AQ-WATCH

ASSESSMENT REPORT WITH DESCRIPTION OF FRACKING SERVICE AND IMPACT OF FRACKING EMISSIONS

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About this document

Work package in charge: WP4 Policy Strategy: Attribution of Air Pollution Sources and Analysis of Emission Reduction Strategies

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1 Abstract /publishable summary

Fracking, and more generally the extraction of oil and natural gas, is gaining interest due to its potential (negative) environmental impacts. These impacts, however, are not yet well understood. The objective of the AQ-WATCH service is to demonstrate potential impacts from fracking on surface air quality so that regions considering allowing fracking gain an understanding of the potential consequences. In contrast to other modules in the AQ-WATCH Toolkit, the fracking service is an informational rather than an operational service.

The term “Fracking” is frequently used to describe the entire oil and natural gas (OnG) exploration cycle while, strictly speaking, fracking actually represents only one step in the entire chain. Since air quality impacts are not limited to the fracking step only, the AQ-WATCH Fracking service considers emissions and pollution impacts from the entire range of OnG exploration processes in one region thus characterizing the full impact of OnG extraction activities.

OnG extraction and the practice of fracking have been practiced in the U.S. for many years. By setting up and validating the service over the U.S., it will be possible to gain knowledge useful for the exploration of its potential in Europe and other parts of the world. Emissions released from OnG activities have shown to be highly uncertain in current emission inventories, and generally there are little to no relevant observations available for improving upon them. Hence it was decided to focus on a past time period in the U.S., for which relevant observations are available to develop a service that is evaluated and for which high confidence in the attribution information can be placed. The AQ-WATCH fracking service for this reason is based on data and analysis of the 2014 National Science Foundation/UCAR and State of Colorado Front Range Air Pollution and Photochemistry Experiment (FRAPPÉ) and the National Aeronautics and Space Administration (NASA) field campaigns (Flocke et al., 2020). The two campaigns took place jointly over the Colorado Front Range in summer 2014 and collected a comprehensive set of ground-based and airborne observations of all relevant chemical compounds. The Front Range of Colorado (population of ~5M) is home to numerous larger municipalities including Denver and also encompasses the Denver-Julesburg Basin, which is the site of major OnG activities and one of the major OnG producing areas in the U.S.

2 Conclusion & Results

The AQ-WATCH Fracking service is an informational tool to provide policy makers and the public with information on the potential negative effects of oil and natural gas (OnG) exploration on air quality. Fracking is only the very first in the OnG extraction process but is commonly used to refer to the full chain from production to delivery. For this reason and to capture the full impact of OnG emissions, this module looks at the air quality effects of all OnG related emissions.

Emissions from OnG are known to be highly uncertain in current inventories which challenges the assessment of their air quality impacts. Hence this service relies on data that underwent comprehensive evaluation and validation. The chosen data are model sensitivity studies that were conducted as part of the summer 2014 NSF/NCAR/State of Colorado FRAPPÉ and NASA

DISCOVER-AQ campaigns in Colorado Front Range. The Colorado Front Range is a highly populated area with intense OnG activities just to the North-East of the urban corridor.

The AQ-WATCH Fracking service provides users with information on surface concentrations with and without OnG emissions of various pollutants including BTEX species, NOx and ozone at various temporal resolutions. The product has a spatial resolution of 4 x 4 km^2 and as such does not resolve the very near-source impacts. These can be multiple times higher but also vary significantly and depend, amongst others, on the type and operation of a well, environmental conditions such as winds and turbulence, and the proximity to the well. In Colorado this so called "setback" has been debate of heated discussions and in 2020 it was revised to enforce new wells to be at least 2000 feet from homes or public spaces compared to the previous distance of 500 feet acknowledging the potential threat of OnG activities to human health (Holder et al., 2019)

3 Project objectives

This deliverable contributes directly and indirectly to the achievement of specific objectives indicated in section 1.1 of the Description of the Action:

Specific objectives of the project	Contribution of this deliverable?
[1] To design and produce new global and regional air pollution atlases that include the climatological distribution of chemical pollutants complemented by quantities such as the diurnal and seasonal variations, air quality and related health indices, premature mortality exceedance frequency, long-term trends, etc.	No
[2] To develop software packages with the capability to provide more accurate daily forecasts of air quality at the regional scale including tailored high-resolution fire smoke and wind-blown dust forecasts; downscaling of air quality forecasts to 2 km resolution in urban areas.	No
[3] To develop a source apportionment service to mitigate air pollution and hence increase the life expectancy of the population in different regions of the world, with special focus on the role of agricultural sources of air pollution and the potentially important effects of fracking operations.	Yes
[4] To develop a new tool-box that will be user-friendly and accessible to decision-makers to evaluate the efficiency of proposed mitigation measures in different industrial sectors on the resulting level of air pollutants in three different regions of the world. This will establish the basis for their wider adoption and generalization.	No

[5] To co-design, co-produce and co-evaluate for the first time prototype products and services with prime users in three regions of the world chosen for their specific level of economic, social and environmental development.	Yes

This deliverable directly contributes to the achievement of specific objectives indicated in the description of the Work Package.

Objectives of WP4	**Relevance in this deliverable?**
4.1 To establish a user driven service for (NRT) source apportionment information	No
4.2 To establish a user driven service for mitigation information on most effective emission reduction measures	No
4.3 To establish a fracking service for the assessment of the impact of fracking activities on air pollution	Yes
4.4 To improve the quality of the above mentioned three services, through validation, customization and targeted developments	Yes

4 Detailed report on the deliverable

4.1 Introduction

4.1.1 What is Fracking

Fracking is an oil and natural gas (OnG) production technique that involves the injection of millions of gallons of water, plus chemicals and sand, underground at very high pressure in order to create fractures in the underlying geology to allow oil and natural gas to escape. Fracking is one process in the full lifecycle of a well (https://www.eia.gov/energyexplained/) and to characterize air quality impacts from OnG exploration, the emissions released during the full range of activities in an area need to be considered. Therefore, the case study underlying the AQ-WATCH Fracking service accounts for the full impact of OnG activities on air quality rather than just fracking by itself.

Fracking gained popularity because it allows extraction of OnG from shale and other forms of "tight" rock which previously had not been possible to be exploited. Figure 1 shows the chain of processes that are involved in extracting OnG from the ground all the way to the delivery to customers. During the fracking phase, large quantities of water, chemicals, and sand are blasted into tight rock formations at pressures high enough to crack the rock, allowing the once-trapped gas and oil to flow to the surface. The fracking process itself only takes a few days compared to weeks for the drilling process and timelines in the order of multiple years for the production, transmission, and distribution cycles.

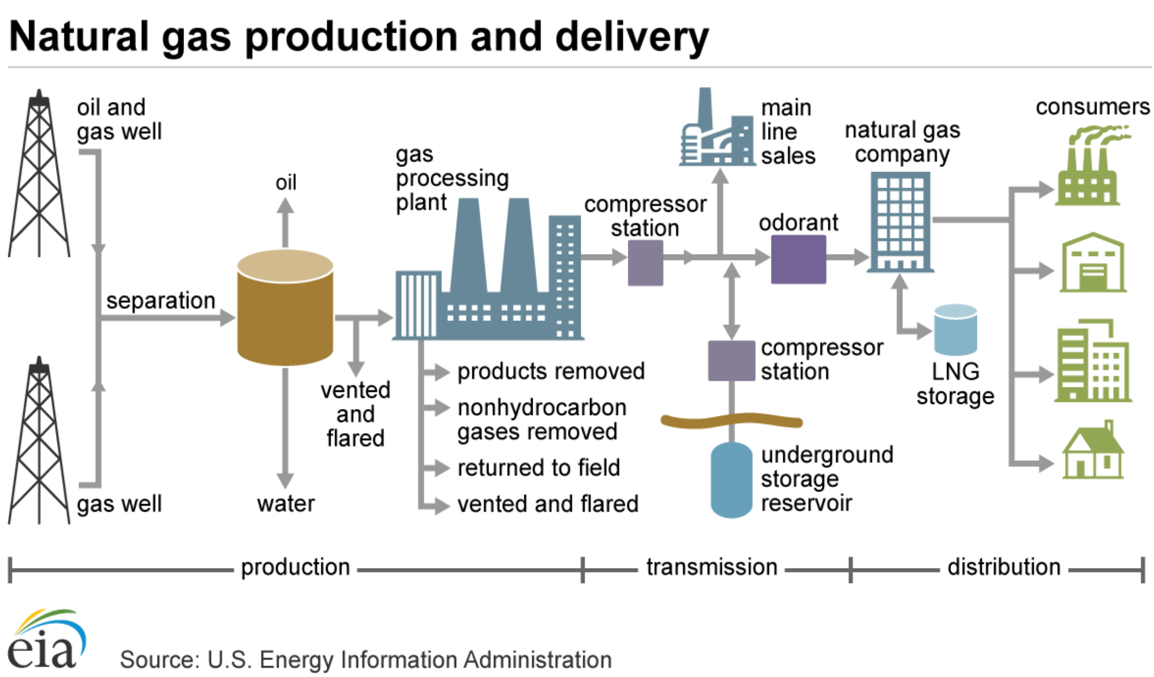

Figure 1: Process chain for natural gas extraction and distribution (Source: U.S. Energy Information Administration)

A study conducted by the Colorado State University (CSU) at various OnG locations in Colorado assessed the emissions that are released by the different processes (https://www.garfield-county.com/air-quality/filesgcco/sites/33/2019/06/CSU-GarCo-Report-Final.pdf). During all stages of OnG extraction large quantities of nitrogen oxides (NOx, carbon monoxide (CO) and volatile organic compounds (VOCs) are released, all of which have negative health impacts and are precursors to surface ozone. Specific interest is placed on the class of benzene, toluene, Ethylbenzene and xylenes, often referred to as BTEX species, which are highly toxic and of high concern for human health. The CSU measurements show emissions of high amounts of all of the above listed VOC compounds and also a large variability across different wells and across the different stages of the OnG cycle. The variability is related to different types of OnG (e.g wet versus dry gas), specificities of the methods applied and the way wells are maintained and operated.

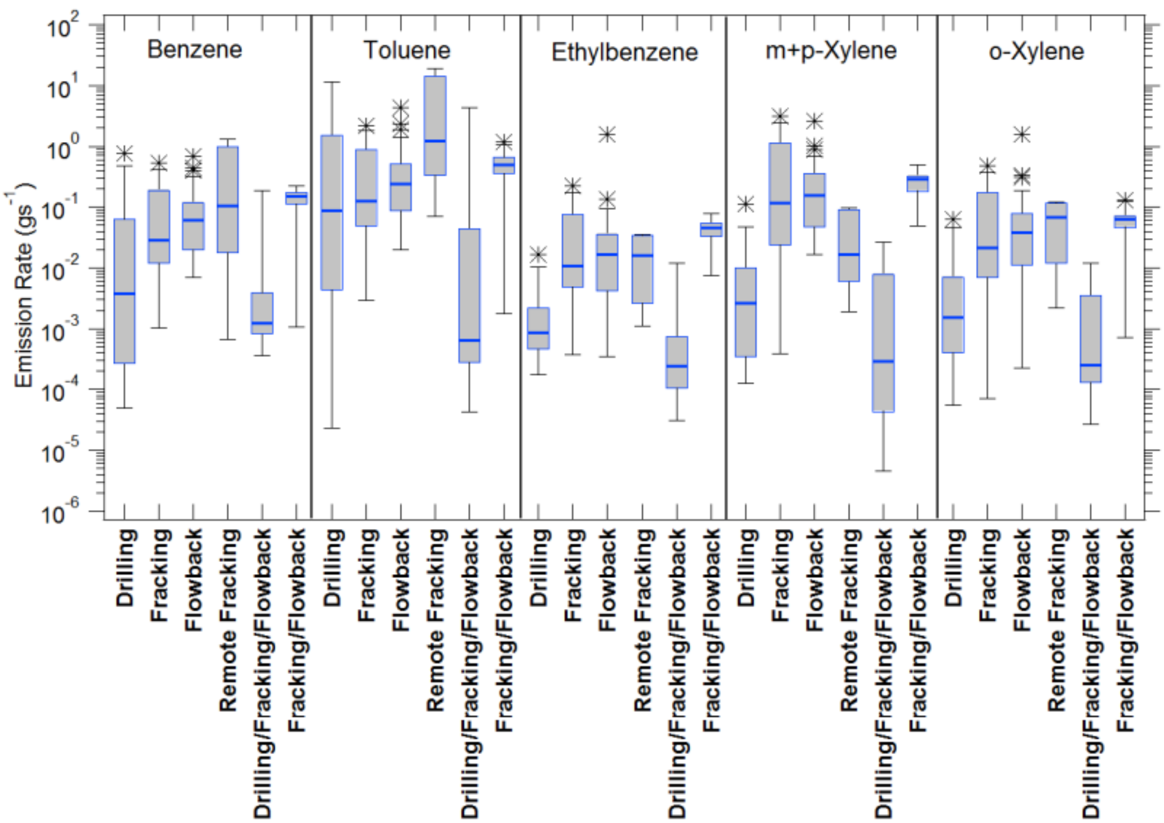

Figure 2: Ranges of emission Rates of BTEX species (Benzene, Toluene, Ethylbenzene, Xylenes) for different operation types (https://www.garfield-county.com/air-quality/filesgcco/sites/33/2019/06/CSU-GarCo-Report-Final.pdf)

4.1.2 The Colorado Front Range

Approximately 80% of Colorado's population of about 5.6 million lives in the Colorado Northern Front Range Metropolitan Area (NFRMA), an area that is in non-attainment of the U.S. 8-hour ozone National Ambient Air Quality Standard (NAAQS) and most recently has been elevated to a “severe” non-attainment rating. The NFRMA is located between the Rocky Mountains to the west and the High Plains to the east and is located at an elevation of roughly 1500-1800 m. The greater Denver metropolitan area, one of the top twenty mega-urban regions in the U.S., is the largest urban area in the region with over 2 million inhabitants, followed by Colorado Springs, and Ft. Collins with about 250,000 inhabitants each, and Boulder, a city of about 100,000 people. The metropolitan area is also one of the nation’s fastest-growing urban centers with Denver’s population expected to increase by nearly 50% by 2030 (e.g., see http://www.metrodenver.org/do-business/demographics/population/).

Over the last years the NFRMA experienced dramatic large increases in oil and gas drilling activities with the number of active oil and gas wells having nearly doubled in Weld County, to the northeast of Denver, between January 2008 and July 2015 to over 27,000 active well sites [Colorado Oil and Gas Conservation Commission (COGCC), 2/2016] (Figure 3). This increase is mostly driven by the introduction of fracking in 2010. Conventional drilling has been taking place in the Denver Julesburg Basin since decades but the process of fracking was a game changer for the OnG exploration. Colorado has experienced a dramatic shift in recent years from vertical to horizontal development, with horizontal wells and fracking comprising 72% of all wells drilled in Colorado in 2017 compared to 5% in 2010 (COGCC, 2017).

In addition to OnG exploration, the area is also home to abundant livestock. This results in a mix of different emission sources: urban, industrial, oil and gas exploration, and agriculture. The complex terrain and associated complex meteorology and flow patterns, coupled with the mix of diverse pollution present challenges with respect to characterizing, modeling and forecasting the transport and photochemical processes contributing to local air quality.

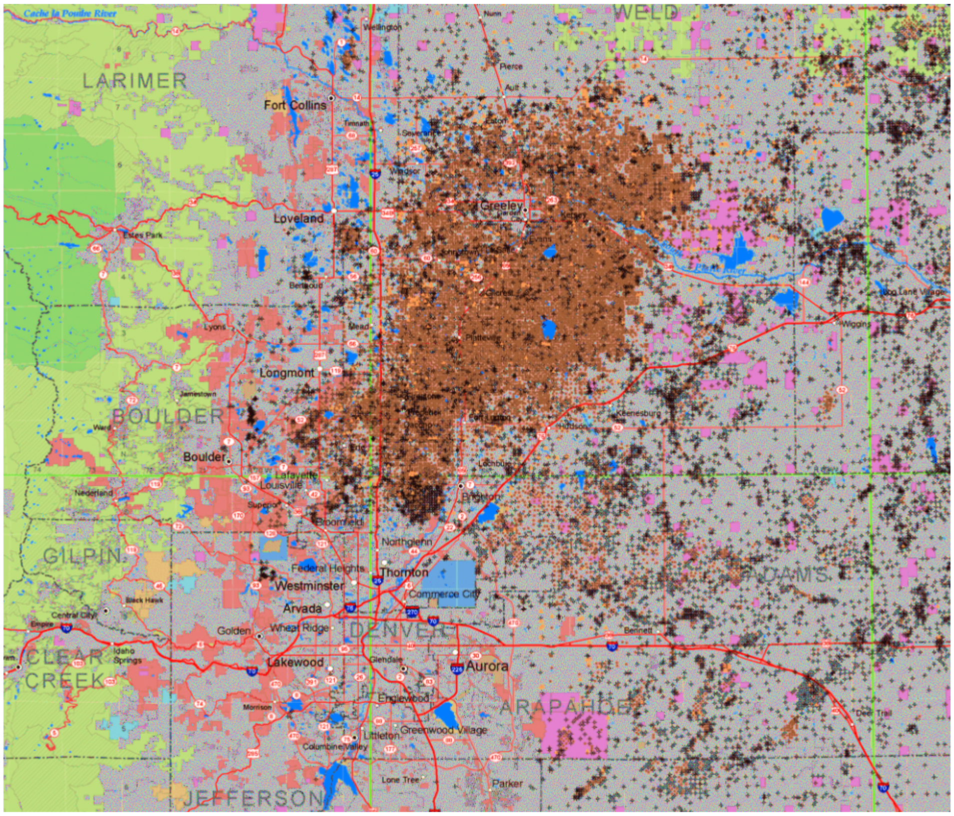

Figure 3: Map of the NFRMA with the location of Ong wells indicated in brown (adapted from https://coloradogeologicalsurvey.org/publications/oil-gas-wells-map-colorado-2015/)

4.1.3 FRAPPE and DISCOVER AQ

Two major field campaigns – the National Science Foundation (NSF)/National Center for Atmospheric Research (NCAR) and State of Colorado Front Range Air Pollution and Photochemistry Éxperiment (FRAPPÉ) and the 4th deployment of the National Aeronautics and Space Administration (NASA) Deriving Information on Surface conditions from Column and Vertically Resolved Observations Relevant to Air Quality (DISCOVER-AQ) – were conducted jointly between 15 July and 20 August 2014 to study summertime ozone pollution in the NFRMA. AQ-WATCH partner G. Pfister has been the co-PI of FRAPPÉ.

FRAPPÉ was designed to identify and quantify the main drivers of summertime ozone in the NFRMA including characterization of emissions and the chemical processing and mixing. DISCOVER-AQ's primary objective was to understand sources, transport, and chemical transformations of air pollutants, particularly those that lead to ground-level ozone and how they relate to column observations from satellites. Particulate matter was not the focus of this study as concentrations are generally low in the NFRMA during summertime except when the region experiences influence from wildfires.

Chemical and meteorological observations were conducted from four different aircraft and multiple mobile vans, ozone sondes, lidars, tethered balloons, and numerous operational and additional surface sites. These measurements were supplemented by comprehensive modeling activities. Additional capabilities were provided by the Colorado Department of Public Health and Environment (CDPHE), the National Oceanic and Atmospheric Administration (NOAA) and others. The full data set is publicly available at http://www-air.larc.nasa.gov/missions/discover-aq/discover-aq.html. An overview of the campaigns and findings is presented in Flocke et al. (2020).

4.2 Model Product feeding into the Fracking Service

Numerous modeling studies have been conducted for FRAPPÉ but the most relevant for the AQ-WATCH Fracking Service is the source apportionment study conducted by NCAR. For this work, the Community Modeling Air Quality System (CMAQ) model version v5.2 beta with the carbon bond mechanism version 6 (CB6r3) chemical mechanism has been used. WRF v3.8.1 was run to create hourly meteorological fields for driving CMAQ. The WRF and CMAQ domain includes a 12 km x 12 km outer domain covering the Western U.S. and a 4 km x 4 km inner domain over Colorado. A full description of the model setup and comprehensive evaluation of the model's performance by comparison with field campaign measurements is given in the FRAPPE Final Report accessible from CDPHE (https://www.colorado.gov/airquality/tech_doc_repository.aspx?action=open&file=FRAPPE-NCAR_Final_Report_July2017.pdf), herein referred to as Pfister and Flocke (2017).

4.2.1 Model Emissions and Model Performance

Base ("a priori") emission inputs for CMAQ were based on a combination of 2017 projected emissions and actual 2014 activity data for OnG sources and electric generation units (EGU), which represented the best available information at the time of the study. At the time of the study, the U.S. EPA National Emission Inventory (NEI) for 2014 or any other 2014 specific inventory had not yet been available. Emissions were improved by iteratively adjusting the emissions to achieve optimal agreement between modeled NOx and VOC emission species but also considering performance in modeled secondary species, specifically ozone. Through careful comparison of modeled concentrations with NCAR/NSF C-130 aircraft data and accounting for model differences in winds it was concluded that in the base inventory all relevant emission species including NOx and primary VOCs were significantly underestimated. While mobile emissions for the Denver area appeared in good agreement with the measurements, both on-road and off-road (construction) emissions for the urban areas outside of Denver had to be doubled to agree with the measured values. In the case of OnG emissions, the emission factors across the entire region had to be increased by a factor of at least two for both NOx and VOC, except for ethane; the measured mixing ratios of which agreed well with the model without needing adjustments. While other model uncertainties cannot be excluded as also affecting the model-measurement agreement, because of the large underestimate in VOCs and through a detailed comparison of not only absolute concentrations but also ratios and temporal and spatial variability relatively large confidence could be placed in the emissions themselves being a major driver of these uncertainties. A large underestimate in bottom-up OnG inventories is not unique to this study but has also been found in previous studies (e.g., Pétron et al., 2014) and can be in parts contributed to leakages, insufficient reporting and a large variability in well emissions profiles dependent on well operations, maintenance and age. All these factors also impact the latest emission inventories.

Table 1 compares the priori and adjusted ("posteriori") NOx and VOC emissions from the FRAPPÉ study to 2011, 2014 and projected 2017 U.S. EPA National Emission Inventory (NEI) emissions for each county as well as the entire Front Range. The posteriori estimate is lower in NO_x than NEI 2011 but higher compared to NEI 2014 (10% for NOx and 30% for VOC) and NEI 2017. VOC emissions are highest in the posteriori inventory. The dominant VOC emission contribution to Front Range VOC comes from Weld County within the Denver-Julesberg Basin (about 60% of the total), which is almost entirely attributed to OnG operations. Weld County's NO_x sources are also major contributors to overall NOx emissions and are a mix of OnG operations (contributing about half), vehicles, and industrial emissions (contributing about one quarter each).

	NOx (tons/year)					VOC (tons/year)				
	EPA 2011	EPA 2014	EPA 2017	Priori	Posteriori	EPA 2011	EPA 2014	EPA 2017	Priori	Posteriori
Adams	23,537	17,612	14,008	14,639	14,639	16,215	12,523	14,171	11,802	11,864
Arapahoe	11,492	10,190	7,295	7,262	7,262	14,327	12,710	11,428	11,975	12,054
Boulder	8,980	8,431	6,901	6,735	8,689	8,554	6,279	7,047	6,126	7,711
Broomfield	1,346	1,297	822	779	888	2,019	1,326	1,744	1,229	1,306
Clear Creek	1,717	1,654	989	552	552	619	550	416	373	379
Denver	18,682	15,403	11,622	11,568	11,568	14,612	12,688	11,729	12,009	12,082
Douglas	7,296	6,876	5,089	4,456	4,456	6,565	5,677	5,575	5,498	5,498
Elbert	1,460	989	962	578	578	1,126	737	965	627	627
Gilpin	449	394	316	311	311	212	166	147	156	159
Jefferson	13,147	10,734	8,426	7,060	7,060	14,103	11,372	11,183	11,313	11,387
Larimer	10,123	7,907	6,744	7,542	11,637	9,896	7,599	7,672	7,731	10,267
Park	820	549	448	390	390	919	707	629	639	639
Weld	30,009	31,293	24,486	29,791	55,331	132,978	101,677	127,962	83,886	153,881
Total Result	**129,058**	**113,328**	**88,108**	**91,663**	**123,360**	**222,145**	**174,009**	**200,668**	**153,363**	**227,853**

Table 1: County total NOx and VOC emissions for U.S. EPA NEI 2011, NEI 2014 and NEI 2017 and the FRAPPÉ a priori and posteriori inventories (Table S2 from Flocke at al. (2020))

A comprehensive evaluation of WRF/CMAQ modeled ozone concentrations has been conducted by Pfister and Flocke (2017) through comparison to surface data, ozone sonde launches and aircraft measurements. The CMAQ simulations represent the overall characteristics of the meteorological measurements, but the model generally underestimates clouds (e.g. Figure 4). This leads to a high bias in ozone photochemical production in the model in addition to inadequate representation of the variability in free-tropospheric ozone as well as other uncertainties of the modeled meteorology. For this reason, the model results tend to represent a more frequent occurrence of conditions conducive to ozone production and an increased likelihood of high ozone days.

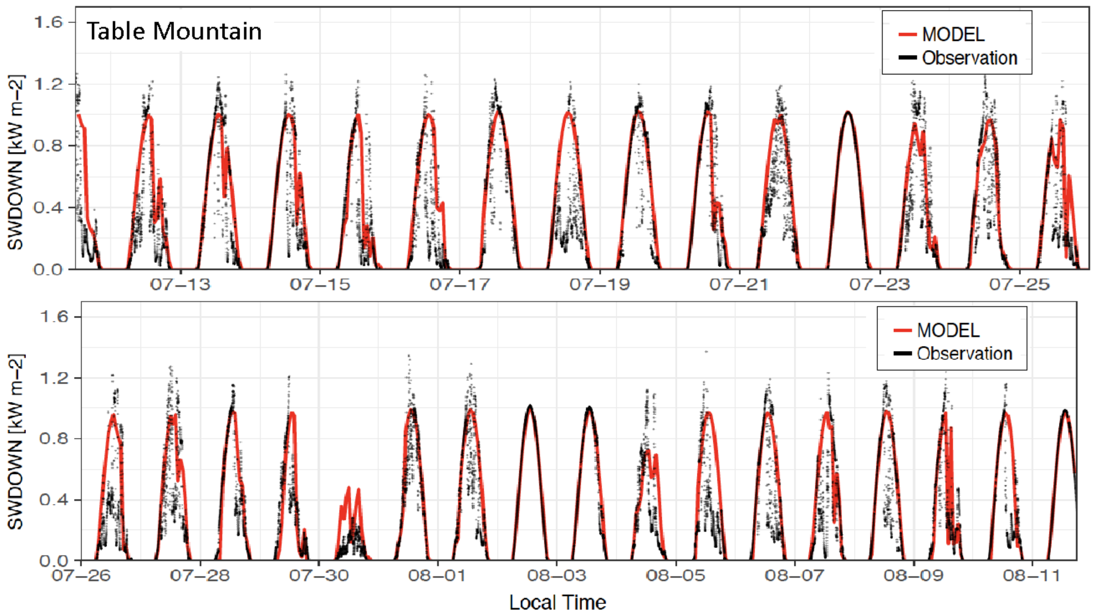

Figure 4: Time series of measured (black) and modeled (red) downwelling shortwave solar radiation at the surface for Table Mountain (north of Boulder) (from Pfister and Flocke, 2017)

A conclusive evaluation of the emission inventories was hampered somewhat by uncertainties in the modeled transport and meteorology, and was challenged even more because of an above normal cloud and thunderstorm activity during the campaign, which as mentioned above was not well represented in the model. Model performance varied strongly from day to day and was sensitive to the spatial and temporal coverage of the observations. Despite these complications, various conclusions could be drawn from the evaluation: (1) The a priori emissions overall underestimated all relevant emission species including NO_x and primary VOCs; (2) Doubling the OnG emissions improved the agreement of NOx and VOCs but VOCs were still underestimated; (3) Quadrupling the OnG emissions would have been needed to achieve optimal agreement between measured and modeled VOCs but significantly increased the high bias in model ozone. Given the findings, the decision was made for the above-described posterior emission scenario with a doubling of OnG emissions. As an example of the modeled ozone performance, Figure 5 shows daily maximum 8-hour ozone concentrations from the simulations with a priori and with posteriori emissions for 22 July 2014, which was the day when the highest and most widespread ozone pollution was encountered during the campaign and with mostly clear skies. A comprehensive and detailed comparison to the range of different observations is provided in Pfister and Flocke (2017).

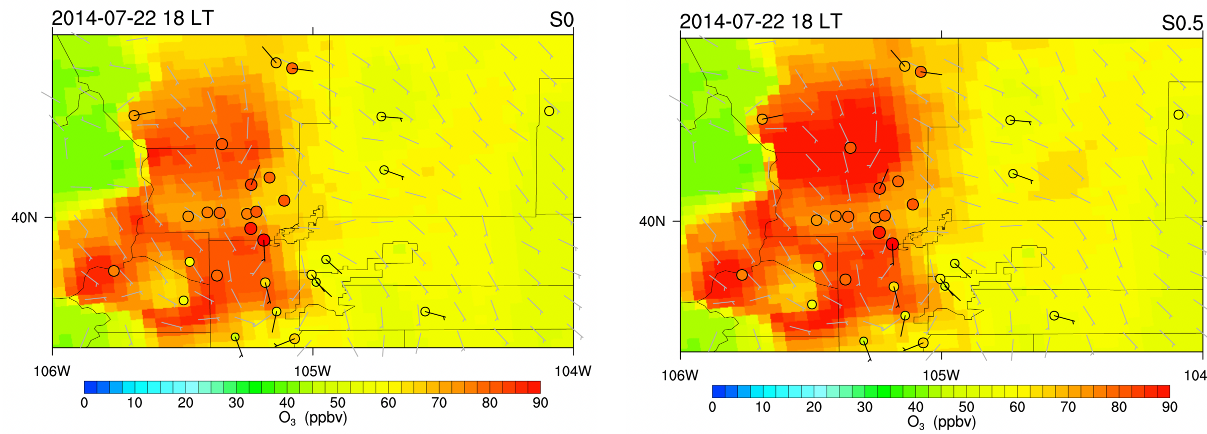

Figure 5: Surface ozone simulated by CMAQ (maps) and observed at the U.S. EPA and FRAPPÉ surface sites (filled circles) for 22 July at 18h local time. Model concentrations are shown for the a priori emissions (left) and the posteriori emissions (right).

4.2.2 Assessment of Air Quality Impacts from OnG Activities

Using the optimized inventory, zero-out emission scenarios were performed to derive an estimate of the ozone source contributions. This is accomplished by running the model while selectively turning off emission sectors and comparing the ozone distribution in each run with the control run in which all emissions are turned on. We note that the different contributions will not add up linearly because of the strongly non-linearity of ozone chemistry. The FRAPPÉ study focused on four different sectors (traffic, OnG, powerplants, industry) as well as looked at the combined contribution of all NFRMA anthropogenic emissions. Even though the AQ-WATCH service only includes the OnG sector we discuss here all sectors to provide the context.

The average enhancement in surface ozone due to local anthropogenic emissions in the NFRMA was estimated in the range of 15 -20 ppbv, varying between 20 and 30 ppbv on high ozone days with largest values typically around the larger Denver metro area; O_3 enhancement maxima reached up to 40 ppbv (as seen on 28 July 2014. Figure 6). This demonstrated that locally produced ozone is the major driver of ozone pollution in the NFRMA. Background ozone in Colorado is found to be generally in the range of 45-50 ppb, which is enhanced compared to concentrations in the remote background atmosphere of the order of ~30 ppb. While this increases the risk of the area to reach the NAAQS (70 ppb for daily maximum 8-hour surface ozone (MDA8)), the background contribution cannot be controlled and it is undeniable that the magnitude of local anthropogenic-driven ozone production is significant and a major factor in putting the area into non-compliance with the NAAQS .

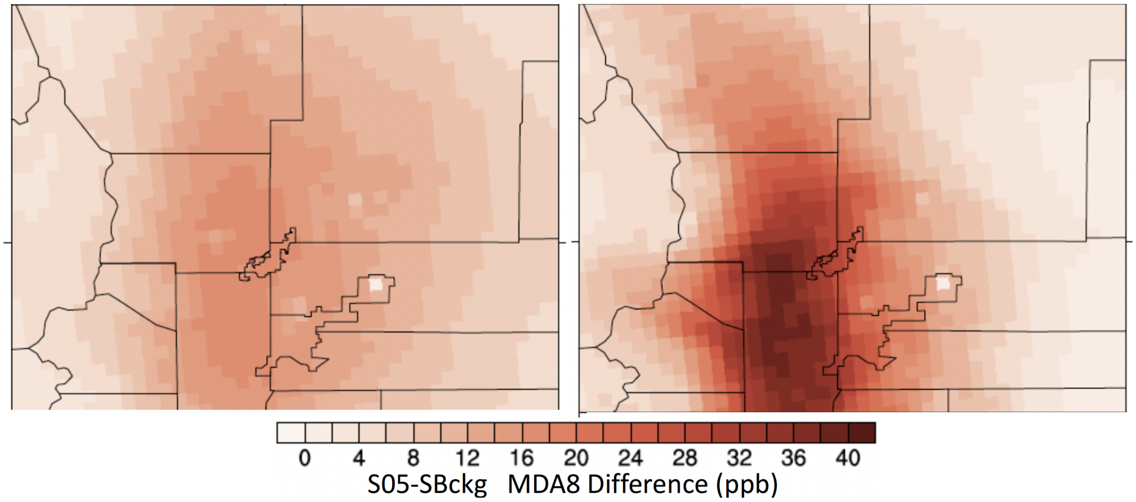

Figure 6: Difference in daily maximum 8-hour surface ozone (MDA8) between a simulation with and without NFRMA anthropogenic emissions. Temporal average over campaign period (left) and results for 28 July 2014 only (right).

In the analysis of the individual emission sectors, mobile (traffic) sources and OnG related emissions were estimated to be the largest contributors to local ozone production (Figure 7). On average, OnG emissions show a stronger influence in the northern part of the NFRMA and the northern foothills, while mobile emissions dominate farther south and in the southern foothills. It was estimated that both sectors contribute, on average, 30-40% each to total NFRMA ozone production on high ozone days. The contribution of industrial emissions and powerplants to NFRMA ozone were overall much smaller but could dominate locally. Other independent studies conducted as part of FRAPPÉ confirm the major role of OnG emissions (Flocke et al., 2021 and references therein).

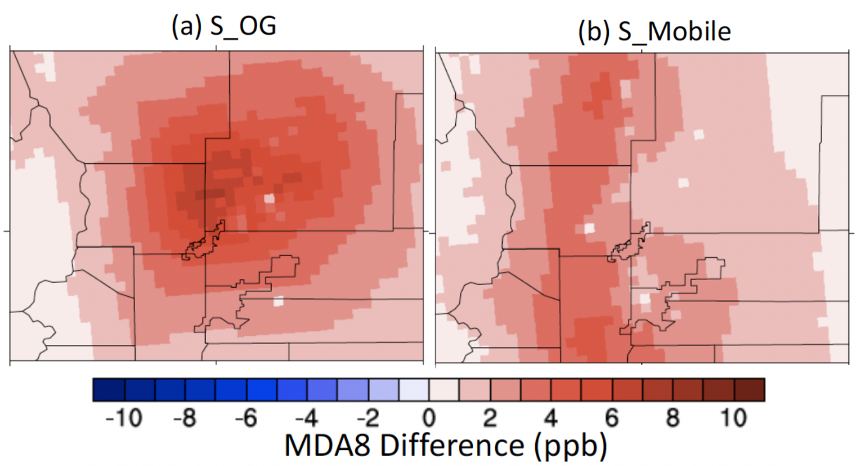

Figure 7: Estimated contributions of OnG emissions (left) and mobile (traffic) (right) emissions to MDA8. Results are the average over the campaign period.

4.3 Integration into the AQ-WATCH Toolbox

As opposed to the other modules in the AQ-WATCH system, this module is not real time and is rather an informative tool on the effects of fracking on air pollution. Its purpose is to provide information on the expected release and dispersion of pollution as a result of emissions from OnG extraction activities in an area where fracking is an important component of the extraction process, in this case the NFRMA. By showing the case of Front Range, Colorado, the module allows policy makers and local authorities in other regions to assess if this tool will be helpful for their decision-making process on new fracking (OnG) activities and how it allows them to assess the potential risk related to fracking in light of health effects on the population.

Such a module could be adopted for any other region for which a fairly accurate OnG emissions inventory is available. It could also be added as a separate sector in the attribution service. This would be challenging for ozone given the non-linear chemistry but would be feasible for species with a more linear chemistry such as CO, ethane or propane. As inputs to the tool serve the simulations with and without OnG emissions for a 6-week period between 10 July and 20 August 2014 at 4 x 4 km^2 spatial resolution over Colorado. Users can visualize various gas phase pollutants and assess the absolute concentrations at the surface with and without OnG activities as well as visualize the absolute difference. The input data are provided in NETCDF format as hourly and 24-hour average concentrations (in the case of ozone the daily maximum 8-hour average ozone (MDA8)). Information on the following pollutants is provided: O_3, NO_2, NO_x, toluene, propane, formaldehyde, benzene and ethane. In addition, ethane emissions are provided to inform on the location of OnG activities. The total data volume amounts to ~4GB.

The basic layout of the AQ-WATCH Fracking Service module is shown in Figure 8. At the very top a user can select the region (which in the case of this module has data only for Colorado) as well as the temporal resolution (hourly or 24-hours) and time period. An info button provides information on the module and underlying data in layman's terms (Figure 9).

The display includes a map where a pollutant can be selected. Users can choose between visualizing absolute surface concentrations with or without OnG emissions as well as the difference between the two scenarios. A time slider allows the user to loop through the times as well as play a movie. Clicking on the map allows the user to select a location. For this location time average statistics and timeseries will be displayed below the map. The module also has the option for users to export the data for the selected location into a CSV file.

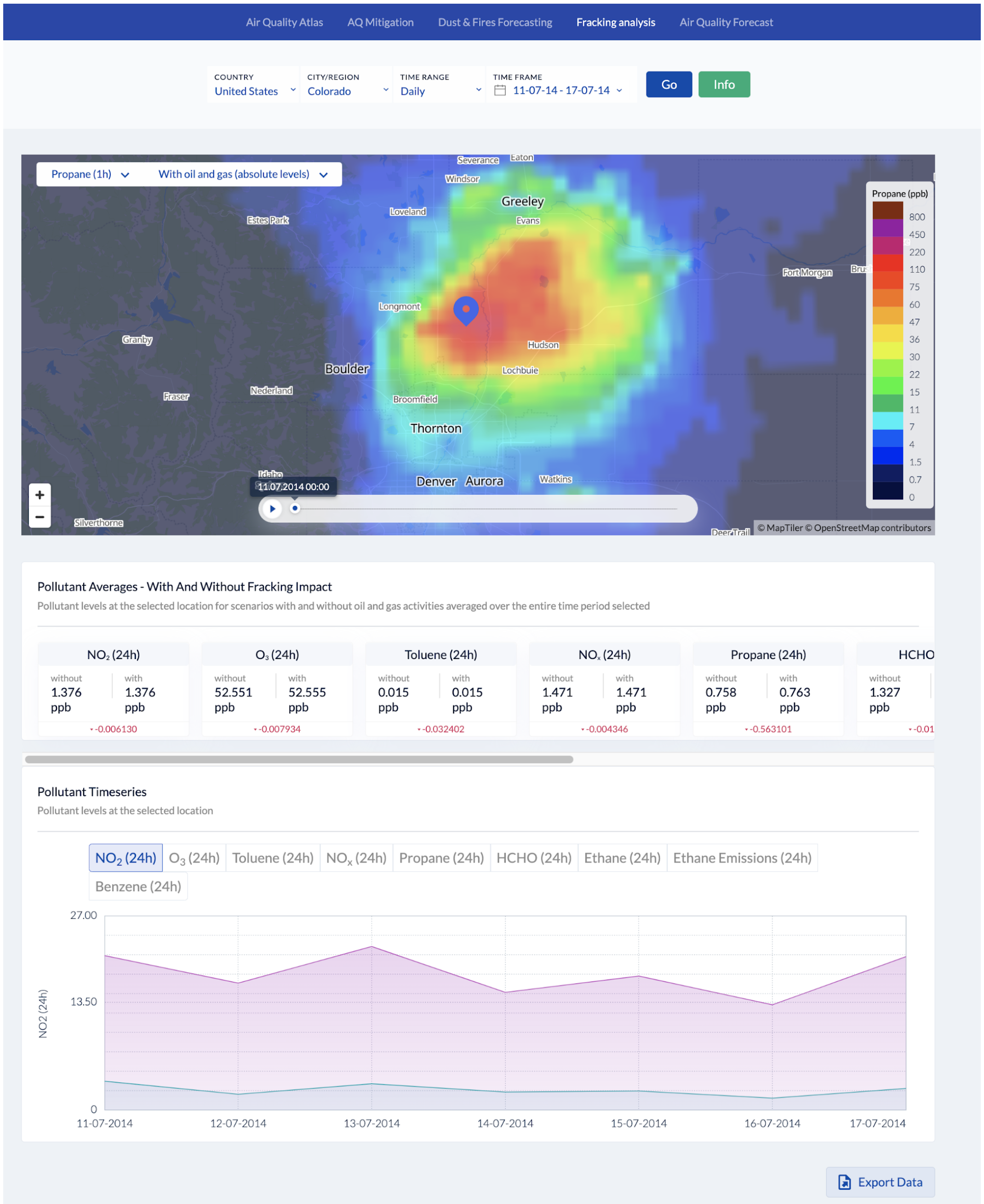

Figure 8: Snapshot of the layout for the AQ-WATCH Fracking Service module.

What is fracking?

Fracking is an oil and natural gas production technique that involves the injection of millions of gallons of water, plus chemicals and sand, underground at very high pressure in order to create fractures in the underlying geology to allow oil and natural gas (O&nG) to escape. Fracking is one process in the full lifecycle of a well and to characterize air quality impacts from O&nG exploration the emissions released during the full range of activities in an area need to be considered. Therefore this service gives a case study for the full impact of O&nG activities on air quality rather than fracking by itself. For more information, see e.g. Energy Explained - U.S. Energy Information Administration (EIA)

Data products in this service

The Front Range of Colorado is home to numerous larger municipalities including Denver. It also encompasses the Denver-Julesburg Oil and Gas Basin, which is the site of major O&nG developments. Since 2007, the Front Range has been classified by the U.S. EPA as a non-attainment area for ozone (O3) due to its summertime exceedances of the National Ambient Air Quality Standard (NAAQS). Characterizing the role of O&nG emissions to air quality in this region is essential for protecting public health (e.g. see this peer-reviewed paper). Volatile organic compounds (VOCs) and nitrogen oxides (NOx) emitted by O&nG extraction are surface O3 precursors but emissions remain highly uncertain. In 2014, a major field project - the Front Range Air Pollution and Photochemical Experiment FRAPPÉ – took place designed to identify and quantify the main drivers of summertime ozone in the Colorado Northern Front Range Metropolitan Area. The rich set of observations provide constraints to model simulations that were conducted and form the basis for this service. The air quality impacts are assessed by comparing simulations with and without O&nG emissions.

A note of caution

Models are needed to characterize impacts of O&nG but models are subject to uncertainties. While the underlying model product represents one of the best constrained products available and the confidence in the general results and conclusions is high, it will not represent the true situation in every detail.

Figure 9: Informational blog accompanying the AQ-WATCH Fracking Service module.

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6 Uptake by the targeted audience

6.1 Uptake by the targeted audience

As indicated in the Description of the Action, the audience for this deliverable is

X	The general public (PU)
	The project partners, including the Commission services (PP)
	A group specified by the consortium, including the Commission services (RE)
	This report is confidential, only for members of the consortium, including the Commission services (CO)

6.2 This is how we are going to ensure the uptake of the deliverables by the targeted audience

- The latest version of the service will be presented to the prime users in Colorado in 2022.
- The deliverable will be available through the AQ-WATCH website: https://www.aq-watch.eu/publications
- The deliverable will be circulated within the consortium via the link: https://owncloud.gwdg.de/index.php/s/EQWP438kM2xhGNb

7 Deliverable timeliness

Is the deliverable delayed?

☐ Yes ☒ No

8 Changes made and/or difficulties encountered, if any

The main challenge is on the accuracy of the underlying model data and on the representativeness and interpretation of the results: While this product relies on one of the best constrained and evaluated OnG air quality impact studies to date, it still remains subject to uncertainties. The accuracy of the data is affected by various factors such as uncertainties in emissions and model representation of physical and chemical processes that need to be considered in the interpretation.

Air quality impacts in this product are estimated at a spatial resolution of 4 x 4 km^2 which has to be taken into account in the interpretation of the results because the impacts in the close proximity to OnG drilling sites is not resolved but is often of most interest to the public. Communication of uncertainties and of the provided information content of the service to users is an essential activity that needs to go hand in hand with providing this service.

The product is for one case study only but research has shown that air quality impacts from OnG can vary significantly across OnG basins where the type of oil and gas can be different, the maintenance and operations of wells varies and where different regulations also can put different constraints on operations. In addition, environmental conditions also affect the impacts of OnG emissions on air quality. For the case of the Colorado Front Range, OnG related particle pollution is also of secondary concern but which might not be the same for other areas.

9 Sustainability

The data for this service are final and not subject to change. Any potential changes would only be made to the visualization part, if specifically requested by a user. The addition of new data sets is feasible under a new contract of project.

9.1 Lessons learnt: both positive and negative that can be drawn from the experiences of the work to date

Bringing research products to the public and policy makers requires finding a common language and understanding and requires effort and time from both sides. Needs and concerns from the users need to be carefully addressed and the value and limitations of the research product, in this case the Fracking Service, need to be fully communicated. Communication and education are of especial importance for the Fracking Service because of the sensitive and political nature of the OnG extraction process and its potentially large environmental and human health impacts.

9.2 Links built with other deliverables, WPs, and synergies created with other projects

The fracking service is part of the Workpackage on Source Attribution and mitigation and this report is therefore also linked to “D4.1 Description of source apportionment service for the focus regions”.

It further links to "D5.5 Application programming interface (API) and a web design framework, fitted to different interface such as touch based devices, both Android and iOS (Demonstrator)"

10 Full track of dissemination activities

Not applicable

11 Full track of publications and IP

11.1 Peer reviewed articles

Not applicable

11.2 Publications in preparation OR submitted:

None during the AQ-WATCH project duration. This is a demo tool with model data that have been discussed in previous peer-reviewed publications and in a detailed report to the State of Colorado (see References).

11.3 Intellectual property rights resulting from this deliverable:

Not applicable