Estimation of Emissions from Oil and Natural Gas Operations in Northeastern Colorado

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Abstract

We present top-down VOC and CH_4 emission evaluation results from a pilot study conducted in the Denver-Julesburg fossil fuel Basin (DJB) in northeastern Colorado [Pétron et al, 2012]. We have used in-situ and canister data collected from a 300-m tall tower located in the DJB and an instrumented vehicle. Our analysis suggests that the emissions of the measured species are most likely underestimated in current inventories.

Introduction

The production of unconventional oil and natural gas in the continental US provides a new and rapidly expanding source of domestic fossil fuel energy. Several states in the Rocky Mountain region have experienced a revival (Wyoming, Colorado, Utah) or a rapid growth (North Dakota) of their oil and gas industry. Several initiatives originating from EPA or the western States in partnership with industry operators have been focusing on estimating emissions for criteria air pollutants (CAPs), including surface ozone precursors (volatile organic compounds and nitrogen oxides), and greenhouse gases (GHGs) from upstream oil and gas production.

Emissions inventories have been developed to help support air quality modeling projects and to provide baseline information for emissions mitigation efforts [Bar-Ilan et al., 2008a, 2008b, 2012; US EPA, 2012]. The uncertainties attached to these bottom-up emissions inventories are often not calculated but are most likely quite large. New methodologies are used or will be used in the next few years to derive more accurate and up-to-date emission calculations. More robust emission estimates are needed to support the design of successful air quality management plans and to measure the success of emissions mitigation efforts. Atmospheric measurements of multiple chemical species [Pétron et al., 2012; Ryerson et al., 2011; Mellqvist et al., 2010] can provide independent information to evaluate bottom-up emissions estimates of CAPs, hazardous air pollutants (HAPs), and GHGs associated with oil and gas exploration, production, and

processing activities.

Methods

NOAA scientists routinely measure the composition of the regional and global atmosphere by sampling air from surface sites, towers, instrumented vehicles, ships, and aircraft deployed around the world. Using a combination of these high-quality measurements and a variety of models, NOAA scientists and their collaborators quantify the emissions of many chemical species (air pollutants, GHGs, and stratospheric-ozone-depleting substances) into the atmosphere and track how these emissions vary over space and time. The air samples collected by the NOAA network are analyzed by instruments either in the field or in laboratories at NOAA and the University of Colorado in Boulder.

For the study in the Colorado Front Range [Pétron et al., 2012], two measurement platforms, the 300-m Boulder Atmospheric Observatory (BAO) tower near Erie, Colorado, and an instrumented vehicle, were used to quantify the ambient levels of close to fifty different species, including methane and a limited suite of volatile organic compounds (VOCs) (Figure 1). All the canisters were analyzed on two analytical systems for close to 50 species, including methane, propane, n-butane, i- and n-pentane, carbon monoxide, benzene and acetylene. Enhancement ratios in the ambient levels of these hydrocarbons above background values are excellent markers of different source types, such as natural gas leaks, feedlots or combustion exhaust. Raw natural gas is 70-90% methane, with smaller amounts of many hydrocarbons covering a wide range in mass and complexity.

The BAO tower is part of a nationwide NOAA network of eight towers that monitors air composition, with a specific focus on GHGs. Of particular interest is the understanding of long-term changes in methane, currently the second most important GHG emitted by human activity, after carbon dioxide.

Results

Since NOAA's atmospheric composition measurements began at the BAO tower in August 2007, we noted that the levels of several light alkanes were much higher at BAO than at any of the other 7 NOAA towers around the country [Pétron et al., 2012]. Furthermore, these higher hydrocarbon levels were well correlated with enhanced methane levels.

To understand the BAO tower data, we collected 88 additional air samples in canisters with the instrumented vehicle downwind of different sources of methane around the Front Range during the summer of 2008 (Figure 1). Canister samples were taken downwind of cattle feedlots, a landfill, and a wastewater treatment plant, at various points across Weld County in the middle of the Denver-Julesburg Basin's (DJB's) Wattenberg oil and natural gas field, and in Boulder, Longmont and Denver.

The hydrocarbon ratios observed in the Wattenberg field in 2008 matched the ratios measured at the BAO tower when it sampled air from the DJB in the summers of 2008 and 2009 [Pétron et al., 2012]. This signature was consistent with emissions from oil and natural gas exploration and production (E&P) activities.

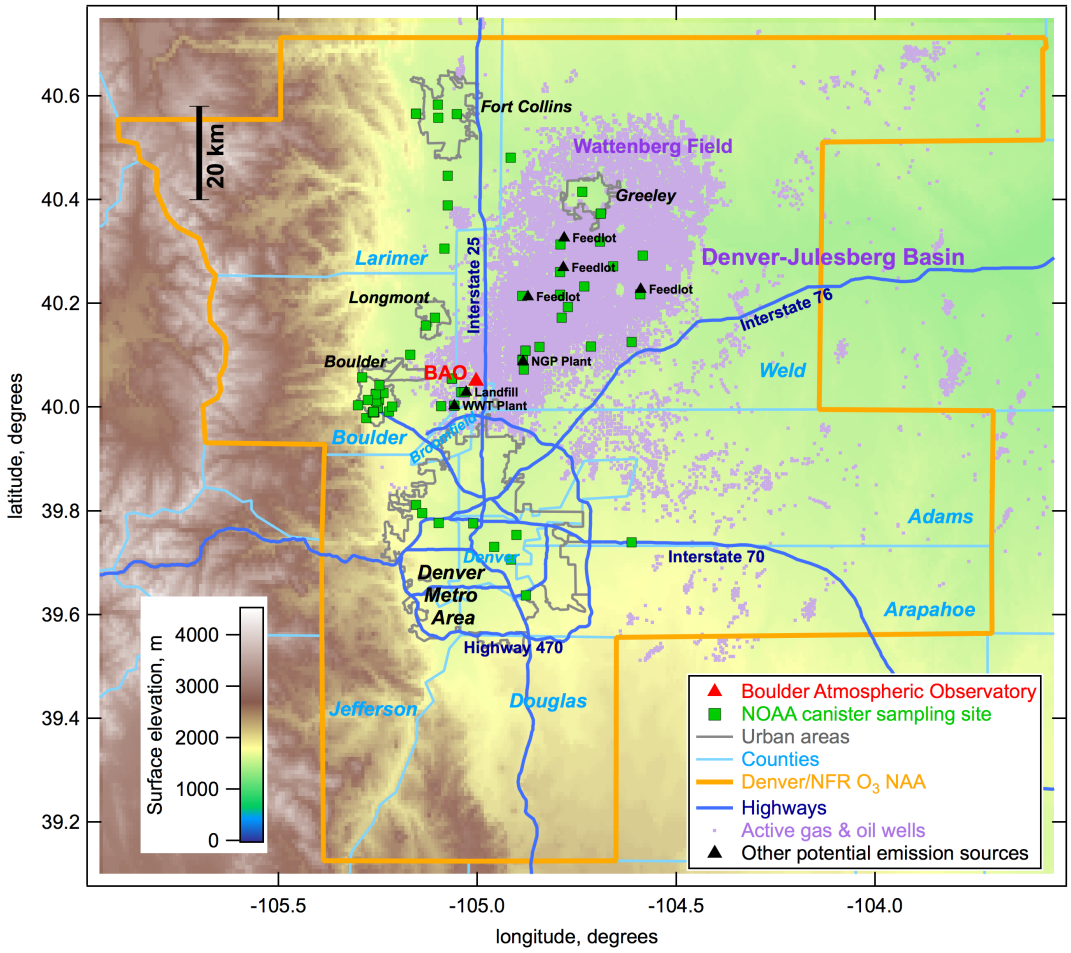

Figure 1. Hydrocarbon sampling has been carried out at the NOAA Boulder Atmospheric Observatory tower since August 2007. Mobile air canister samples were taken at the locations shown by the green squares in June and July 2008. Also shown are Front Range cities, counties, highways, and the Denver/Northern Front Range Ozone Non-Attainment Area; oil and gas wells active in the summer of 2008 (purple dots); and a few other potential methane emission sources sampled in 2008 (black triangles). *[Source: Pétron et al., 2012]*

To estimate emissions from our measured ambient hydrocarbon ratios, we used industry and regulatory raw natural gas hydrocarbon composition data [COGCC, 2007; Bar-Ilan et al., 2008a] and regulatory estimates for flashing emissions from condensate tanks in Weld County [Bar-Ilan et al., 2008a].

We derived estimates of methane emitted from raw natural gas leaks in Weld County in 2008 that are twice as large on average as the regulatory/industry estimates [Pétron et al., 2012]. The wide variation in the raw gas composition data and flashing emissions data limits our ability to estimate the methane leak rate to better than about a factor of two by this method. Our analysis finds that oil and gas E&P emissions of other hydrocarbons such as benzene are most likely higher than those in the regulatory emissions inventory for Weld County in 2008.

Conclusions

This analysis demonstrates that high quality ambient measurements can put independent constraints on emission inventories. The study described here is a first step. We can employ other approaches based on atmospheric measurements to evaluate inventories and to detect the impacts of emission controls on atmospheric pollution levels. For example, our study did not discriminate between the measurements taken before or after the incremental implementation of emission controls on oil and gas E&P equipment beginning in 2008. We continue to carry out targeted sampling in plumes for specific oil and gas E&P processes and equipment. We are also making basin-wide emission calculations using aircraft sampling and high-resolution wind measurements.

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References

Bar-Ilan A., et al. (2008a), Development of baseline 2006 emissions from oil and gas activity in the Denver-Julesburg Basin, WRAP Phase III report, 34p, available at http://www.wrapair.org/forums/ogwg/PhaseIII_Inventory.html.

Bar-Ilan A., et al. (2008b), Development of the 2010 oil and gas emissions projections for the Denver-Julesburg Basin, WRAP Phase III report, 26p, available at http://www.wrapair.org/forums/ogwg/PhaseIII_Inventory.html.

Bar-Ilan A., et al. (2012), Final Emissions Technical Memorandum, No. 4a (Colorado Basins), 33p, available at http://www.wrapair2.org/pdf/Memo_4a_OG_Jun06_2012_Final.pdf.

Colorado Oil and Gas Conservation Commission (COGCC) (2007), Greater Wattenberg area baseline study, report available in the Library section at http://cogcc.state.co.us/.

Mellqvist, J., Samuelsson, J., Johansson, J., Rivera, C., Lefer, B., Alvarez, S., and Jolly J. (2010), Measurements of industrial emissions of alkenes in Texas using the solar occultation flux method, *J. Geophys. Res., 115*, D00F17, doi:10.1029/2008JD011682.

Pétron, G., et al. (2012), Hydrocarbon Emissions Characterization in the Colorado Front Range — A Pilot Study, *J. Geophys. Res.*, *117*, D04304, doi:10.1029/2011JD016360.

Ryerson, T. B., et al. (2011), Atmospheric emissions from the Deepwater Horizon spill constrain air‐water partitioning, hydrocarbon fate, and leak rate, *Geophysical Research Letters*, *38*, L07803, doi:10.1029/2011GL046726.

US EPA (2012), Inventory of US Greenhouse Gases Emissions and Sinks: 1990-2010, Chapter 3, 74p.