ASSESSING AIR QUALITY IMPACT ON NON-ATTAINMENT REGIONS IN OHIO RESULTING FROM POWER PLANT CLOSURES AND SHALE GAS ACTIVITY

Saikat Ghosh*
Center for Air Quality, Ohio University, Athens, OH, USA

Kevin Crist
Center for Air Quality, Ohio University, Athens, OH, USA

1. INTRODUCTION

Oil and gas production in the United States has increased significantly due to horizontal drilling and hydraulic fracturing in shale formations. Substantial growth in shale oil and gas exploration has changed the long term energy outlook in the country. Shale production is projected to increase upto 7.9 million barrels (MM) per day of oil and 32.7 trillion cubic feet (tcf) per day of gas by 2050 in United States (EIA, 2018). This would result a tremendous growth in net natural gas exports and total liquids production and help creating jobs and improve the economy in United States.

Recent expansion of shale oil and gas exploration in eastern and southeastern Ohio has been a key driver of Ohio's economy. Horizontal wells in Utica Shale started producing oil and natural gas in 2011, but production rapidly increased to about 21 times during 2017. The production reached record highs of 259 barrels per day of oil and 10.8 million cubic feet per day of natural gas during June 2017 (EIA, 2017). Oil and gas industry has contributed about $43 million to six Ohio counties during the period of 2010-2015 through real estate property taxes paid for the wells (Ohio Oil & Gas Association, 2017). This tax is estimated to grow to $250 million over a period of 2016-2026 in these counties due to increased production.

The economic opportunities in shale extraction comes with few environmental risks. Shale oil & gas production activities can generate air emissions and pose a threat to the regional air-quality (Alvarez and Paranhos, 2012, McKenzie et. al., 2012). Figure 1 shows the different emission sources in shale oil & gas production, transport and processing activities. Venting, allowed during well completion to initiate gas production in a drilled well, is a significant source of methane and non-methane volatile organic compounds (VOC). Pneumatic devices and connecting valves leak significant amount of VOC. Drill rigs, fracturing pumps and compressors emit nitrogen oxides (NOx). Such emissions can have detrimental impacts on human health and ecosystems. Contribution of one single well to the air pollution is trivial and such small sources associated with each well are widely distributed. The aggregate emissions from thousands of well activity can have significant impact on the regional air pollution, particularly ozone.

Chemical transport modeling in Haynesville Shale over Texas and Louisiana showed an increase of up to 5 ppb in 2012 8-hr averaged ozone design values (Kemball-Cook et. al., 2010). This study also predicted a maximum increase of 17 ppb above background in daily 8-hr averaged ozone due to shale gas exploration. A similar study in Marcellus region of Pennsylvania (Roohani et. al., 2017) predicted an increase of up to 2.5 ppb in 2015 ozone design values.

While huge expansion of shale extraction is anticipated in Ohio, increased emissions from exploration activities can be offset when the produced natural gas is used in electricity generation. The net electricity generation from coal is projected to reduce from 1355 to 919 billion kilowatt-hours during 2015-2040 (EIA, 2016). While electricity generation from natural gas was forecasted to increase from 1348 to 1942 billion kilowatt-hours during 2015-2040. This analyses in AEO2016 used Clean Power Plan (CPP) that requires states to develop plans to reduce carbon dioxide (CO_2) emissions from existing fossil fired electric generating units. The CPP plan stimulated the shift from coal to natural gas and renewables in the AEO2016 analyses. Coal-fired electric generating capacity and related emissions decreases through 2030, even without the Clean Power Plan or lower natural gas prices due to market driven factors and technological advancements (EIA, 2018).

Therefore, it is necessary to model the impact of a future emissions scenario that will account both increase due to shale drilling expansion and decrease due to shift of coal to natural gas in

**Corresponding author:* Saikat Ghosh, Center for Air Quality, Ohio University; Athens, OH 45701;
E-mail: ghoshs@ohio.edu

power plants. This work aim to simulate the net impact on ozone of shale expansion and switchover or closing of coal-fired power plants. A chemical transport model was utilized to simulate impact of oil & gas production during 2011 and 2023. A net impact of oil & gas production and electricity generation (EGU) was also computed.

3. EMISSIONS

2011 National Emissions Inventory version 6.3 (USEPA, 2016) modeling platform was used for the base case modeling in this project. The 2023 emissions for oil and gas sector and EGUs were retrieved from NEIv6.3 future year inventory.

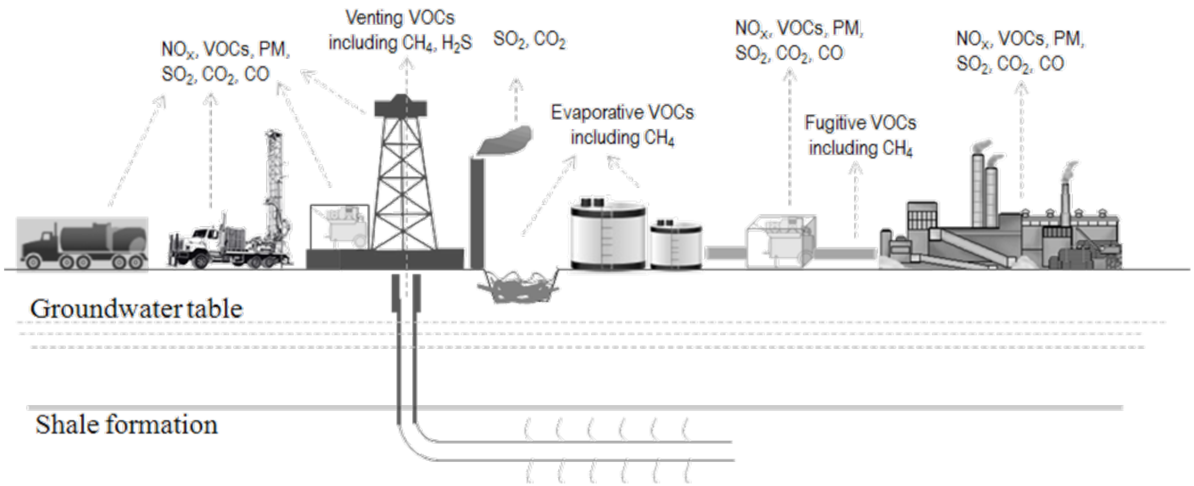

Figure 1: Different sources of emissions associated with oil and gas production

2. MODEL SETUP

A 2011-based air quality modeling platform was developed for this project. Photochemical model simulations were performed using EPA's Community Multiscale Air Quality (CMAQ v5.2) with updated Carbon Bond 6 (CB6r3) gas phase chemistry (USEPA, 2017). The modeling domain contains of 25 vertical layers and a horizontal grid resolution of 12 km x 12 km. 2011 baseline year was selected to leverage the 2011 NEI and because the year was historically typical for ozone formation (USEPA, 2013).

A modeling episode should be selected with multiple exceedances and some low points so that the modeling is able to capture different synoptic meteorological cycles (USEPA, 2014a). For the current simulations, June 30 to July 15, 2011 was selected as the modeling episode because it fits this criteria, with numerous ozone exceedances across the state.

The modeling platform was developed with gridded meteorological inputs from simulations with the Weather Research and Forecasting model (WRF v3.4) for the year 2011. The WRF simulations were obtained from Lake Michigan Air Directors Consortium (LADCO). Detailed methodology and model performance of the WRF simulations were provided in the USEPA report (USEPA, 2014b).

USEPA utilized AEO 2016 data to forecast oil and gas production data for the future year of 2023. The AE02016 shows 2023 projection factors of 4.8 for natural gas production, 1.9 for crude oil production and 3.3 for average oil and gas production in the East EIA supply region which includes Ohio.

The total VOC emissions were 10178 tons during 2011 and 47927 tons during 2023. The NOx emissions were 319 tons during 2011 and 1347 tons during 2023. The major sources for VOC emissions were fugitives, well completion venting (blowdowns), pneumatic devices and oil well tanks. While drill rigs and artificial lifts were major upstream NOx sources. The county level information about the emissions from 2011 and 2023 inventory were processed with SMOKEv3.7. Figure 2 shows the geographic distribution of SMOKE processed gridded emissions from 2023 inventory of oil and gas production in Ohio.

The future year 2023 emissions in this sector were created using IPM v5.16. The electricity demand projections within IPM was obtained from AEO2016. Figure 3 illustrates the NOx emissions from power plants in the annual inventories of 2011 and 2023. The total NOx emissions in Ohio from this sector were 1.04 MMT in 2011 and 0.37 MMT in 2023. The total VOC emissions in Ohio from the EGUs were 1503 in 2011 and 895 tons in 2023.

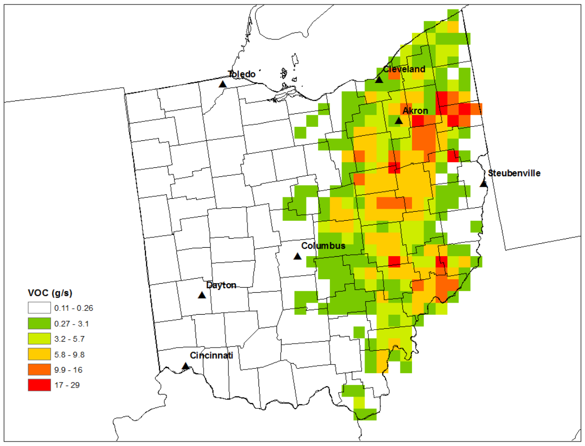

Figure 2: SMOKE processed total VOC emissions (g/s) in Ohio from 2023 year in NEI

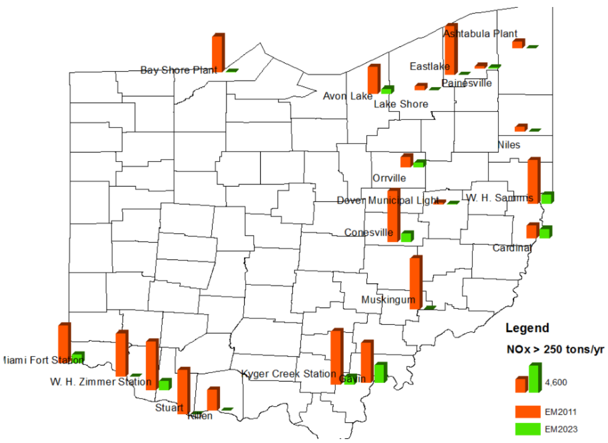

Figure 3: Spatial plot of power plants with their annual NOx emissions (> 250 tons/ year) during 2011 and 2023

4. SIMULATIONS

A series of simulations were performed with different emission scenarios to assess the potential impacts of shale oil & gas activities and power plant reductions on regional ozone levels. All simulations were performed with 2011 meteorology and basecase inventory for June 29 to July 15 with 1 day ramp-up. Table 1 shows the set of simulations and the respective emissions total in Ohio.

4.1 Impact of 2011 Oil & Gas Inventory

The first sensitivity simulation was performed to provide the differential ozone impact of oil and gas production during 2011 in Ohio. Figure 4 shows the increase in regional ozone due to oil and gas production during 2011 (Scenario I – Scenario II). Hourly averages were used in these analyses since the ozone impact was nominal due to low production during 2011. The episode average increase is nominal upto 0.02 ppb. Some relatively significant decrease in ozone levels was modeled in some locations probably due to titration effects of the NO_x emissions from oil and gas.

Table 1: List of simulations and respective emissions

Scenario	Simulation Name	Ohio Emissions (tons /year)	
		NOx	VOC
I	Basecase 2011	565503	732132
II	Basecase 2011 without nonpoint oil & gas in Ohio	565184	721954
III	Basecase 2011 with 2023 nonpoint oil & gas in Ohio	566531	769881
IV	Basecase 2011 with 2023 nonpoint oil & gas and EGUs in Ohio	499901	769272

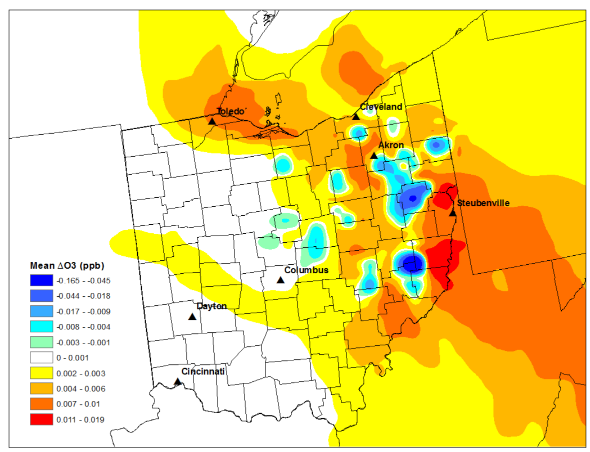

Figure 4: Average Δ 1-hr ozone levels contributed by oil and gas during 2011 (Scenario I-Scenario II)

4.2 Impact of 2023 Oil & Gas Inventory

The second set of sensitivity analysis (Scenario III-Scenario I) was performed to obtain the ozone impact of projected 2023 oil and gas production in Ohio. Figure 5 shows the episode average impact on 8-hour average ozone levels in Ohio. Figure 5 shows the episode average impact ranging from 0.06 to 0.22 ppb as contribution of 2023 oil and gas production. High levels were shown at the eastern part of Ohio, near Akron and Steubenville, where most production activity occurs.

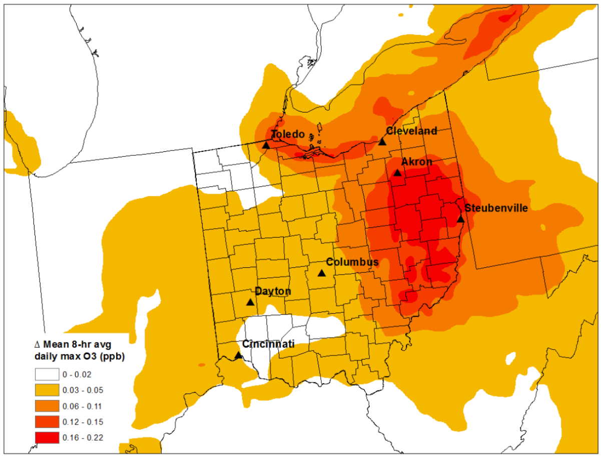

Figure 5: Mean Δ 8-hr ozone levels contributed by oil and gas during 2023 (Scenario III-Scenario I)

4.3 Impact of 2023 Oil & Gas & EGU

The combined impact of increase in oil and gas activity and decrease in coal driven power plant generation was simulated in the final sensitivity simulation (Scenario IV – Scenario I). Figure 6 shows that the large projected decrease of emissions from power plants washed away the nominal impact of oil and gas production during 2023. The mean 8-hour averaged ozone during the modeling episode was simulated to decrease upto 4.8 ppb. The spatial map in Figure 6 shows that the entire region should observe decrease in average ozone levels with lowest decrease near Cincinnati, Cleveland, Steubenville and Southeast Ohio.

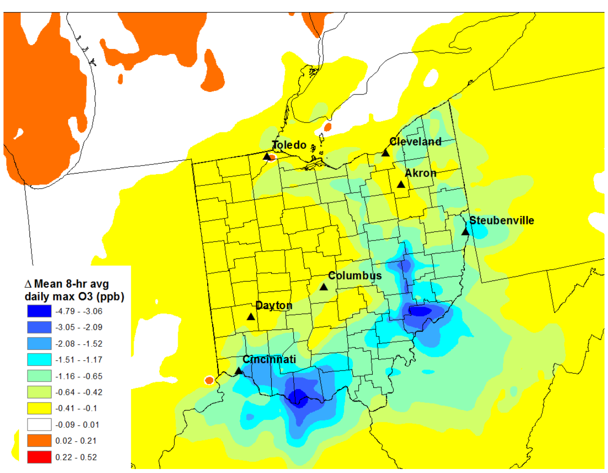

Figure 6: Mean Δ 8-hr ozone levels due to EGU and oil and gas during 2023 (Scenario IV--Scenario I)

5. DESIGN VALUE

USEPA (2014b) recommend using design values to demonstrate attainment using fractional changes in ozone between modeled future and base year at monitors. A design value is a statistics that describes the air quality status of a given location relative to NAAQS. For this modeled attainment test ratio of the model's future to basecase predictions are calculated called "relative response factor" (RRF). Future design values are obtained by multiplying modeled RRF by the observed baseline design value as shown in equation below.

$$(DVF)_I = (RRF)_I \times (DVB)_I \qquad (1)$$

Where, (DVB)i is the baseline design value for site I based on ozone observations; (RRF)i is the relative response factor calculated for site I; and (DVF)i is the future design value for site i.

The baseline design value (DVB)i is the three year average of the 4^{rth} highest measured 8-hour ozone value for a given monitor. 2011 baseline design values for the monitors in Ohio were obtained from USEPA AirTrends.

The RRF is the modeled ratio of mean 8-hour ozone values in future scenario to the same for 2011 base case. USEPA (2014b) recommends using modeled values from ten "high ozone days" in basecase simulation in a 3X3 grid array centered on the monitoring site i.

Figure 7 shows the change in 2011 design values with Scenario IV simulation of 2023 EGUs and oil and gas production. Scenario IV shows tremendous decrease upto 4 ppb in 2011 design values due to large reduction of NO_x emissions from coal power plant closures. The large decreases were observed in counties of Washington, Clermont, Athens, Jefferson, Noble, Lawrence, Geauga, and Clinton.

6. SUMMARY

The modeling shows nominal increase in regional ozone during 2011 due to oil and gas production activity in Ohio. This is evident from the low production during 2011 when exploration of shale formation in Ohio was initiated. The future year modeling of 2023 showed upto 1 ppb increase in 8 hr ozone with only oil and gas production. However, large reduction upto 4 ppb in 8 hr ozone was modeled with both 2023 emissions of oil and gas and power plants. It is to be noted that modeling was performed with the 2011 basecase altering only the nonpoint oil and gas production and electricity generation from 2023 future year in USEPA NEI. This shows that the power plant closures in Ohio largely offset the increase in ozone due to shale production activities.

Such modeling outputs need to be viewed with caution in regard to the uncertainty with the emissions inventory. Emission factors used in the estimates by USEPA need to be reviewed. The oil and gas production also tremendously expanded by 2015. USEPA is developing a emissions dataset for 2016 and this may provide better assessment for understanding the net benefit of fuel switching of coal to natural gas for electricity generation.

Future work is recommended to holistically model the entire Utican and Marcellus region for shale production. This should provide policy makers better information about the net impact of the shale production and power plant closures.

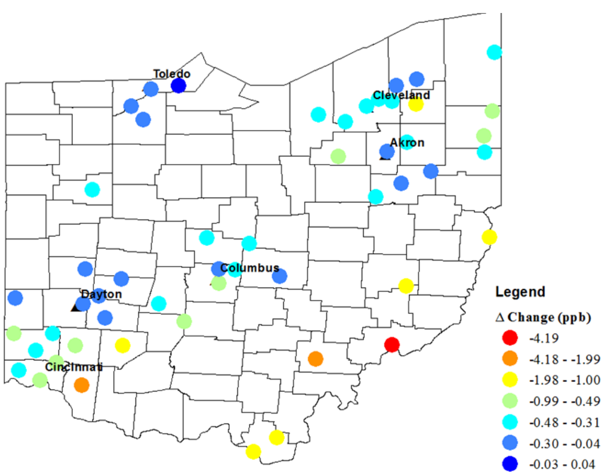

Figure 7: Spatial map of the Δ decrease in the 2011 design value due to 2023 projected emissions from EGUs and oil and gas production growth in Ohio (Scenario IV)

7. REFERENCES

Alvarez, R. A., & Paranhos, E, 2012. Air pollution issues associated. *Air Pollution Issues Associated*. EM Feature June.

Kemball-Cook, S., Bar-Ilan, A., Grant, J., Parker, L., Jung, J., Santamaria, W., Yarwood, G., 2010. Ozone impacts of natural gas development in the Haynesville Shale. *Environmental Science & Technology*, **44**, 9357-9363.

McKenzie, L. M., Witter, R. Z., Newman, L. S., & Adgate, J. L., 2012. Human health risk assessment of air emissions from development of unconventional natural gas resources. *Science of the Total Environment*, **424**, 79-87.

Ohio Oil & Gas Association, 2017. The Utica Shale Local Support Series: Ohio's Oil and Gas Industry Property Tax Payments. Ohio Oil & Gas Association, Columbus, OH 43215

Roohani, Y. H., Roy, A. A., Heo, J., Robinson, A. L., & Adams, P. J., 2017. Impact of natural gas development in the Marcellus and Utica shales on regional ozone and fine particulate matter levels. *Atmospheric environment*, **155**, 11-20.

U.S. Environmental Protection Agency, 2013. Development of 2011 Modeling Platform and Early Release of Emissions Inventories. https://www.cmascenter.org/conference/2013/slides/eyth_development_status_2013.pptx

U.S. Environmental Protection Agency, 2014b. Meteorological Model Performance for Annual 2011 Simulation WRF v3.4, Research Triangle Park, NC. (http://www.epa.gov/scram001/)

U.S. Environmental Protection Agency, 2014a. Modeling Guidance for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5, and Regional Haze, Research Triangle Park, NC. http://www.epa.gov/ttn/scram/guidance/guide/Draft_O3-PM-RH_Modeling_Guidance-2014.pdf

U.S. Environmental Protection Agency, 2016. 2011 National Emissions Inventory, Version 6.3 Technical Support Document. https://www.epa.gov/sites/production/files/2016-09/documents/2011v6_3_2017_emismod_tsd_aug2016_final.pdf

U.S. Environmental Protection Agency, 2017. CMAQv5.2 Operational Guidance

Document. Research Triangle Park, NC. (www.epa.gov/cmaq)

US Energy Information Administration, 2016. Annual Energy Outlook 2018: With Projections to 2040. U.S. Department of Energy, Washington, DC 20585

US Energy Information Administration, 2017. Annual Energy Outlook 2017: With Projections to 2050. U.S. Department of Energy, Washington, DC 20585

US Energy Information Administration, 2018. Annual Energy Outlook 2018: With Projections to 2050. U.S. Department of Energy, Washington, DC 20585