Improvements to Oil and Gas Emissions Modeling in the Uinta Basin, Utah

UTAH DEPARTMENT of ENVIRONMENTAL QUALITY
AIR QUALITY

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Abstract

The Uinta Basin in eastern Utah experiences high ozone concentrations during the wintertime, where oil and gas production and transmission are the primary sources of VOCs and NOx in the region. Correct modeling of oil and gas emissions in SMOKE is crucial to better-performing photochemical modeling of wintertime ozone formation in the Uinta Basin ozone nonattainment area. Researchers at the Utah Division of Air Quality (UDAQ) and Utah State University have worked to improve Utah's oil and gas emissions inventory and its representation in SMOKE. Recent and ongoing studies inform improvements to Utah-specific oil and gas speciation profiles and temporalization of oil and gas activities – specifically for emissions from crude oil tanks and pumpjack engines. As an enhancement to the traditional area-source processing method for the oil and gas sector, UDAQ employs a custom Python tool to prepare our high-resolution oil and gas emissions inventory for processing as point sources in SMOKE. Sensitivity runs in SMOKE explore the impact of these updated oil and gas emissions processing methods to better characterize ozone precursor emissions in the Uinta Basin.

Background & Methods

The Uinta Basin is a primarily rural area over Uintah and Duchesne Counties, as well as the Uintah & Ouray Reservation and surrounding Indian Country. Oil production occurs mostly in the western side of the basin and gas production in the southeast. A large coal-fired power plant is a significant NOx source in the region, in addition to several midstream (e.g. compressors) oil and gas operations throughout the basin. The area is currently in marginal ozone nonattainment for the 2015 8-hour standard.

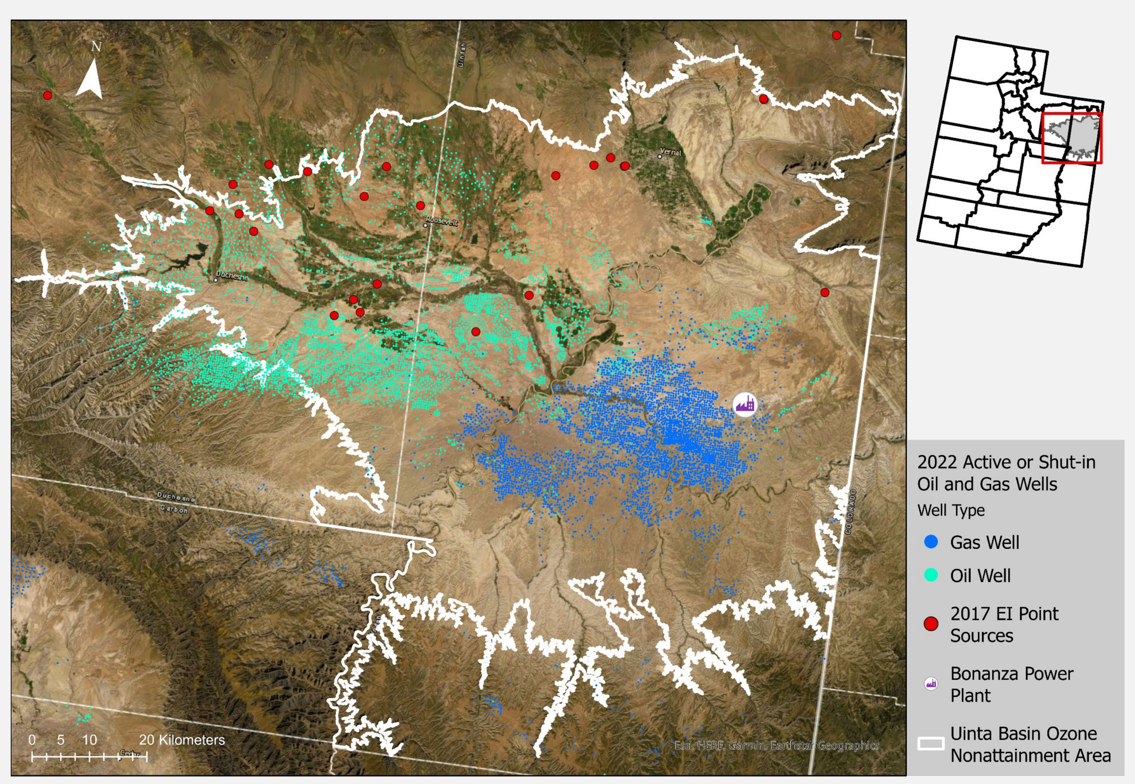

Figure 1: Map of the Uinta Basin in eastern Utah, an oil and gas producing region. Actively producing and temporarily shut-in oil and gas wells (2022) are shown as green and blue dots, respectively. Red dots indicate midstream oil and gas emissions sources included in Utah's point source emissions inventory (2017). The region is home to a coal-fired power plant, also depicted on the map. The Uinta Basin nonattainment area (white outline) is drawn at the 6,250 ft elevation line enclosing the basin where pollutants are trapped during wintertime inversions. The area is currently in a one-year extension period for marginal ozone nonattainment.

Top-down emissions estimations in the Uinta Basin in 2013 (a high-production year) indicated that existing oil and gas emissions inventories underestimate VOC emissions. Simulated ozone approximates observed values better with top-down than bottom-up EI (Figure 2) [1]. Recent oil and gas research and modeling projects have made efforts to close this gap. Highlighted in this poster are studies of Uinta Basin gas composition from tanks & fugitives [2], produced water ponds [3], and pumpjack engines [4]. Results from these studies were leveraged to increase emissions from leaking tanks, ponds, engines, pneumatics, and fugitives. The Utah Oil and Gas Emissions Inventory (OGEI) [5], developed jointly by UDAQ with EPA Region 8 and the Ute Tribe, presents the emissions at facility-level with specific locations, providing high spatial-resolution data for air quality studies and modeling applications. Researchers at UDAQ and USU have developed processing tools and made improvements to SMOKE modeling to incorporate the OGEI to UDAQ's photochemical modeling platform.

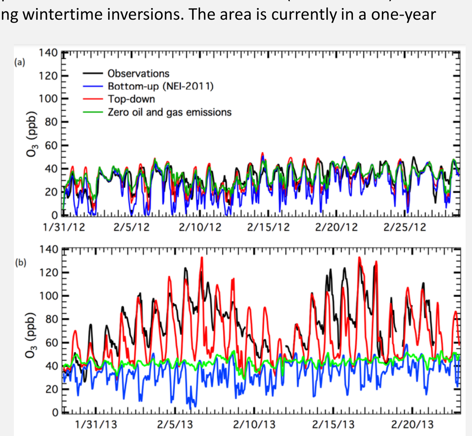

Figure 2: (Ahmadov, 2015 [1]) "Time series of measured and modeled hourly O3 mixing ratios at Horse Pool in a) 2012, and b) 2013."

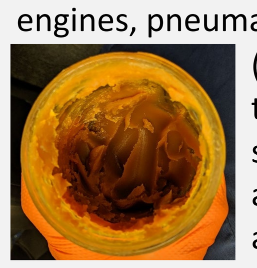

Figure 3: Photo of Uinta Basin yellow wax (crude) from the Uinta Basin Composition Study. [2]

Results

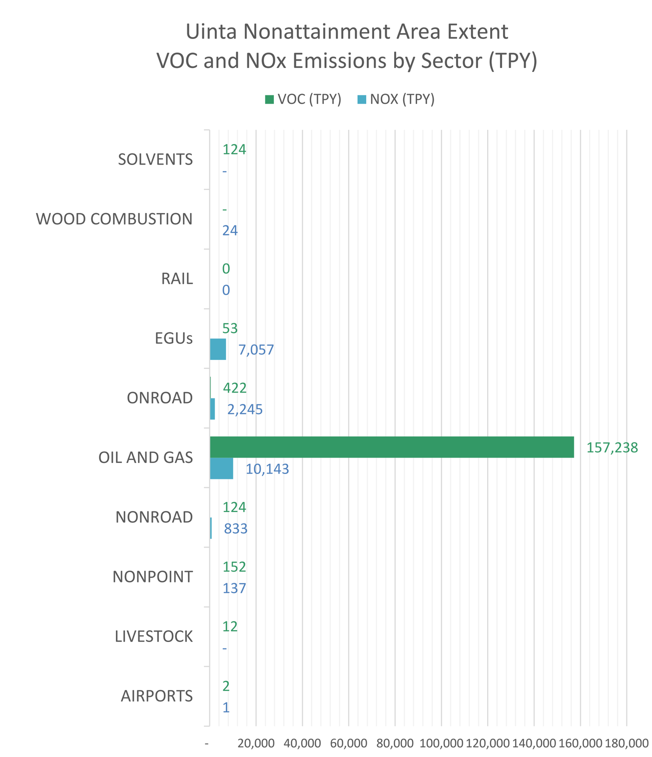

Figure 4: Post-SMOKE VOC and NOx emissions from all sectors, summed over all 1.3km grid cells intersecting the Uinta Basin nonattainment area extent (Figure 1). Oil and gas operations are the dominate VOC and NOx emissions sources, followed by NOx from Bonanza Power Plant in the electric generating unit (EGU) sector. Results temporalized for a February 2013 weekday.

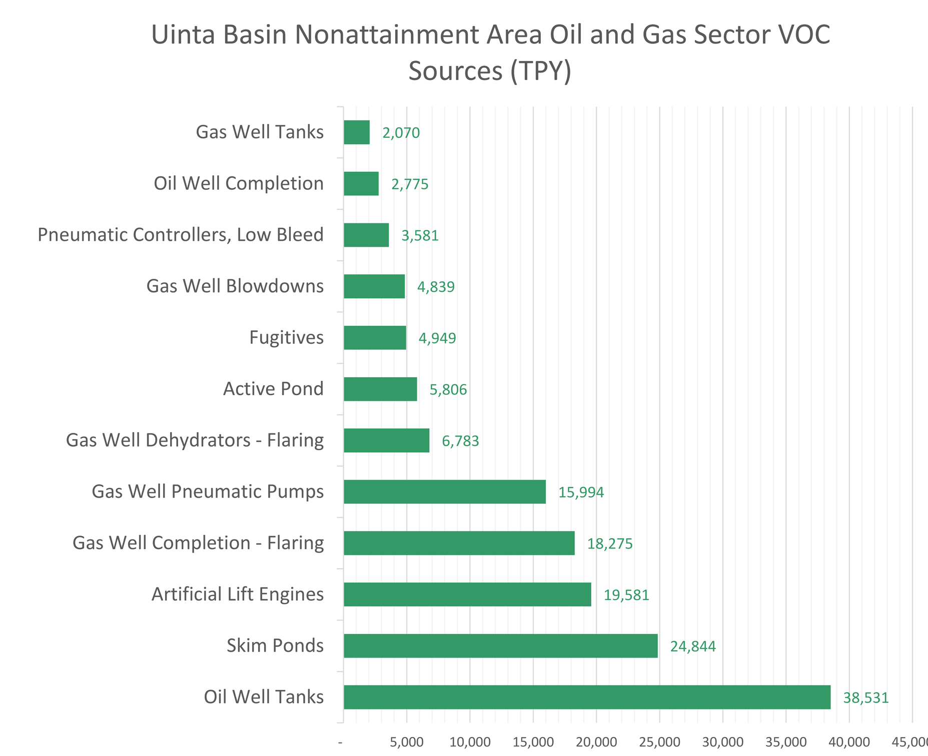

Figure 5: Post-SMOKE VOC emissions in the Uinta Basin nonattainment area extent from the top 12 highest emitting SCCs. Recent studies have shown that VOC emissions from artificial lift engines are significant, especially when run on unprocessed fuel gas from the well [4]. Emissions from skim ponds (produced water disposal facility) were calculated using a mass-balance approach based on a recent EPA sampling campaign [6]. Emissions from oil tanks were elevated using a Monte-Carlo simulation which estimated additional emissions from failing tank control devices [7]. Results temporalized for a February 2013 weekday.

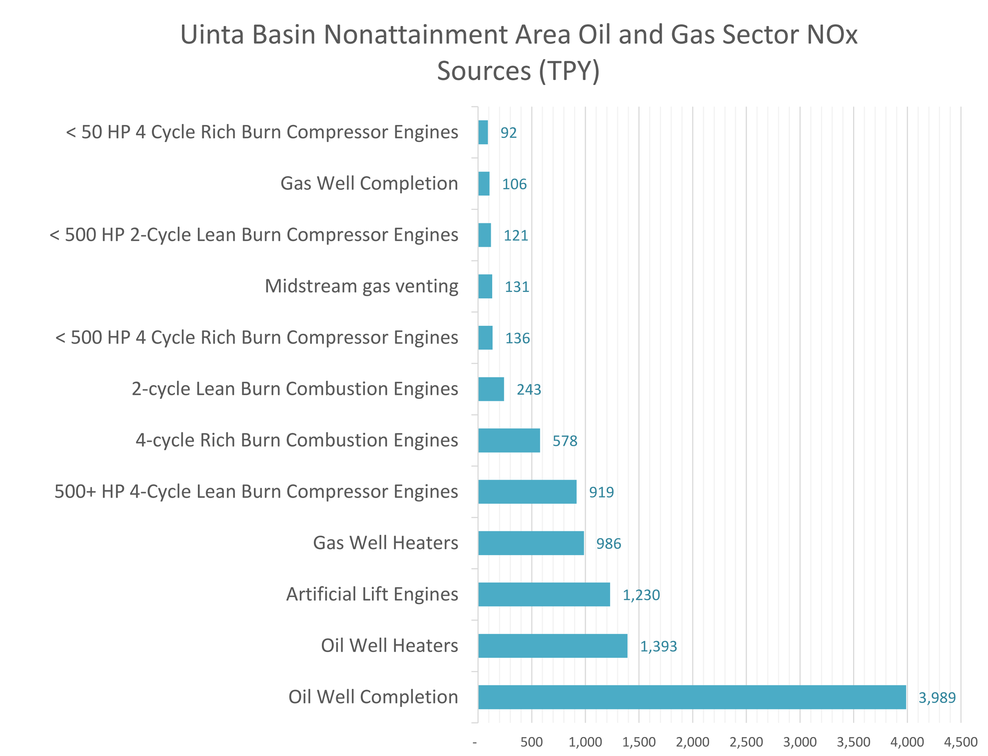

Figure 6: Post-SMOKE NOx emissions in the Uinta Basin nonattainment area extent from the top 12 highest emitting SCCs. Recent studies have shown that NOx emissions from artificial lift engines in the Uinta Basin are less than previously estimated [4]. Results temporalized for a February 2013 weekday.

Figure 7: Updated speciation profiles (outlined in blue boxes) used in Utah's SMOKE platform compared to previously used EPA default profiles for the same SCCs. **A)** Flash gas speciation profiles for oil well tanks and gas well tanks derived from the Uinta Basin Composition Study (UBCS) [2], compared to flash gas profiles from a WRAP survey of operator-collected composition data in the Uinta Basin. New profiles include higher methane weight percentages, decreasing the estimated total oil tank VOC emissions post-SMOKE. Images to the top left show a dirty thief hatch from which flash gases can be emitted, an oil well pad tank battery, and several contractors in the process of collecting a pressurized liquid sample from the center of a typical vertical separator (liquid phase). **B)** Raw gas speciation profiles from the UBCS compared to a WRAP profile and a Uinta Basin Indian Country-specific profile developed from EPA Region 8 permits. Raw gas from gas producing facilities remains mostly unchanged, while raw gas from oil producing facilities has higher VOC content than previously estimated. Images to the top right show a typical horizontal separator where gas samples are collected from the top (gas phase), and a collection of pneumatic controllers from which raw gas can be emitted. **C)** New speciation profiles from a recent pumpjack engine emissions study [4] compared to a generic combustion engine default profile. All new profiles include higher reactive VOC percentages, and rich burn engines have a greater aromatic composition. Images to the bottom left show the location of the pumpjack engine on the pumpjack, and an operating pumpjack engine stack expelling visible emissions. **D)** Produced water pond profiles for both a skim pond and an active evaporation pond [3] compared to a default wellhead produced water profile. Skim ponds are early in the disposal process and often have standing, open-air oil along the surface to be skimmed. This exposed crude emits primarily VOCs, while later-process evaporation pond emissions include more CH4. Images to the bottom right show an example produced water disposal facility configuration, including a concrete vault (also pictured), a skim pond, and several evaporation ponds. **E) Table showing how CB6 model species are assigned to carbon groups.**

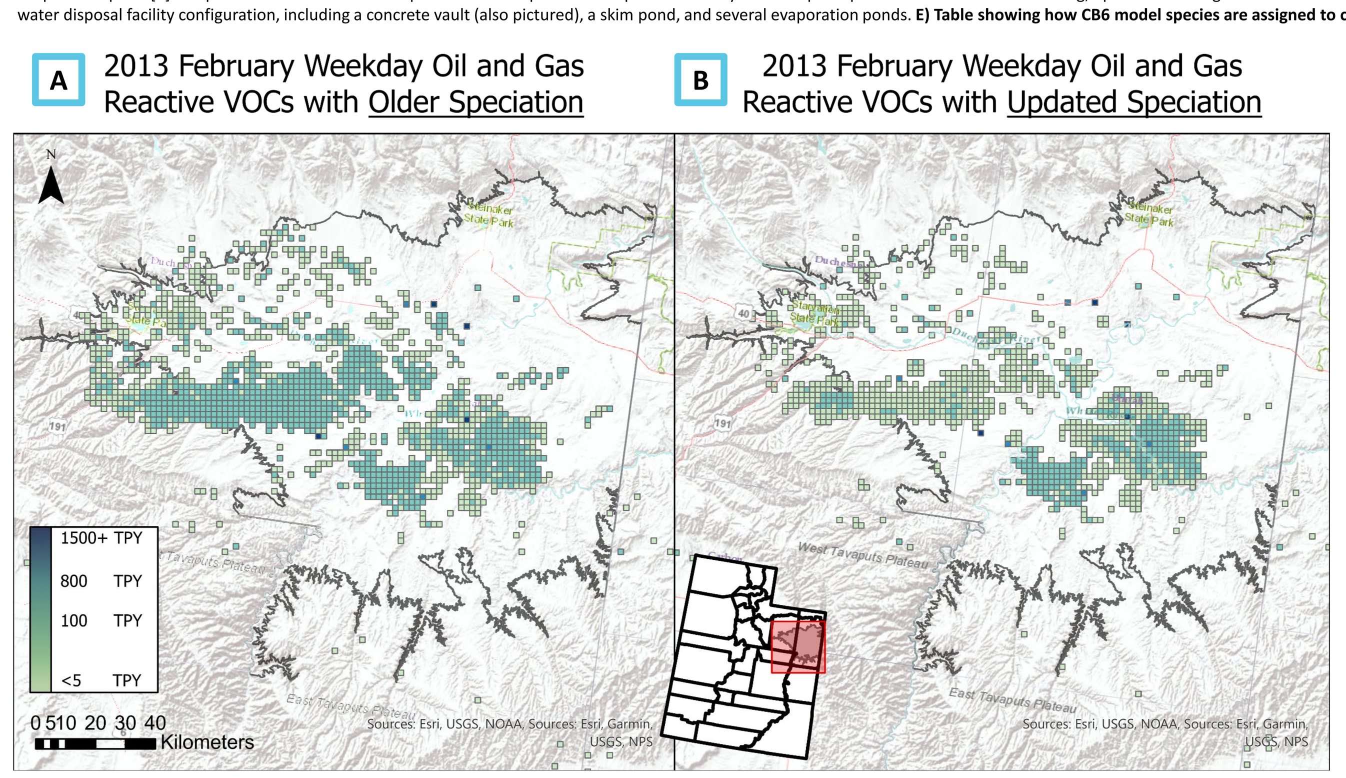

Figure 8: Spatial representation of reactive VOCs ("reactive VOCs" include aromatics, alkenes, aldehydes, ketones. *Figure 7, Table E*) post-SMOKE using **A)** default EPA speciation profiles (Figure 7, unboxed), and **B)** updated speciation profiles (Figure 7, inside blue boxes). With updated speciation, reactive organic emissions from the oil-producing western side of the Uinta Basin decrease because the previous WRAP profile estimated higher aromatic emissions from oil tanks (flash gas) than the updated UBCS profile. Higher CH4 partition in the updated UBCS flash gas profile than in the WRAP profile also contributes to less reactive compounds in the updated EI. Oil and gas sources are represented as point sources. Results temporalized for a February 2013 weekday.

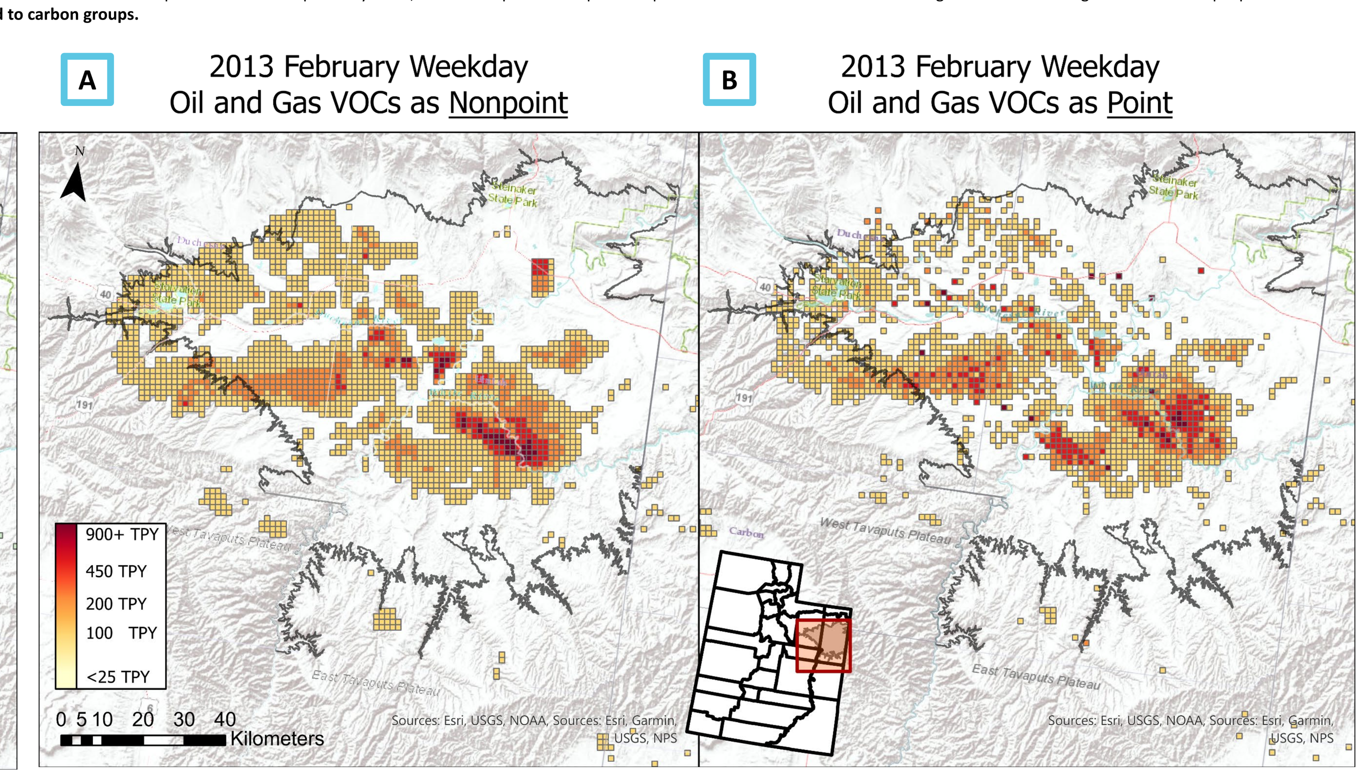

Figure 9: Spatial representation of all post-SMOKE treating the oil and gas sector emissions as **A)** nonpoint sources, using EPA platform AGREF in SMOKE and 1.3km spatial surrogates derived from the same spatial base data as used in EPA's 4km, 12km, and 36km surrogates, and **B)** unique point sources, where emissions are spatially allocated to the latitude/longitude coordinate associated with that specific emissions source. Utah's oil and gas inventory was prepared as SMOKE point source FF10 with Dr. Huy Tran's custom-made Jupyter Notebook tool: https://usu.box.com/s/7zgtttc8aue8oxpf0ttb95d7t24k8rod Results temporalized for a February 2013 weekday.

Next Steps

Improvements to the oil and gas emissions inventory in the Uinta Basin have resulted in a marked increase in VOC emissions compared to previous model platforms (Figure 10).

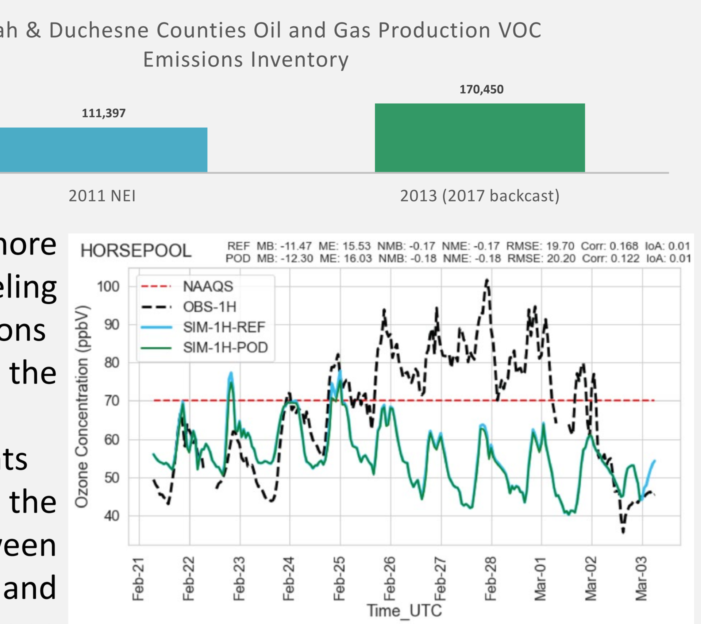

Figure 10: (*Above*) Uintah & Duchesne counties' VOC emissions inventories, comparing 2011 NEI to 2017 EI with gap-filling, backcast to 2013. (*Below*) (Tran, 2021 [8]) CAMx ozone performance evaluation at Horsepool for winter 2019 episode using a similar version of the Utah oil and gas emissions inventory and updated speciation profiles (SIM-1H-REF).

However, more recent modeling demonstrations show that the inventory improvements do not close the gap between observed and modeled ozone in the Uinta Basin. [8] High-emitting SCC categories such as emissions from tanks still have uncertain speciation; a comparison between directly measured and simulated flash gas emissions showed that process simulation modeling of flash events underpredicts the presence of aromatics in emissions [2]. Other uncertainties in VOC emissions estimations may be attributed to super-emitters: a small subset of emissions sources from which a large portion of pollutants are emitted. Leaks from oil and gas production and transmission in the Uinta Basin are not well-constrained. Still, improvements to VOC emissions estimations may not improve photochemical model performance. It is hypothesized that the Uinta Basin is NOx-sensitive, so upcoming research focus will center on improving estimations of NOx emissions. Work is ongoing to develop an updated top-down emissions inventory based on long-term CH4 measurements in the Uinta Basin. Lastly, underprediction of ozone during the wintertime in the Uinta Basin may be due to a lack of relevant chemical reactions available in the widely-used CB6 mechanism. Utah researchers are currently investigating wintertime ozone model performance using the RACM2 mechanism.

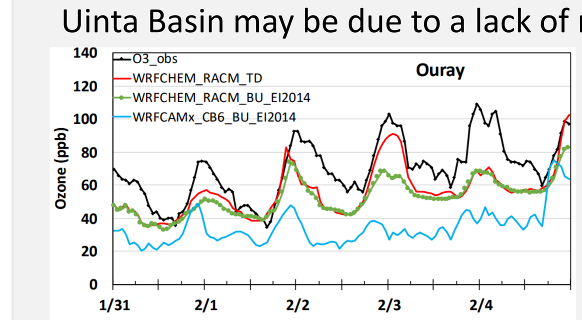

Figure 11: (Lyman, 2020 [9]) WRF-CHEM ozone performance evaluation at Ouray for winter 2013 episode using the 2014 version of the Utah oil and gas emissions inventory. Observations are compared to model simulations using various chemical mechanisms.

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