Characterizing and Comparing Anthropogenic CH_4 Sources in the DJ Basin using Mobile Surveys

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Pragmatic Target and Approach

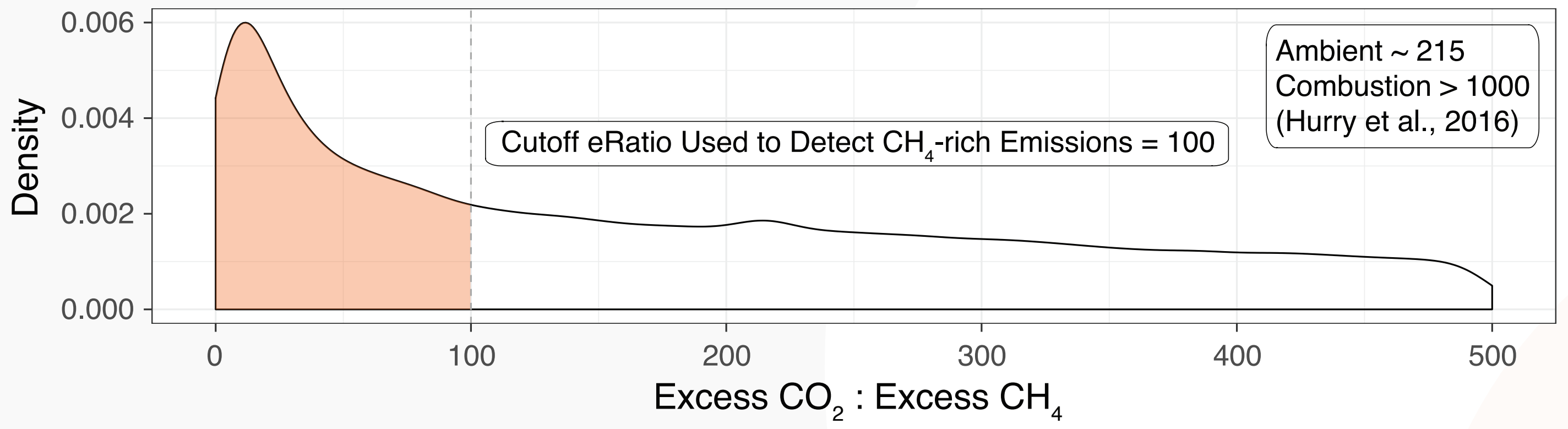
CH_4 is a potent GHG with 28-36 times the warming potential of CO_2 over 100 years, and so it is an efficient target for efforts to minimize climate change. Knowing the relative impact of different emissions sources should allow us to make well informed and effective policy decisions to regulate and reduce GHG emissions and improve local air quality.

There are several ways to detect CH_4 emissions including satellites, drones, mass balance airborne studies, road-based fencelines and optical gas imaging. Together they lend to a "triaged" approach to curbing emissions, in that satellite hot-spots inspire regional studies, which can isolate major emission sources for OGI and repair. This particular project leverages the detailed spatial and geochemical data attained through road-based surveys to compare the emission frequency and severity of different sources, as well as to characterize ambient and anomalous geochemical signals.

Detecting and Attributing Anomalies

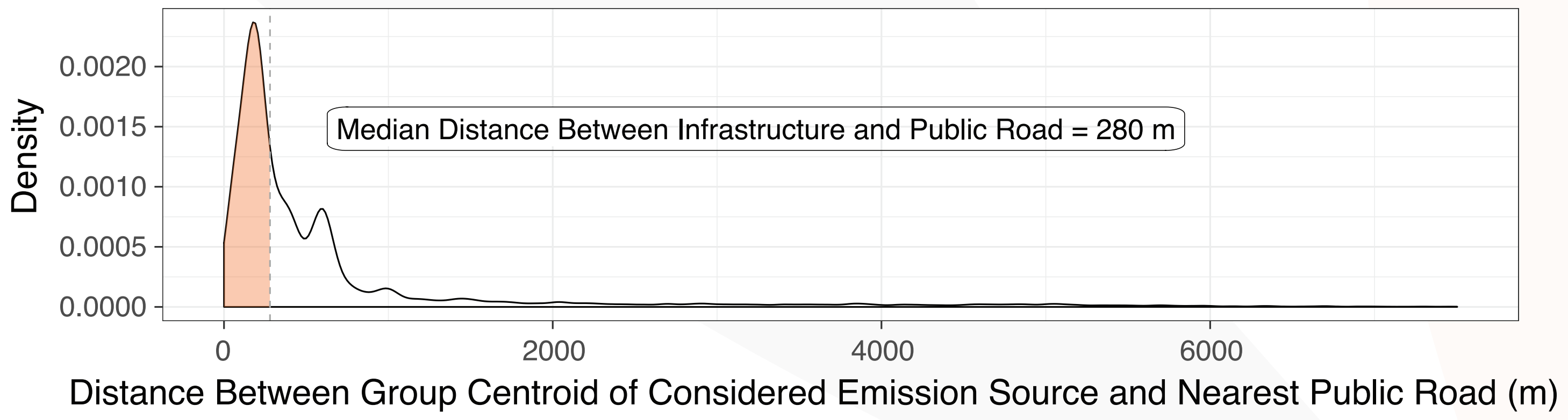
CH_4-rich plumes were defined as periods ≥ 3 sec in duration where the ratio of superambient CO_2 to superambient CH_4 remained < 100, based on Hurry et al. (2016) and Atherton et al. (2017) (Figure 1). Excess concentrations were calculated from background estimates derived from an algorithm designed to set the min. concentration of each gas observed during a moving window as the ambient atmosphere at that moment. The window interval was optimized for each survey to account for atmospheric variability, and ranged between 152-704 sec with an average of 380 sec.

Figure 1. Using eCO_2:eCH_4 < 100 to define CH_4-rich anomalies



373 groups of infrastructure, representing 559 individual units, were sampled ***downwind*** and ***within 280 m***. Infrastructure were grouped if within 45 m of another, to avoid overestimating both sources and emissions. Groups were assumed to be emission sources if ***CH_4-rich ≥ 50% of the times they were sampled***. Algorithms were written in R, with assistance from QGIS.

Figure 2. Narrowing our search improves attribution certainty



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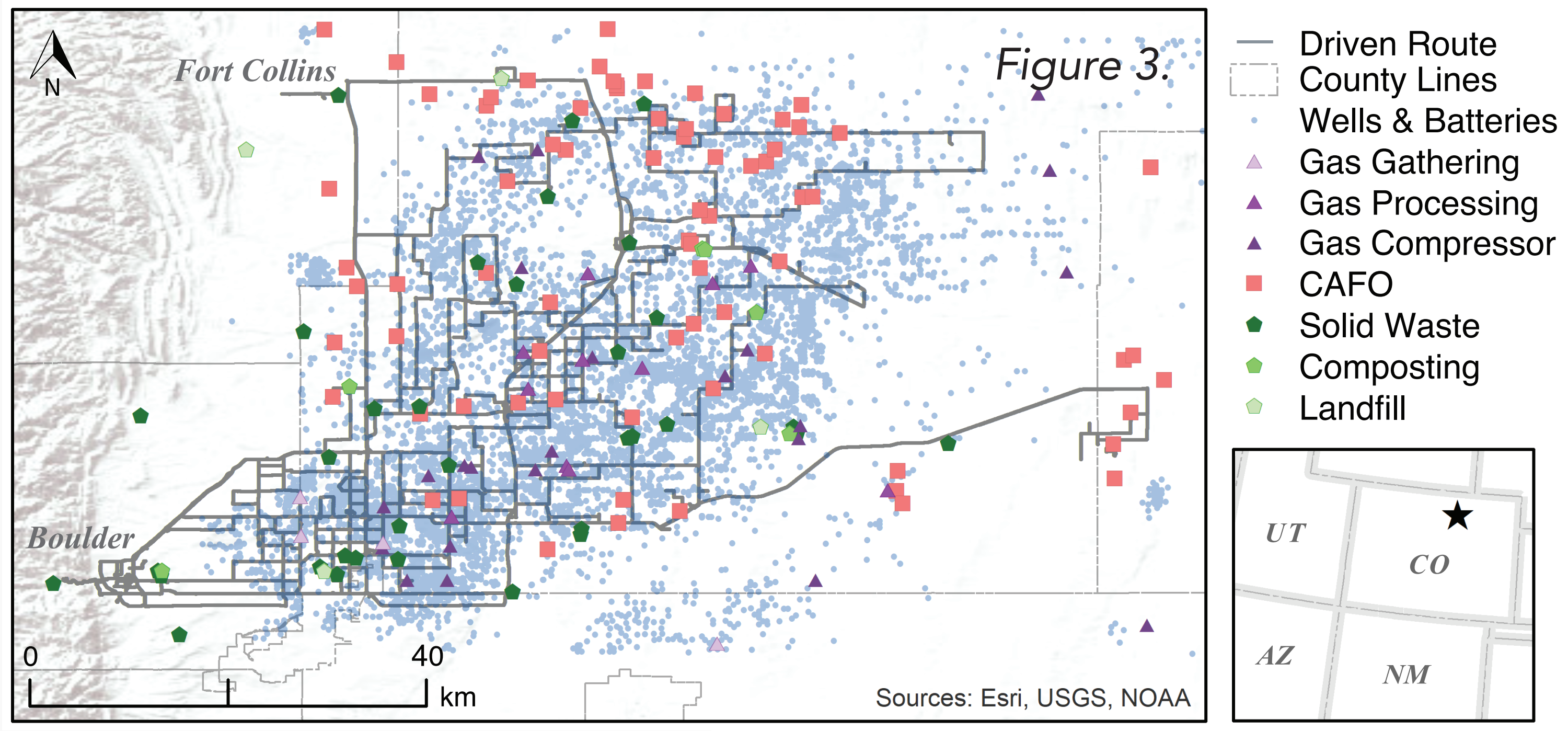
Spatial Comprehension and Resolution



Over the summer of 2014, 503,095 geo-located multi-gas measurements were collected in the complex multi-use landscape of Colorado's Denver-Julesburg Basin using a Picarro Surveyor, a vehicle-based Cavity Ring-Down spectroscopy and wind measurement system (Figure 3). A cumulative 3,700 km of data were collected at 1 Hz resolution.

Emission Frequency by Source Type

Most sampled groups of infrastructure contained sources of the same type, though one contained both a well and a Concentrated Animal Feeding Operation (CAFO) (Table 1). Certainty accounts for adjacent groups, but not infrastructure > 280 m from roadside. Emitting criteria are ***highlighted*** in the methods (left).

Table 1. Sample size may skew reported frequencies in some cases

Infrastructure	Sampled (n)	Emitting (n)	Frequency (%)	Certainty (%)
Wells & Batteries	338.5	48	14.2	88.9
Gas Gathering	1	0	0	100
Gas Processing	5	2	40	100
Gas Compressor	8	2	25	100
CAFO	15.5	3	19.4	100
Solid Waste	3	0	0	100
Composting	2	1	50	100
Total	**373**	**56**	**15**	**90.3**

Emission Chemistry by Source Type

Mean excess concentrations of the most CH_4-rich plumes, standardized to 10 ppm CH_4, reveal signatures for the different source types (Table 2). Plumes from wells and CAFOs appear to have the greatest difference in geochemical composition. More work will be done on this.

Table 2. Comparative chemistries

Infrastructure	eCH_4	:	eCO_2	:	eH_2O (ppm)
Wells	10	:	13	:	5,218
Gas Processing	10	:	580	:	148,901
Gas Compressor	10	:	402	:	31,207
CAFO	10	:	935	:	1,029,491
Composting (n = 2)	10	:	461	:	12,981

5 plumes with max. eCH_4 were used, unless otherwise stated.

Plume Frequency and Duration

19.8% of measurements comprised CH_4-rich plumes and 18.1% of plumes met attribution criteria. Long-lasting plumes can briefly elevate ambient atmospheric estimates and obscure plume detection, but most plumes were short-lived relative to the min. interval used to calculate background concentrations (152 sec) (Table 3).

Table 3. Plume duration statistics

Total plumes observed (n)	3104
Total attributed plumes (n)	563
Mean duration (s)	33.6 ± 84.4
Median duration (s)	9
Max. duration (s)	976
Min. duration (s)	3

Estimating Rates using Gaussian Dispersion

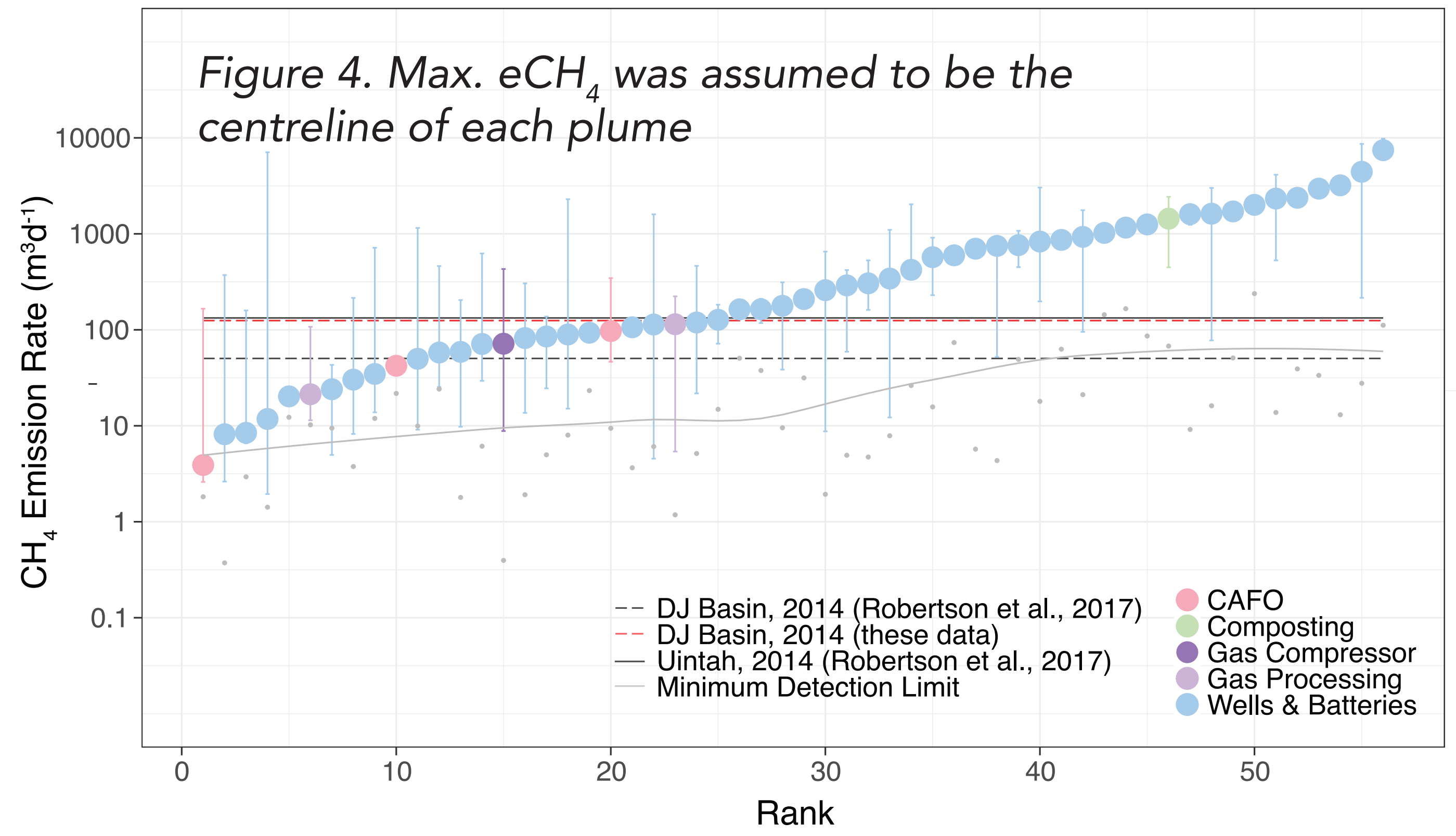
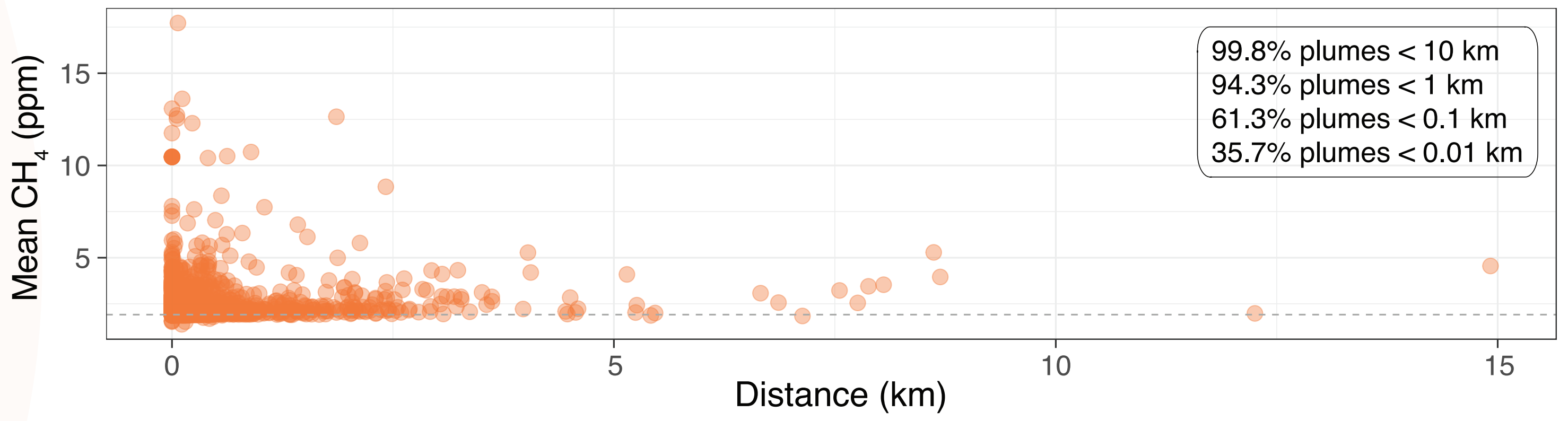


Figure 4. Max. eCH_4 was assumed to be the centreline of each plume

The median emission rate for each emitting group is shown in Figure 4, with error bars revealing the range. Though the mean median emission rate of all sampled wellpads (124.7 m^3d^{-1}) was higher than what was reported by Robertson et al. (2017) (50.3 m^3d^{-1}), it was less than what was reported for Uintah (132.9 m^3d^{-1}). An explanation for the discrepancy might be that we had a larger sample size which included the heavy tail distribution that is characteristic of CH_4 emission sources in O&G developments, where a few units are responsible for the majority of total emissions by volume (Brandt et al., 2016). CAFO emission rates reported here are underestimated, given that they are area, not point, sources.

Emission Severity

Figure 5. Mean CH_4 over the haverine (geospatial) distance of each plume



Ambient CH_4 for the study (1.91 ppm, gray dotted line) was marginally elevated relative to the global mean of 1.83 ppm reported by Dlugokencky in 2016 (Figure 5).

Requests and Recommendations

In the immediate future, these data will be compiled into an article for peer review, so feedback at this stage is greatly appreciated.

Road-based atmospheric surveys are relatively efficient, in terms of cost and spatio-temporal coverage; and the algorithms applied in this study allowed us to make invaluable comparisons between emissions from different source types. It is our recommendation that road-based surveys incorporating computational analyses occur in tandem with airborne emission inventory work in order to better understand and address the relative impact of different industrial sectors.

References

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