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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Mobile measurement of methane emissions from natural gas developments in Northeastern British Columbia, Canada" *by* Emmaline Atherton et al.

Anonymous Referee #3

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The authors present data and analysis from six mobile measurement surveys in the Montney formation which include methane emission concentration and rate information from 1600 passes near wells. The routes were surveyed 3-6 times each and designated as new wells, old wells, and a control. The authors use the methane and CO2 concentration and meteorology data to calculate emission rates of methane from wells. They analyze the data using online well number, production, age, etc. information to show which types of wells or activities emit most or most often. And finally, they compare their results to available data from recent studies in other formations in U.S. Collection of mobile data, especially when one is at the whim of wind to assure downwind of well measurements, is no easy task. The authors have conducted a great

survey of sites in the Montney formation. This study is exactly the type of research that is needed to clarify and quantify the emission rates of methane from different formations and sources. The authors have done a lot of work and the publication of this paper (especially with the availability of the data upon request, as noted at the end of the manuscript) will be a great addition to the current body of knowledge on methane emissions from oil and gas sources. However, there is some more analysis, organization, and sentence structure improvement that is needed for this paper before publication. Please see my General and Specific comments below: General Comments: 1. Various groups have used different approaches to quantifying methane emission rates (e.g., EPA's OTM 33 method, use of different tracers for close or far quantifications using the Tracer Ratio Method, reverse plume modeling, etc.). One of the things that all the methods above have in common is method validation. It seems that the authors of this paper have not conducted any method validation studies. This is a major weakness in the study. I would recommend that a quick methane and CO2 release study and measurement be added to the paper. However, I understand that time and funding may not be available to do this. Instead, I suggest the authors do a detailed uncertainty analysis (maybe even add a section to the paper) where they discuss and calculate a theoretical uncertainty for their measurements and calculations. The authors have a short section on this, but since no method validation has been done, the uncertainty analysis should more exhaustive. 2. Another point that is not clarified in this paper is the difference between measurements made from unconventional vs conventional wells. The authors make a distinction between new and old wells. The attribute the increase in the oil and gas activity in the area to the use of unconventional extraction methods. However, when they discuss the wells measured, they do not show any information on the unconventional vs conventional wells. Are all the wells measured unconventional? 3. The authors do not distinguish between short term operations and permeant emission sources in their calculations. This may be difficult to do, but at least a discussion of how these would affect the regional emission calculations should be added. 4. Some of the writing in the paper is confusing. The sentence structures do

not flow well. I have given some specific examples of this in the “Specific Comments” section, but strongly suggest the co-authors who were not directly involved in the writing of the manuscript read the paper and comment on sections. Sometimes it is easy for the authors to unintentionally disregard clarity as they themselves are so familiar with the subject of the study. 5. The authors use two different tenses and two different voices (active and passive) throughout the paper. I suggest choosing only one. Two different voices and tenses make it confusing for the reader and require re-reading of sections. Specific Comments: 1. Abstract: The writing style of the abstract does not lend itself to clarity. The flow of the sentences is not coherent. I suggest re-writing it for better clarity and flow. For example: “We also observed emissions from facilities of various types that were highly repeatable.” is one of the sentences that is unclear and confusing. Or “This value exceed reported bottom-up estimates of 78,000 tonnes for all oil and gas sector sources in British Columbia, of which the Montney represents about 55% of production”. The abstract starts very abruptly. I suggest rewording the first sentence. 2. Page 1, Line 2: What do the authors mean by “incidence”? 3. Page 1, Line 4: Are authors including all oil and gas locations in “development”. I suggest clarifying this or using a different word. 4. Page 1, Line 6: The use of “infrastructural” here has the same problem as the previous comment. 5. Page 2, Line 5: What do the authors mean by “a petroleum system”. 6. Page 2, Line 14: Please rewrite “Over a 100-year... (ICPP, 2014)” for clarity. 7. Page 2, Line 33: I have noted this in the abstract too. Please describe what you call “infrastructure”. 8. Page 3, Line 1,2: Please re-write sentence for correct grammar. 9. Page 3, Line 13: Please define “super-emitters” and use appropriate references. 10. Page 3, Line 26: Do the authors have some estimate of numbers of wells? 11. Page 4: The authors use the words unconventional and hydraulically fractured interchangeably. These two do not mean the same thing. Unconventional oil and natural gas extraction refers to both hydraulic fracturing and horizontal drilling. 12. Page 4, Line 8: Is 1Hz frequency the rate of data collection? 13. Page 4: What were the average distances from wells? If this data is available, can it be used with meteorology data for plume dispersion modeling? 14.

Page 4, Line 14: Please re-write for correct grammar. 15. Page 4: Please note which routes the numbers are based on in Figure 1. 16. Page 4, Line 19: What do the authors mean by “raw” ? 17. Page 4, Line 23: What are wind speed units? 18. Page 4, Line 25: Since the authors have given the manufacturer of the other instruments used, why not indicate what type of GPS was used? 19. Page 4, Line 32: Please re-write “However, our surveys... unusable.” for clarity. 20. Page 5: Were the same approaches used for both CO2 and CH4 data handling and analysis? Please add a few sentences to clarify this. 21. Page 5, Line 10-12: Please add some statistical data. 22. Page 5, Line 20-21: Please re-write for clarity. 23. Page 5, Line 21: What do the authors mean by “normal air”? 24. Page 5: What are some sources of CO2 in the area? As this can be a major concern in your calculations, please add a few sentences to address this. 25. Page 6, Lines 1-2: Please re-write for clarity. 26. Page 6, Line 2: What do the authors mean by “developmental”? 27. Page 6: Are there any large dairy operations in the area? 28. Page 6, Line 15: Please re-write sentence for clarity. 29. Page 6, Line 16: I thought the authors used one route as control. Did they actually make measurements from oil and gas structures on this route and include them in the analysis? If yes, then should the designation not be changed? 30. Page 6, Line 19: Following up on the previous comment, please give numbers of the differences in the oil and gas densities. 31. Page 6, Line 30: What was the speed of the car during these measurements? This is important as it can have an impact based on the width of the plumes. 32. Page 6, Lines 31-32: What is the difference between 314 and 319 meter designations? Also, should this not be in the methods section instead of the results section? 33. Page 7, Line 1: What do the authors mean by “ In each, we see a peak of signatures near $\sim$215 which is representative of natural”? 34. Page 7, Line 5: relative to what? 35. Page 7, Line 25: What are the other methods? 36. Page 7, Line 27: Should this be associated? 37. Page 7, Line 30: Please define what you mean by “... a piece of infrastructure...” 38. Page 7, Line 32-34: Please re-write for clarity. 39. Page 7: I suggest adding clarifying sentences like, Well pads were the most common oil and gas structures encountered/sampled during our survey (%# of total sites).

40. Page 8, Lines 5-8: Please re-write for clarity. 41. Page 8, Lines 14-17: Please use a consistent theme for capitalization. 42. Page 8, Line 20: Please replace the term “probably” with one with a more scientific connotation or even some statistics. 43. Page 8: Please explain, clearly, what each category of wells encompasses. For example, does authorization mean that permit was granted? Was work on the pad started? Was temporary drilling part of the study or as noted previously was it excluded? 44. Page 9, Line 27: 60 out of how many? 45. Page 10, Line 2: Please reword “. . . less emission prone. . .” 46. Page 10, Line 20-32: This paragraph does not belong in this section. I suggest either deleting it or moving it to a more appropriate location. 47. Page 12: Please give a more detailed (method definition, details, and statistics) of the setup of your calculations. 48. Page 13, Line 5: Have the number of wells changed since 2012? Would this affect the calculations in this paper, especially when dealing with the comparison to other sites/studies? 49. Page 13: Please add a discussion of possible reasons for the differences in this study and others noted here. Uncertainty range? Different basins? Different measurement approaches? 50. Page 13, Line 29: Please give numbers. 51. Please revise the Conclusion. It needs more specific numbers and information. Also, the addition of super-emitters at the end does not make sense as this paper was not directly making measurements from such sites based on the previously discussed statistics. 52. Figure 1: Is it possible to add the location of the wells here as a light gray background? It would be helpful in visualizing the type of routes. Also, please make sure that your designations of routes in this figure and the paper are the same. After reading through, I found TABLE 1 in Tables. Do authors mention this table in the text of the manuscript? 53. Figure 2: What are 88 industry-defined areas? 54. Figure 3: This is not a comment on this figure, but in looking at this and other figures, having a table with route numbers, names, and characteristics would be very helpful. Something like Table 1 55. Figure 4: Please revise caption to explain graph better. What are the gray lines? 56. Figure 5: Please re-write caption for clarity. Also, the addition of the uncertainty discussion as noted before, will help this figure. 57. Figure 7: Why are there zero-zero points in this graph? Although physically

a zero-zero point makes sense, I do not think the addition of the points is statistically sound. 58. Figure 9: Please add numbers in the increasing sample size legend. Were any of the wells in this area re-worked? This will change the definition of well age in this discussion.

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