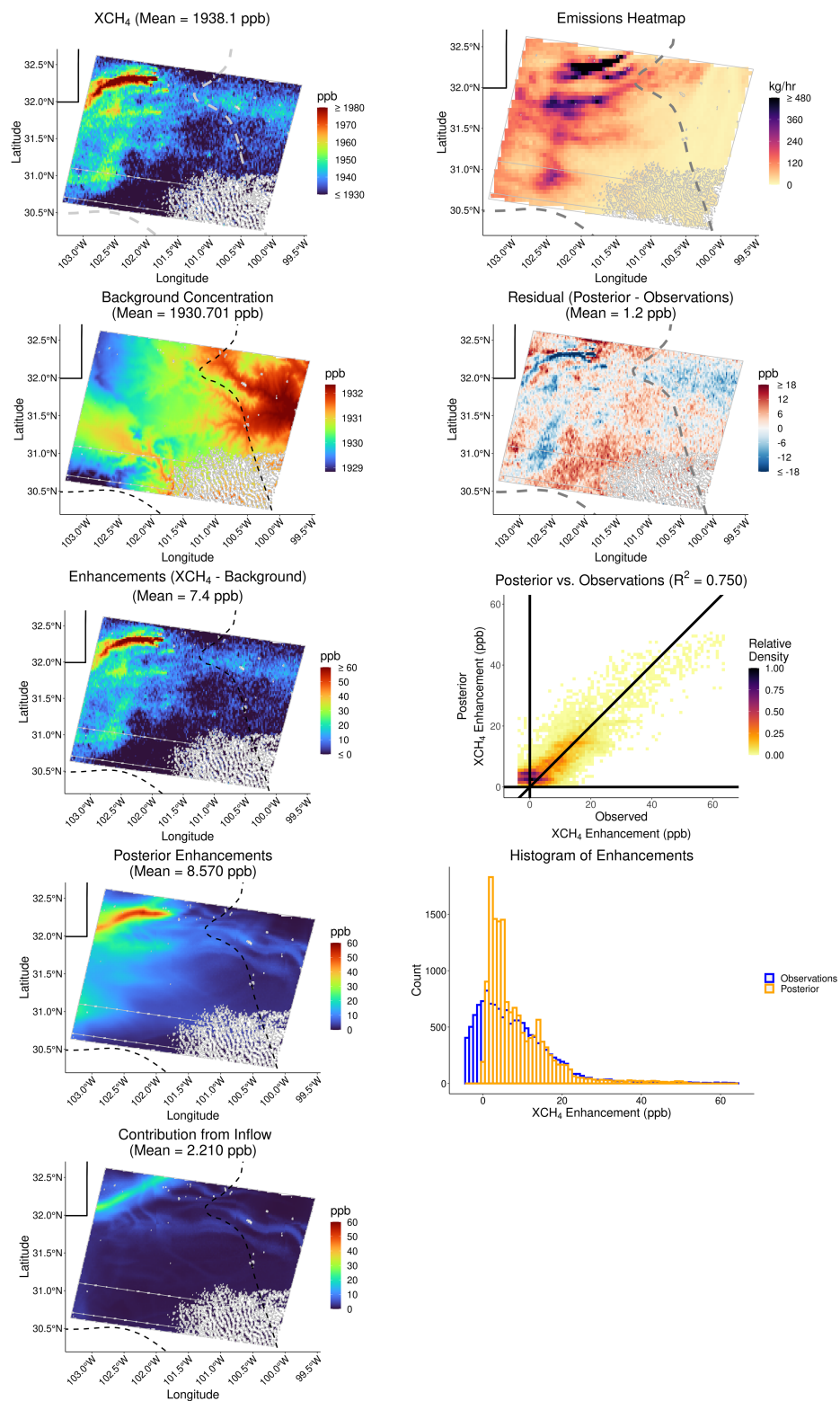


Figure S6. Summary figures for data from target 056, collect 03490380, observations from 26 Oct. 2024.

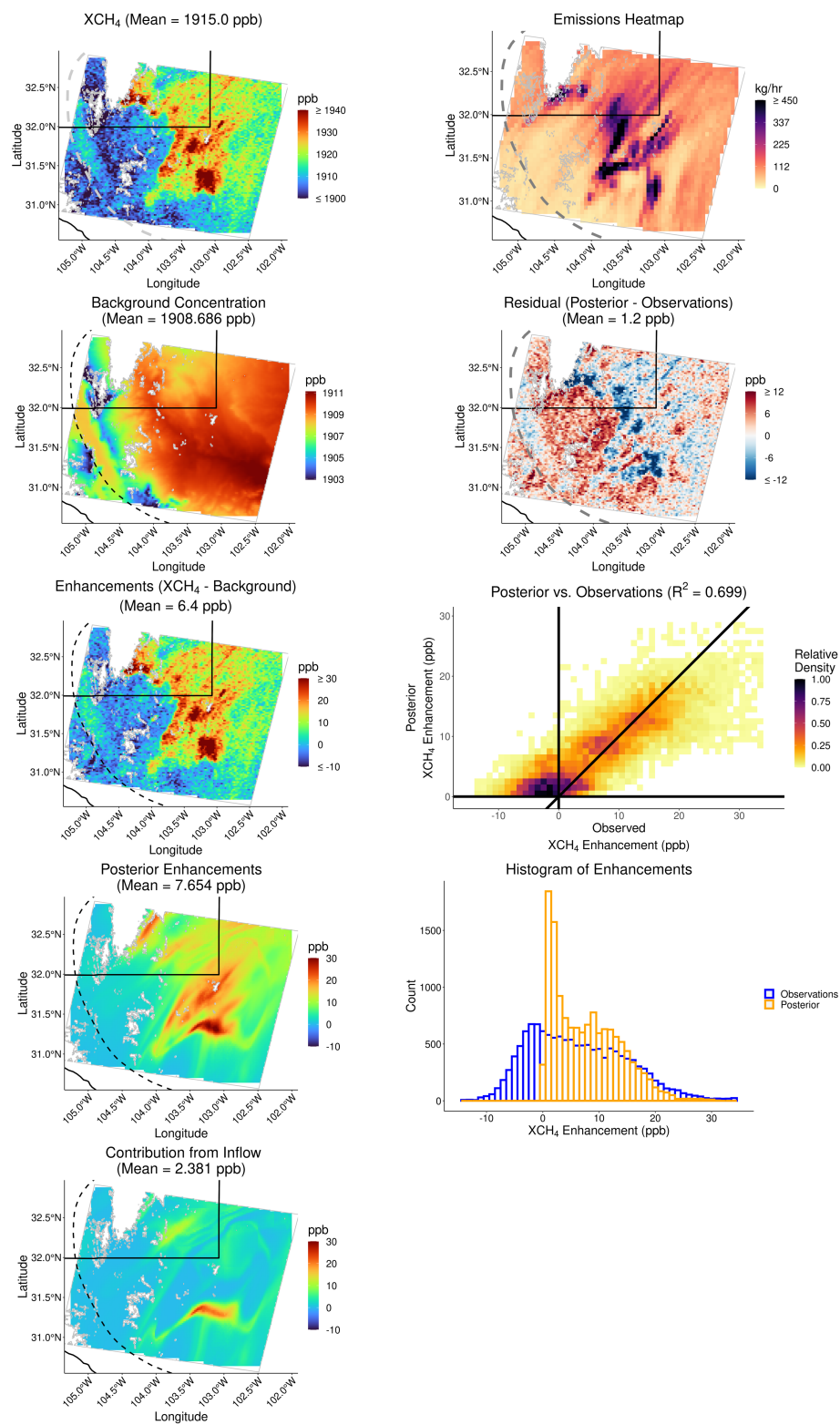


Figure S7. Summary figures for data from target 057, collect 03580390, observations from 27 Oct. 2024.

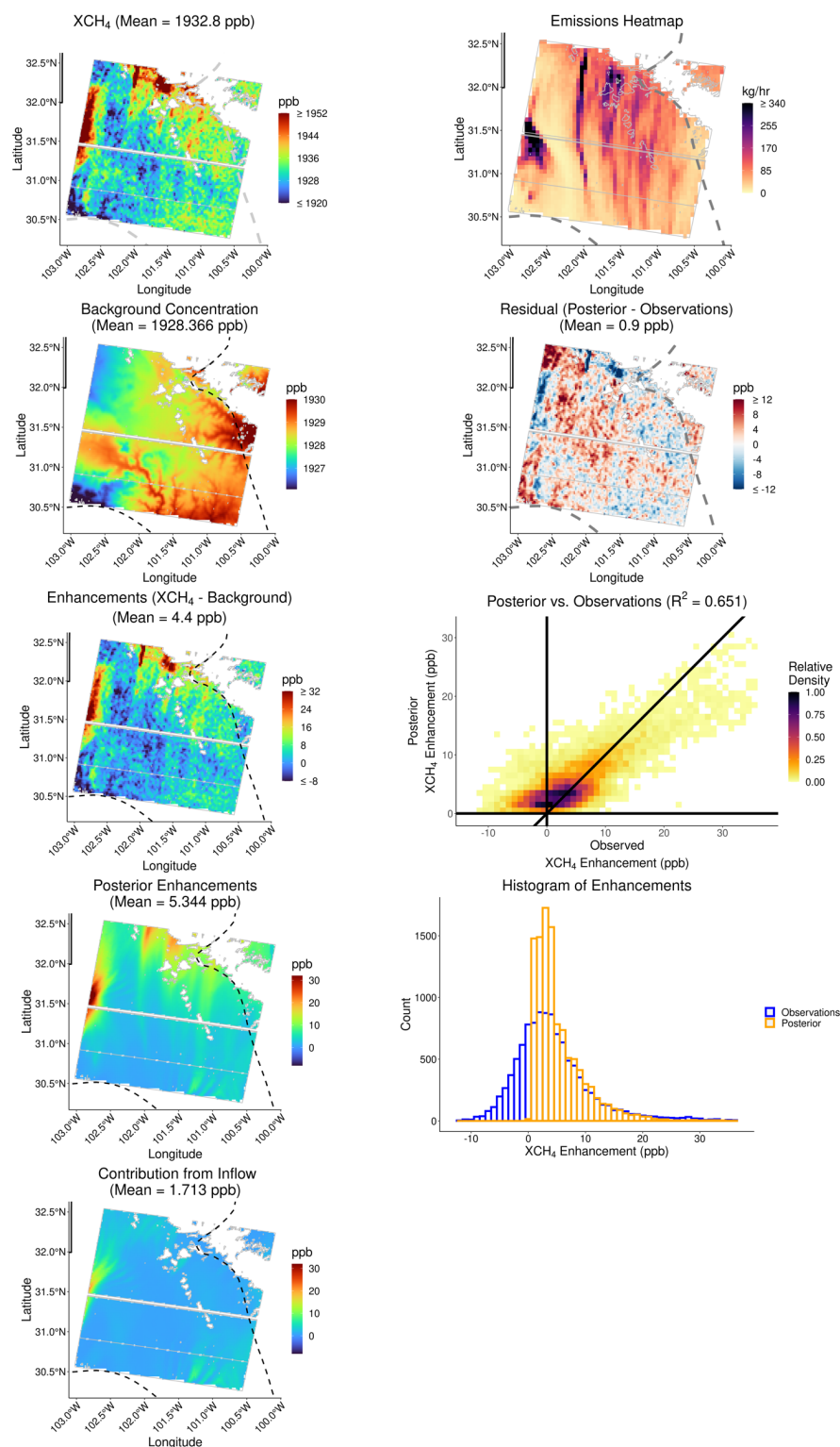


Figure S8. Summary figures for data from target 056, collect 046F0380, observations from 22 Nov. 2024.

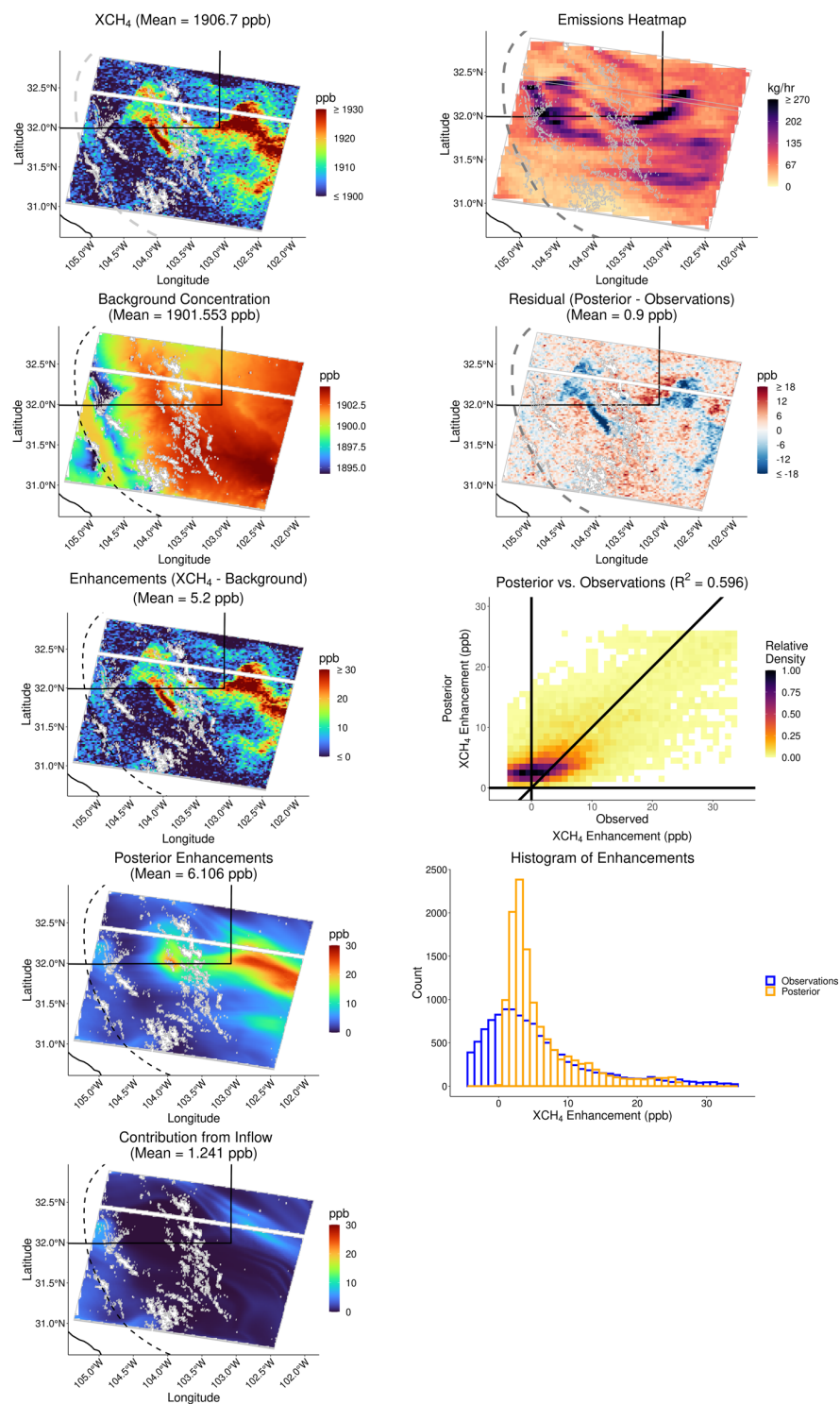


Figure S9. Summary figures for data from target 057, collect 05750390, observations from 29 Dec. 2024.

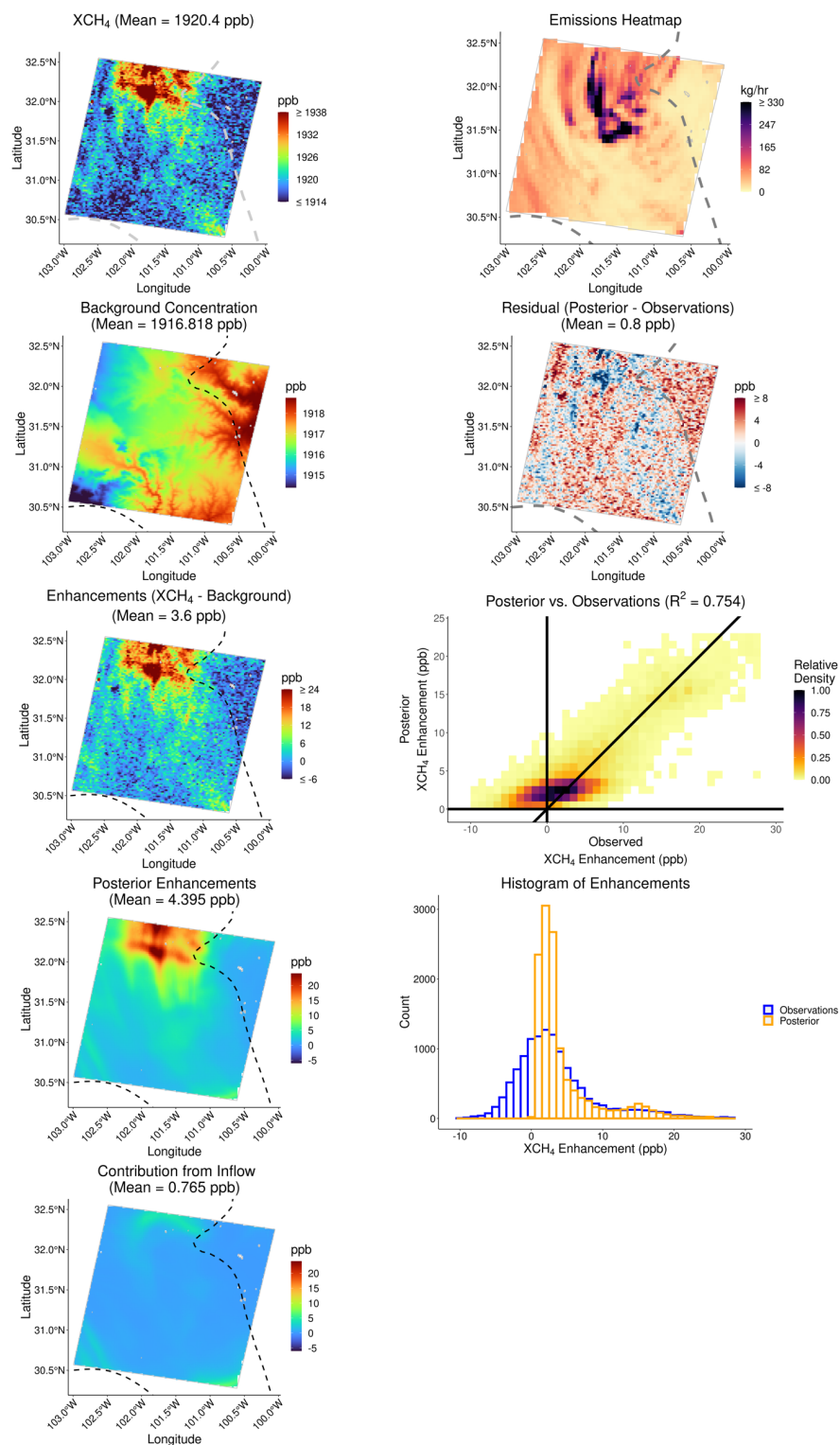


Figure S10. Summary figures for data from target 056, collect 09060380, observations from 20 Mar. 2025.

Date	Target	Collect	Avg Wind Spded (m/s)	Model	Value (kg/hr)	Lower Bound (kg/hr)	Upper Bound (kg/hr)
11 Sept. 2024	t005	c01430050	4.58	CORE	234693	174883	298315
				MFIM	316003	202188	429892
				EI-ME	254040	208313	325171
				Mass	204659	164007	245311
				MFIM_adj	432727	276872	588683
22 May 2024	t006	c00040060	5.14	CORE	69311	45943	99338
				MFIM	33464	14356	51659
				EI-ME	184021	150897	235547
				Mass	69840	29105	110576
				MFIM_adj	46164	19805	71264
26 Oct. 2024	t056	c03490380	2.28	CORE	170593	124863	222651
				MFIM	211421	135814	279007
				EI-ME	142491	116843	182388
				Mass	68603	49774	87432
				MFIM_adj	250001	160597	329920
22 Nov. 2024	t056	c046F0380	4.99	CORE	201231	149504	258998
				MFIM	142632	69438	200111
				EI-ME	116760	95743	149453
				Mass	78784	42987	114581
				MFIM_adj	149623	72841	209920
20 Mar. 2025	t056	c09060380	6.68	CORE	117085	85812	152643
				MFIM	104474	57084	156213
				EI-ME	130825	107277	167456
				Mass	91194	39778	142609
				MFIM_adj	113917	62244	170332
30 Sept. 2024	t057	c01DF0390	3.08	CORE	175355	130863	225088
				MFIM	306585	266381	405022
				EI-ME	216214	177295	276754
				Mass	110830	83864	137795
				MFIM_adj	351530	305432	464398
13 Oct. 2024	t057	c02710390	5.88	CORE	286028	216910	363520
				MFIM	237952	154702	321694
				EI-ME	173847	142555	222524
				Mass	163097	118788	207407
				MFIM_adj	315549	205150	426600
27 Oct. 2024	t057	c03580390	6.53	CORE	293402	224581	368258
				MFIM	236967	134009	339782
				EI-ME	170756	140020	218568
				Mass	174747	121287	228208
				MFIM_adj	281090	158961	403050
29 Dec. 2024	t057	c05750390	7.88	CORE	332058	247847	425088
				MFIM	184760	103634	273770
				EI-ME	157108	128829	201098
				Mass	157071	97252	216889
				MFIM_adj	199139	111699	295076

Table S1. Emission rate estimates for each scene, according to this inversion, the operational CORE inversion, the EI-ME and a simple mass balance approach. Upper and lower bounds are given, as well as the wind speed for each observation. The target number and collect number are used to organize scenes within the MSAT data system. We did not assess the uncertainty of the MFIM model with the CORE background, but the spread would be comparable to the normal MFIM case for that scene.

Target	Collect	Date	Basin Total (kg/hr)	Distinct Sources (kg/hr)	Relative Contribution
t005	c01430050	11 Sept. 2024	316003	25290	8.00%
t006	c00040060	22 May 2024	33464	835	2.50%
t056	c03490380	26 Oct. 2024	211421	27142	12.84%
t056	c046F0380	22 Nov. 2024	142632	0	0.00%
t056	c09060380	20 Mar. 2025	104474	15067	14.42%
t057	c01DF0390	30 Sept. 2024	306585	4839	1.58%
t057	c02710390	13 Oct. 2024	237952	19799	8.32%
t057	c03580390	27 Oct. 2024	236967	1778	0.75%
t057	c05750390	29 Dec. 2024	184760	10087	5.46%

Table S2. The relative contribution of distinct sources to the basin total for each set of observations.

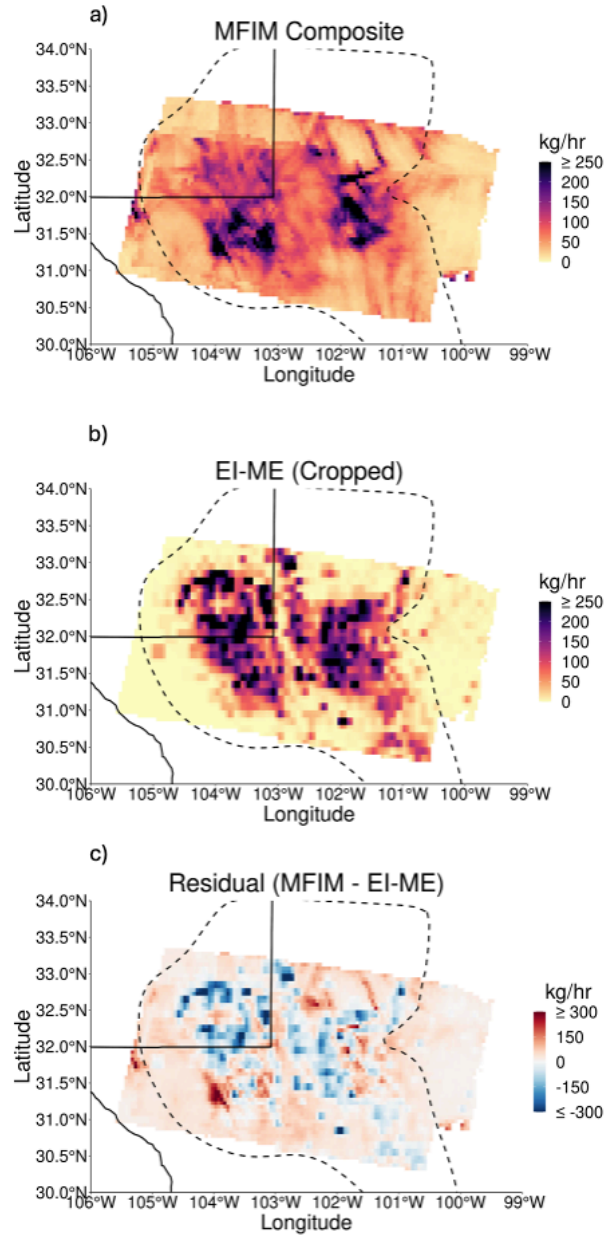


Figure S11. (a) The composite of the emissions estimates from all 9 scenes in the Permian basin, which allows us to approximate the long-term average emission rate and the spatial distribution of those emissions. (b) The EI-ME was averaged to the 0.05° x 0.05° resolution of MFIM to allow for cropping over the same region as the MFIM composite. (c) The residual between MFIM and the EI-ME Reveals broad agreement in the spatial distribution. Discrepancies between the two are especially prevalent in regions near the edge of the composite with fewer realizations of observations. Solid black lines are state and national boundaries, the dashed black line is the outline of the Permian Basin from the EI-ME.

Target	Collect	Date	Mean (kg/hr)	Median (kg/hr)	Difference
t005	c01430050	11 Sept. 2024	316003	316076	-0.02%
t005	c00040060	22 May 2024	33464	33467	-0.01%
t056	c03490380	26 Oct. 2024	211421	211474	-0.03%
t056	c046F0380	22 Nov. 2024	142632	142648	-0.01%
t056	c09060380	20 Mar. 2025	104474	104397	0.07%
t057	c01DF0390	30 Sept. 2024	306585	306703	-0.04%
t057	c02710390	13 Oct. 2024	237952	237980	-0.01%
t057	c03580390	27 Oct. 2024	236967	236718	0.11%
t057	c05750390	29 Dec. 2024	184760	184812	-0.03%

Table S3. Here we report the basin total emission rates for each scene using both the mean and the median as the measure of central tendency. We demonstrate that the basin total is insensitive to the choice of metric.

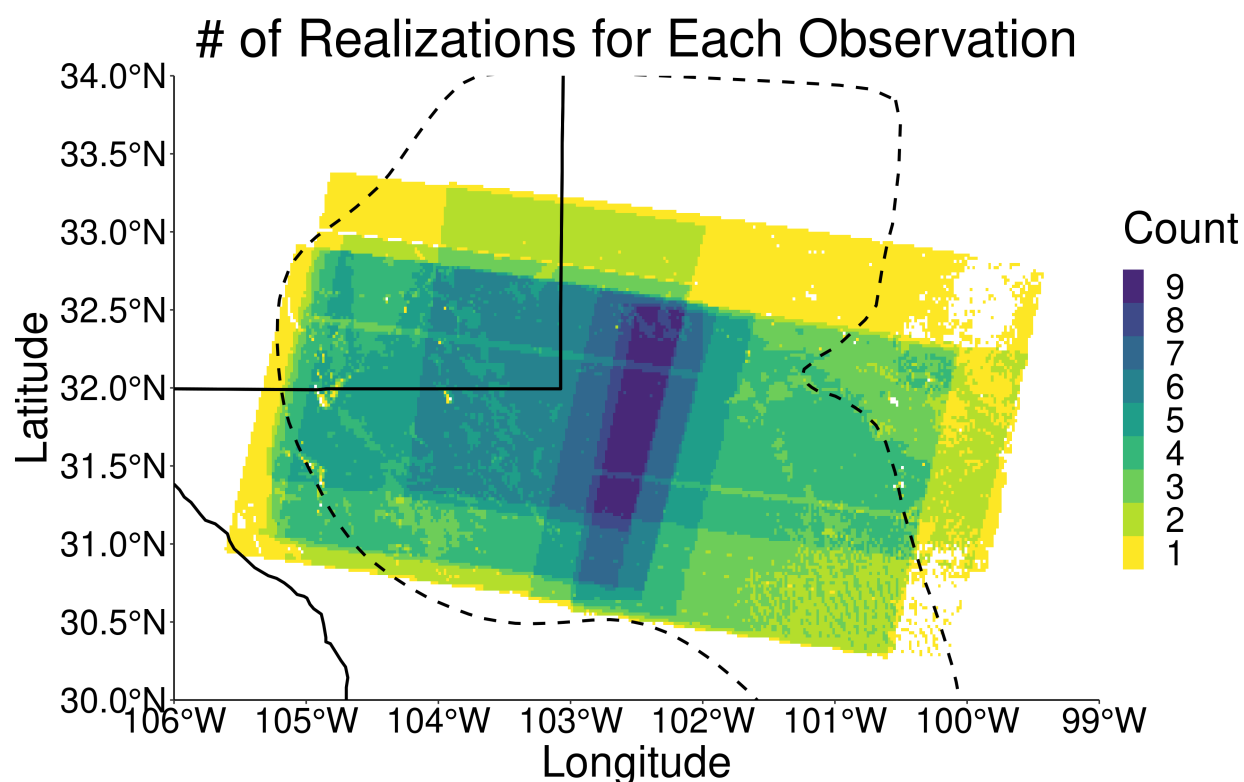


Figure S12. Here we show the number of realizations for each observation made over the Permian Basin. Regions of high overlap near the middle of the basin received as many as 9 observations, while some locations near the edges of the basin were observed only once. Most of the observations used in the composite were observed 3-6 times. The composite emissions estimate was calculated by averaging the emissions estimates for any grid cell that was observed more than once.

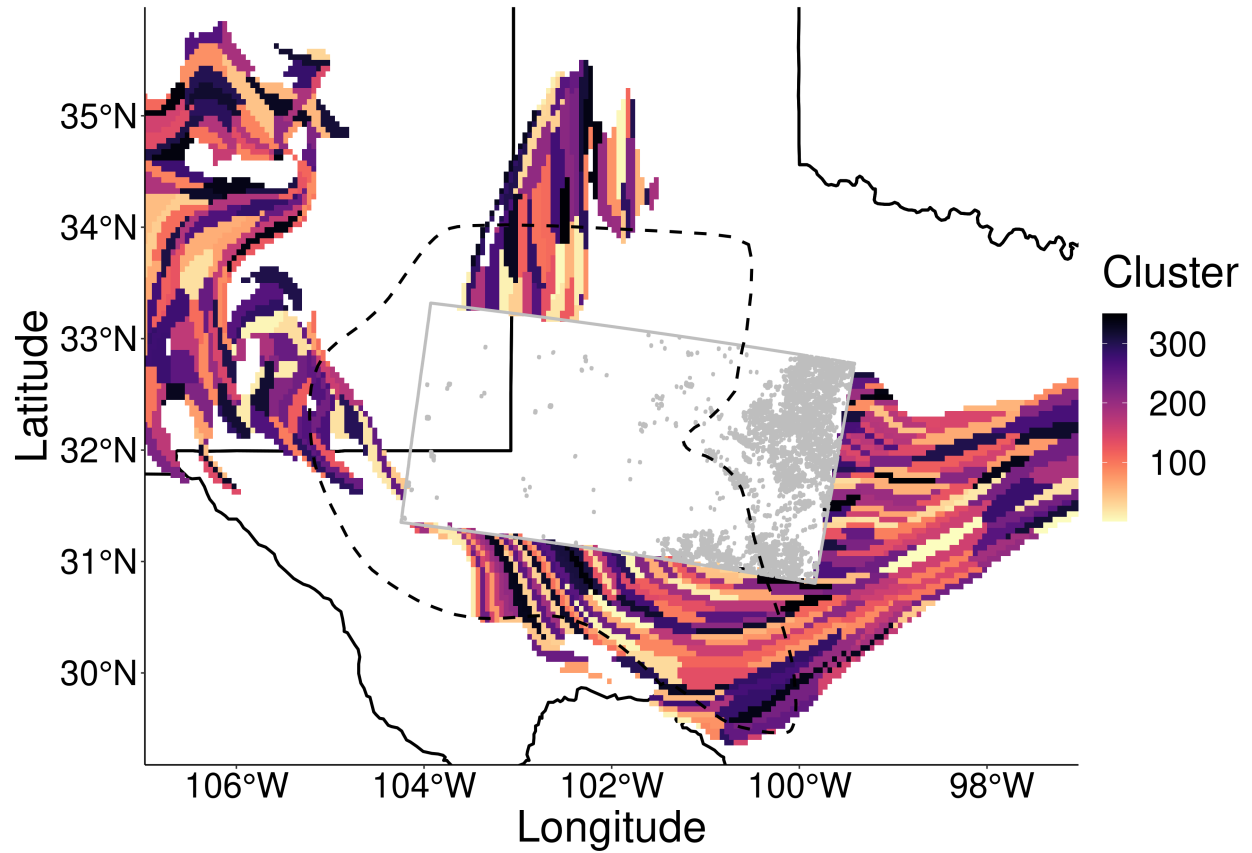


Figure S13. The influence footprint from all observations for MethaneSAT data collected on 11 Sept. 2024, clustered according to cosine distance of the columns of the Jacobian matrix using K-means clustering. The grey outline shows the borders of the MethaneSAT data, the dashed black line outlines the Permian Basin, and the solid black lines depict the borders of Texas, New Mexico and Mexico. Portions of the footprint with a negligible influence on the observations are omitted.