

Interactive comment on “Oil and gas impacts on air quality in federal lands in the Bakken region: an overview of the Bakken Air Quality Study and first results” by A. J. Prenni et al.

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The authors thank the reviewers for the positive comments regarding the manuscript. Here we respond to the comments from Reviewer 2 only, as there were no recommended corrections from Reviewer 1.

Reviewer Comment 1.) It should be clarified in the introduction that while VOC and NO_x from oil and gas operations can drive high ozone, this requires strong inversions and has not been observed in the Bakken.

Response: The section has been reworded (page 4, lines 64-69) to clarify this point.

C11747

‘Emissions of VOCs and NO_x associated with oil and gas extraction can drive elevated ozone concentrations (Olague, 2012), which can impact national parks (Rodriguez et al., 2009) and other sensitive areas. High wintertime ozone concentrations have also been associated with oil and gas activities (Ahmadov et al., 2015; Edwards et al., 2014; Helmig et al., 2014; Schnell et al., 2009); however, these wintertime ozone episodes occur during strong inversions, which are not typically observed in the Bakken region.’

Reviewer Comment 2.) The introduction references Howell et al. to say that oil and gas can impact particulate pollution. However, this reference is a study of oil sands, which is a very different process than that occurring in the Bakken, this should be noted.

Response: This is a fair point. However, given that the Introduction is already quite long, rather than adding text to differentiate between processes related to oil extraction in the Bakken versus the Oil Sands, we have simply removed the reference to the Howell et al. paper here. The sentence is very general, and does not really need a reference, and the following sentences describe how particle concentrations might be impacted by oil and gas activities. We’ve also added a new reference regarding fugitive dust emissions, so that the section now reads (page 5, lines 89-94): ‘Ambient particle concentrations also can be impacted by oil and gas activities. Increased particle loading has the potential to degrade visibility (Malm et al., 1994), a protected air quality related value in Class I areas, and can cause adverse health effects (e.g. (Laden et al., 2006)). These particles can be the result of direct emissions, such as fugitive dust from mobile sources (Ilan-Bar et al., 2011), or formed from reactions of precursor species such as SO₂, VOCs, and NO_x.’

Reviewer Comment 3.) It would be good to have some type of figure or more quantitative measures demonstrating the results of the HYSPLIT analysis indicating that higher concentrations were from lower wind speeds (Section 3.1).

Response: A figure has been added to the manuscript: Figure 3 in Section 3.1.

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All other figures have been renumbered accordingly. The text has been modified slightly to reflect this addition (page 14, lines 270-279). 'To better understand the cause for the elevated concentrations, hourly ensemble back trajectories with a maximum length of 5 days were generated using version 4.9 of the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model (Draxler and Hess, 1998), as shown in Figure 3 for NO₂ data collected during the two study periods. Gridded meteorological data from the 12-km North American Mesoscale Model (NAM12, <http://www.emc.ncep.noaa.gov/NAM/.php>) (Janjić, 2003) were used as input. During the study period, back trajectory analysis showed that the periods with highest concentrations (top 5%) for SO₂ and NO₂ corresponded to trajectories that were shorter (slower speeds) and were more likely to be impacted by closer sources. In contrast, the lower concentration days had higher wind speeds and winds were preferentially from the west.'

Reviewer Comment 4.) For Figure 12, it needs to be made more clear if all the species are averaged between 8 a.m. and 4 p.m. measurements as ethane is or if the other species are a single measurement and when that measurement is made.

Response This point has been clarified in the text and in the Figure caption. In the text (pages 20-21, lines 421-423) it now states: 'NO_x, SO₂ and BC concentrations are daily average values; in contrast, ethane data are calculated as the average of two grab samples per day: one collected in the morning (typically 8 AM), and one collected in the afternoon (typically 4 PM).'

The figure caption has also been updated to read: 'Timeline of ethane, NO_x, SO₂, and BC during the second study period in 2013-2014. NO_x, SO₂ and BC concentrations are daily average values; ethane data are the average of two grab samples per day, one collected in the morning and one collected in the afternoon.'

Other changes

In creating the new figure in response to Comment 3, we found a minor error with the

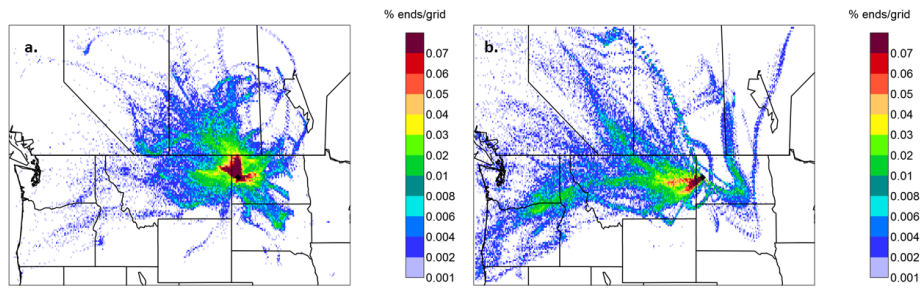
C11749

SO₂ dataset that was used to create Figure 3, specifically for the data from THRON. The data have been updated, and a revised Figure 3 (now Figure 4) has been uploaded. The revised data do not change the conclusions from the figure.

We have added two new references regarding the data analysis package used throughout the paper (page 16, lines 314-315). The text reads: 'Trend analysis throughout the paper was conducted using the Open Air package in R (Carslaw and Ropkins, 2012; Carslaw, 2014).' Carslaw, D.C. and K. Ropkins, (2012). openair – an R package for air quality data analysis. *Environmental Modelling & Software*. Volume 27-28, 52-61. Carslaw, D.C. (2014). The openair manual – open-source tools for analysing air pollution data. Manual for version 1.0, King's College London.

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C11750



'Figure 3. Back trajectory residence times showing areas where air masses resided during the two days prior to arriving at THRO-N. a) Trajectories arriving when the hourly NO₂ concentration was at the 95th percentile (4.63 ppb) or higher for the two Bakken Studies combined. b) Trajectories arriving when the hourly NO₂ concentration was at the 5th percentile (0.57 ppb) or lower for the combined measurements from both studies. Trajectories were generated using the Hysplit Model in ensemble mode with a start height of 10 m. All trajectories have a duration of two days, so longer lengths correspond to high wind speeds. Note that transport patterns associated with the highest concentrations tend to arrive from a smaller area, indicating probable stagnation, while those associated with the lowest concentrations correspond to travel from more distant areas, indicating high wind speeds, and are more predominantly from the west.'

Fig. 1.

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