National Park Service
U.S. Department of the Interior

Natural Resources Stewardship & Science
Air Resources Division

Modeling to Evaluate Contribution of Oil and Gas Emissions to Air Pollution

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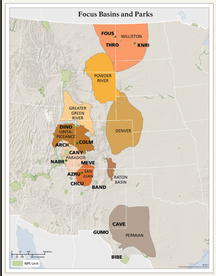
Background



Historically, U.S. oil and gas production was considered a small well-dispersed area source of air pollution. This has changed with advancements in technology including horizontal drilling and hydraulic fracturing; oil and gas development has grown significantly (EIA, 2014a), and is now the largest reported anthropogenic source of Volatile Organic Compounds (VOCs) emissions in numerous states (EPA, 2015a). It is also a significant source of emissions of other pollutants known to contribute to air quality concerns including nitrogen oxides (NOx), sulfur dioxide (SO2), particulate matter (PM) and air toxics (Adelman et al., 2014).

The US Energy Information Administration (EIA) reports that oil production growth in the U.S. has risen by about 3 million barrels per day from January 2001 to July 2014 (EIA, 2014a). Natural gas production has increased from 53.74 to 70.46 billion cubic feet per day within this time period (EIA, 2014a). The trend is expected to continue with the number of oil & gas wells in the lower 48 states projected to increase by 84% between 2013 and 2040 (EIA, 2014b).

Much of this expansion in oil and gas development is occurring in once remote regions of the country, near National Parks and other protected areas.

Study Purpose


Photo Credit: Barkley Sive

The NPS is concerned that increased emissions from the O&G sector could adversely affect resources and visitor experience in many park units near increasing development. This includes impacts from ozone, particulate matter and NOx emissions, which contribute to vegetation effects, degradation of air quality, visibility impairment, and nitrogen deposition.

In order to address these concerns, a modeling study was conducted to directly simulate and evaluate the impact of emissions associated with O&G production on National Parks and Class I areas in the western US. This study will identify regions and parks most likely to be impacted by the O&G source sector, which in turn will guide the design of future analyses, monitoring efforts and special studies.

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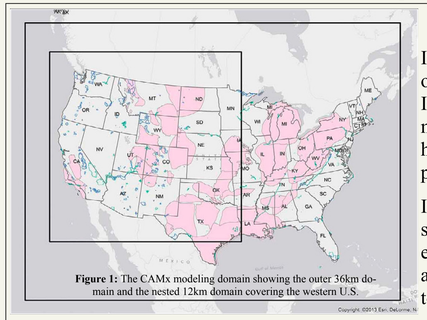


Figure 1: The CAMx modeling domain showing the outer 36km domain and the nested 12km domain covering the western U.S.

Methods

Impacts were modeled using the Comprehensive Air quality Model with Extensions v6.1 (CAMx) to simulate chemical transport and transformation. Inputs to CAMx include a full year of meteorological modeling input data and emissions inventories, both representing conditions as they occurred in 2011. Inputs for the modeling platform were developed by the Intermountain West Data Warehouse (IWDW), including the 2011 Three State Air Quality Study (3SAQS) emission inventory (Adelman and Baek, 2015). Details of meteorological modeling, emissions inventory development and model performance are available on the IWDW website (IWDW-WAQS, 2016; UNC and ENVIRON, 2014). This modeling platform has been utilized in numerous policy applications, which has led to a high level of model performance evaluation and scrutiny. Such scrutiny increases the acceptance of model results, performance and conclusions, specifically for the Western US.

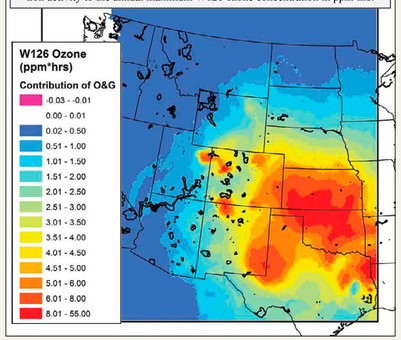
In general, this study focuses on emissions associated with oil and gas production and to some extent, processing sources (i.e., it excludes downstream oil and gas distribution or refining sources). Oil and gas impacts were derived using a brute force source apportionment method (BFM). The BFM estimates contributions of sources to air quality by simply removing the emissions sources of interest one by one and re-running the model to calculate the change in air quality due to the change in emissions (in this case oil and gas sources). Because there are known data gaps in oil and gas emission inventories and because this study only quantifies the emissions from a portion of the oil and gas production processes, it can be considered to represent a lower bound of oil and gas emissions.

The model domain includes the entire continental U.S. at a 36km resolution and a 12km nested domain covering the western U.S. - *results presented are for the 'nested' 12km domain only* (Figure 1). The map also shows the locations of the National Parks, both Class I and Class II (outlined in blue) and other federally administered Class I areas (outlined in green) which were analyzed in this study. In all, 162 total National Park units and 66 US Fish & Wildlife Service or US Forest Service Class I areas were assessed for oil and gas impacts.

Results & Discussion

Ozone is known to cause negative human health impacts and damage to sensitive vegetation and ecosystems. For this reason, two O_3 metrics were assessed, the W126 and the NAAQS.

Figure 2. Modeled contribution of emissions associated with oil and gas production activity to the annual maximum W126 ozone concentration in ppm-hrs.



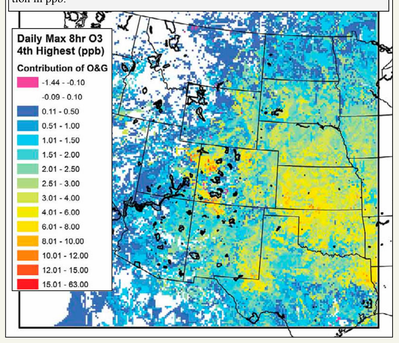
The W126 is a biologically-relevant seasonal index used to evaluate the risk to vegetation health. The NPS has adopted W126 thresholds for vegetation exposure that are protective of the most sensitive resources found in park units—a cumulative W126 threshold below 7 ppm-hrs is considered protective of the most sensitive plant species.

Results (Figure 2):

⇒ There are 68 units where the modeled O&G emissions contribute more than 10% of the base case W126 metric. There are 95 units with maximum contribution of more than 1 ppm-hours.

⇒ Along with large portions of Oklahoma, Texas and Nebraska, the four corners region shows up as a hotspot for oil and gas contributions to the ozone W126 index.

Figure 3. Modeled contribution of emissions associated with O&G production activity to thefourth highest daily maximum 8-hr averaged ozone concentration in ppb.



The National Ambient Air Quality Standard (NAAQS) for ozone is set at 70 ppb for a rolling 8-hour average.

Results NAAQS:

⇒ There are 88 units where the maximum contribution of O&G emissions to the 4th highest 8-hr ozone concentration is greater than 2 ppb; there are 139 units with an O&G contribution to the 4th highest 8-hr ozone concentration greater than 1 ppb. The largest contribution occurred at Washita Battlefield at 7 ppb. Figure 3

⇒ Modeled oil and gas emissions contributed 5.3 ppb to the 4th highest 8-hr ozone concentration at Aztec Ruins NM, 3.0 ppb at Mesa Verde NP, 6.6 ppb at Hovenweep NM.

Visibility is an important resource worthy of conservation and protection in NPS areas, as established under the NPS Organic Act and the Clean Air Act (CAA) of 1977.

The model analysis looked at the oil and gas contribution to haze on the 20% best and worst visibility days (consistent with current regional haze metrics) as well as the number of modeled days with a significant 24-hour average oil and gas visibility impact (defined as a 0.5 deciview or more).

Visibility Results (Figure 4):

⇒ Although visibility modeling results are more localized, the analysis suggests that O&G significantly degrades visibility at a number of class I & II national parks and class I wilderness areas near O&G fields, including those in the four corners region, which shows up as a modeled hotspot, as shown in Figure 4.

⇒ At 36 NPs and Class I areas, O&G caused more than 0.5 DV of haze on more than 20 days a year.

⇒ At Aztec Ruins nearly every day of the year had contributions greater than 0.5 DV. This indicates the potential for the regular occurrence of visible haze, which can detract from the visitor's experience.

⇒ At Mesa Verde, there are 19 days in the modeled year where oil and gas contributes more than a half a deciview to haze.

Figure 4. Modeled contribution of emissions associated with oil and gas production activity to visibility on the 20% haziest days.

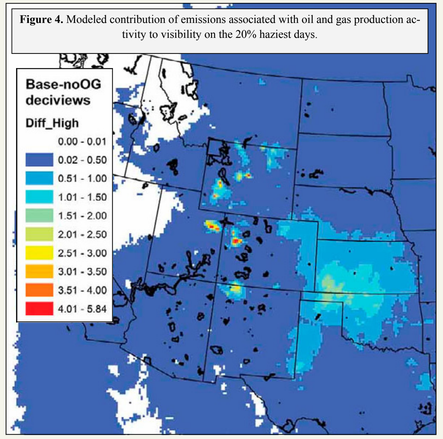
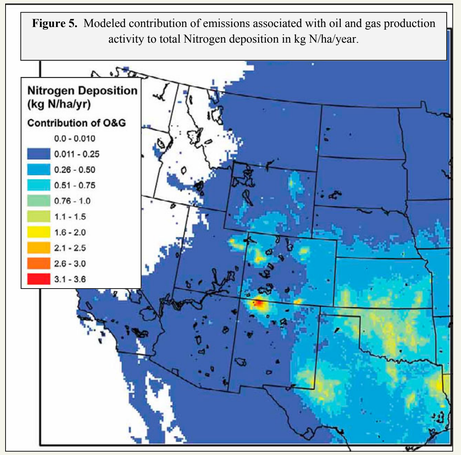


Figure 5. Modeled contribution of emissions associated with oil and gas production activity to total Nitrogen deposition in kg N/ha/year.



Nitrogen deposition is a powerful fertilizer and in excess, can cause changes in soil and water chemistry, acidification of soil and surface water and result in changes in community structure, biodiversity, reproduction, and decomposition (Fenn et al., 1998). Many lands in the western US evolved with low levels of nitrogen deposition and are sensitive to small increase in nitrogen deposition (Baron, 2006).

In this study, nitrogen deposition is assessed using critical load thresholds, defined as "a quantitative estimate of the exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to preset knowledge" (Nilsson and Grennfelt, 1988).

Nitrogen Deposition Results:

⇒ There are 26 units where the modeled contribution of O&G emissions to nitrogen deposition pushes the total modeled nitrogen deposition from below the CL to above the CL.

⇒ As shown in Figure 5, the four corners region shows up as a hotspot for oil and gas contributions to total nitrogen deposition.

⇒ For instance, in Aztec Ruins NM, total modeled nitrogen deposition exceeds the critical load of 3 kg/ha/yr nitrogen and oil and gas contributes approximately 33% of the total nitrogen deposition. In Mesa Verde NP, total modeled nitrogen deposition is just below the critical load of 3 kg/ha/yr and oil and gas contributes approximately 16.6% of the total deposition.