Speciation of VOC emissions related to offshore North Sea oil and gas production by Wilde et al.

This paper will be an important contribution to the literature. It addresses the fact that there are "few observational constraints on the nature of atmospheric emissions from this region". This region has a large number of oil and gas operations within it and as such it is presumed that there are significant emissions from these processes. The paper characterizes those emissions from a large number of research flights encompassing over 120 flight hours and the paper divides the study area into four different sectors that have geologically distinct fossil fuel reservoirs. Whole air samples were collected and then subsequently analyzed for a range of NMHCs (C2-C8). Methane and ethane were also measured on-board and these are discussed in the paper as well.

The paper is well written and a large amount of high quality work went into conducting the flights, analytical work, data analysis, and synthesis and I applaud the author's efforts. In my view the paper could be improved by making it a bit more concise. At times, I found it rambling and overly speculative.

I like Figure 2 as it nicely shows that the four different sectors have i-pentane to pentane ratios that are indicative of oil and gas operations influence. Somewhere I would state that emissions from sources other urban and O & G are not expected in this region (e.g., fires). In section 3.1.2 there is a discussion about correlations with tracer compounds. Here in a lead up to discussing Figure 3 it is stated that mixing ratios of propane are often elevated in regions of O & G production (true). It then goes on to state that light alkanes are often co-emitted in such regions and since propane is a well known tracer for O & G operations, a strong correlation with propane indicates a common source. I suggest reformulating the discussion in this section a little bit. A problem with the reasoning put forward in the first part of the paragraph is that there are other sources that contain all the light alkanes such as auto exhaust and they will correlate with propane and each other because they are co-emitted from this source also. So I would discuss Figures 3a and 3b more holistically - in other words taken by itself Figure 3a doesn't really have a great deal of meaning – however combined with 3b it does. So I would just rewrite this section a bit to more clearly make the point. I would also encourage the authors to look at expected relative and absolute abundance of NMHCs in the North Sea vs an urban area in the UK – this could be a good metric for establishing the influence of O &G operations on the region. The authors have already done this analysis (Fig 7) for each field type – just need to compare to an urban area. The relative abundance of the light alkanes compared to other NMHC species should really show up in such an analysis. Depending on the outcome of this analysis, some of the other sections that further explore the evidence that the observed emissions are from O & G operations could be shortened

Statements such as: "Aromatic compounds benzene and toluene were also well correlated with propane in West Sheltand, possibly representative of the fact that this region is dominated by oil production and hence emissions of higher carbon number species are expected (Warneke et al., 2014)" are what I referred to earlier as speculative. Not sure this reasoning is solid either. Another explanation is that the source is combustion and not O & G. This is where I think you can make some good points by looking at the absolute concentrations of propane to these compounds and compare to an urban area.

The strongest argument in this section is found in this sentence: "In general, much weaker correlations of all species with acetylene (compared to propane) were observed in all regions (Fig. 3b and Table 1). Particularly weak correlations were seen in West Shetland ($-0.07 < r < 0.53$), supporting the conclusion

that O&G activities were the dominant source of VOC emissions in this region with little influence from other sources"

The discussion of the benzene to toluene ratio: be consistent with discussing the B/T ratio and don't switch back and forth between B/T and T/B as it adds unnecessary confusion. I found the significant positive correlations interesting – especially when combined with the high B/T ratios. I am not aware of previous studies showing the relatively tight correlations of these species attributable to O & G operations – perhaps point this out or if there are other studies that have shown this then reference them. The tight correlations are interesting in general because of the disparate lifetimes of the two species. I suggest adding more discussion on this. I would discuss this in the context of expected transport times. In the discussion of Figure 4b the bit of highly correlated data with B/T > 4 is unusual and the sentence describing it is in need of some rework. It states:

"… implying evidence of either an aged emission source due to the high proportion of benzene relative to toluene or an additional source of benzene that is not co-emitted with toluene"

-if it was an aged emission then it would not correlate strongly and if the benzene is not co-emitted with toluene it also would not be correlated strongly. So needs more – and better – explanation. To get ratios of B/T that high starting from a traffic emission source would take 6 days ish of aging which would lead to essentially no correlation.

OH reactivity section: …Fig. 7b indicates that in the more remote offshore environment, where there are significantly less emission sources and VOC concentrations are generally lower, OH reactivity is dominated by fast reacting species with OH. This is an interesting conclusion. Perhaps it shows that a) the emissions from the North Sea O&G operations are relatively well controlled and b) urban areas in the region are still responsible for a large the VOC reactivity in the region. If this is a conclusion, I think it should be stated.

Comparison with inventories
The comparisons are interesting but they don't ultimately inform on the accuracy of the NAEI source profiles – as stated.

Other:

Page 3 line 25: Provide urls for the different projects

Page 4 line 10: Nowegian misspelled

Page 5: **Laboratory analysis of VOCs**
Provide more information on analytical specifications – particularly uncertainty in analyses. This doesn't have to be long but to give a sense of whether we are talking +/- 5% or +/-50% and if there is a drop off in precision for the higher MW species on the PLOT column. Source of the calibrations standard, etc.

Page 6 lines 7 and line 9 – units should be consistent and SI

Page 6 line 11: WAS was defined earlier as Whole Air Sampling which doesn't make total sense here.

Page 6 line 25: instead of referencing Hong et al., 2019, it would be better to say: (at $[OH]_{avg}$ = 1.3E06 and T = 260K).

Page 8 line 4: Table 1 – what are the two Norwegian sectors in the table?

Page 8 line 15: I suggest being consistent with r and r^2

Page 12 line 25: ..simple metric to identify key species that most readily from peroxy radicals (Gilman et al., 2013) – this has been known since the 1970s so you should either just cite the earlier source or Gilman and the earlier source.