UTAH DEPARTMENT *of* ENVIRONMENTAL QUALITY

AIR QUALITY

AIR QUALITY RESEARCH PROJECTS

2014-2015

Local Research for Local Problems

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Introduction

While Utah enjoys clean air during most of the year, its unique topography and meteorology make it susceptible to elevated levels of fine particulates (PM2.5) during winter inversions and ozone during the summer. To improve scientific understanding of the complex conditions that lead to these high pollution levels, the 2014 Utah State Legislature awarded $1 million in one-time funding to the Department of Environmental Quality (DEQ) for air quality research. DEQ selected research projects that complemented the agency's long-term planning objectives for addressing the causes of air quality problems in the state. The 2015 Legislature awarded DEQ an additional $200,000 to continue this research program during 2015 and 2016.

At the conclusion of each legislative session, DEQ identified research projects that would address pressing air quality problems and build upon departmental efforts already underway. This funding had the added benefit of engaging the Utah scientific community in solving air quality problems through research tailored to the state's unique conditions.

DEQ anticipates that it will prepare and complete at least two major State Implementation Plan (SIP) revisions between 2016 and 2020. These regulatory requirements drive the need for focused, problem-specific research on fine particulate pollution during winter inversions along the Wasatch Front and ozone pollution in the oil and gas producing region of the Uinta Basin.

Both of these air quality problems are driven by meteorological and chemical processes. These processes must be more completely understood in order for the State of Utah to provide effective solutions. In addition, as air quality health standards become more stringent, it becomes increasingly difficult to find areas in the economy for pollution reductions. For this reason, regulations, and the costs to implement them, must target the most effective and responsible options. A more comprehensive understanding of the mechanisms that influence the buildup of pollution will help DEQ find the most appropriate regulatory solutions.

We hope that this brief overview of the completed research projects, along with those that are still in progress, will provide an understanding of the ways DEQ is working to protect one of the key resources — clean air — that all Utah residents hold dear.

Visit www.deq.utah.gov/ProgramsServices/programs/air/research/index.htm for a more in-depth look at the research, including scientific and technical descriptions, and research results as they become available.

Wasatch Front Research Projects

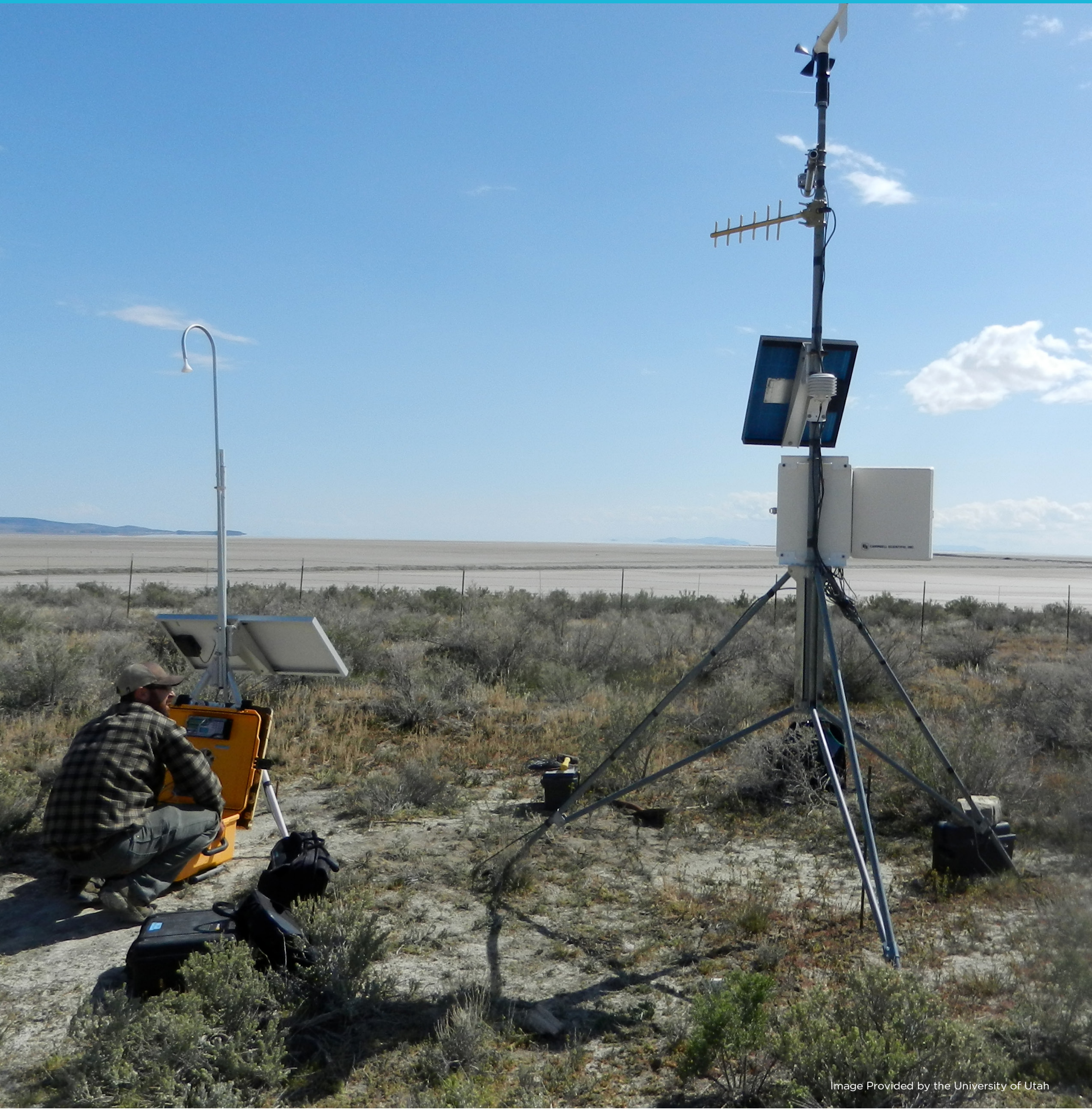
Image Provided by the University of Utah

Air Quality Modeling During Wintertime Air Pollution Episodes

Temperature inversions are one of the primary causes of wintertime PM2.5 pollution along the Wasatch Front and the Cache Valley. It is extremely difficult to recreate inversion-pollution events in a model because event conditions are influenced by clouds, winds, snow depth, and even the reflectivity of the snow itself.

Purpose

An accurate air quality model that reflects actual conditions is critical to the Division of Air Quality's (DAQ) efforts to find solutions to Utah's PM2.5 pollution problems.

Research Plan (July 2015-January 2016)

1. Conduct research on the weather-related components of the air quality model to improve understanding of the natural forces that influence Utah's weather and how these forces affect the formation of PM2.5. Advances include:
    a. Better understanding of snow conditions through the use of ground- and satellite-based monitors.
    b. New data from studies undertaken during the last few years in the Salt Lake Valley and the Uinta Basin.
    c. Improved accounting of the rapid urbanization of the Wasatch Front and impacts from drought on the water level of the Great Salt Lake.
    d. New methods to account for clouds and ice fog during an inversion.
    e. Methods for handling light winds in the inversion model.
2. Ensure that the model results match the observations at the air quality monitors. Model improvements must result in a more realistic reproduction of the inversion episodes. The availability of detailed measurements from previous studies will provide relevant information for this comparison.

Expected Outcomes

- Improvements will allow the air-quality model to reproduce pollutant build-up near the ground for long periods of time. This is consistent with observations from DAQ monitoring instruments.
- The ability to capture these effects in a model will improve DAQ's ability to test the effects of newly proposed regulations.
- More accurate information will assist DAQ in the cost-benefit analysis for new rules.

Air Toxics Monitoring along the Wasatch Front

Air toxics are pollutants that are known or suspected to cause cancer or other serious health problems including reproductive effects and birth defects, and adverse environmental effects. A review of the air toxics data that DAQ collected in Bountiful between 2002 and 2012 showed that several toxic species, derived mainly from human-made sources, were present at levels exceeding safe exposure thresholds. However, these measurements were only representative of the Bountiful area.

Purpose

To assess population exposure to air toxics along the Wasatch Front, DAQ needs to determine the most current levels of the toxic pollutants and how they vary across areas.

Research Plan (December 2014-May 2016)

1. Collect air toxics measurements at three air quality monitors in Utah and Salt Lake counties. To account for the variation in air toxics levels over time, collect data once every three days, which is a greater frequency than past measurements.
2. Measure air toxics species, including:
    a. Gaseous organic compounds
    b. Carbonyls
    c. Metals

Expected Outcomes

- Determine current ambient levels of the air toxics.
- Identify time periods and locations with high potential for health risks.
- Identify likely sources of the air toxics to help DAQ implement control strategies.

Automobile Start and Idling Emissions under Utah-Specific Conditions

Approximately 76-percent of the combined NOx and VOC emissions from cars are produced during the first three minutes after a cold start. Reducing vehicular emissions is a central component of the State Implementation Plans (SIPs) developed by DAQ to improve air quality in the Wasatch Front and the Cache Valley.

Purpose
Better assessment of vehicular start and idling emissions under Utah-specific conditions will help DAQ develop effective air pollution control strategies.

Research Plan (July 2014-October 2015)
Conduct tailpipe testing at Utah State University and Weber State University from late 2014 through winter 2015. The objectives of the testing were to:

1. Measure the differences in emissions between cold starts (engine off for more than 12 hours), hot starts, and continuous idling.
2. Verify whether emissions are different under different weather conditions.
3. Determine how long catalytic converters (vehicular emissions control devices) can remain at optimal operating temperatures under Utah's seasonal conditions.

The number and age of vehicles tested represented a vehicle fleet typical of the Wasatch Front and Cache Valley.

Interim Findings
A catalytic converter must reach and maintain an optimum temperature to effectively convert unsafe exhaust pollutants into less harmful compounds. Modern automobiles do not require more than one-to-two minute warm-up time for proper catalytic converter operation following a cold start.

Expected Outcomes
- Better information on how long a catalytic converter can remain at optimal operating temperature under Utah's wintertime and summertime conditions.
- More accurate information on vehicular emissions to improve DAQ's emission inventories.
- More accurate information on idling emissions and their impact on Utah's air quality to assess the effectiveness of anti-idling programs to help reduce pollution levels.
- Emissions data that can be used to update EPA's nationwide mobile-source emissions model.

Contribution of Wood Smoke to PM2.5 along the Wasatch Front

The Wasatch Front often experiences elevated levels of PM2.5 during wintertime inversions. A study several years ago analyzed the contribution of wood smoke from residences and cooking emissions from grills to the buildup of PM2.5 during inversions. However, the individual contribution of these sources of wood smoke to total PM2.5 was unclear.

Purpose

Further research is needed to determine the extent to which wood-burning emissions contribute to PM2.5 levels along the Wasatch Front.

Research Plan (June 2015-July 2016)

1. Employ a technique that uses levoglucosan, a chemical that can be uniquely associated with emissions from wood burning, to determine the contribution to PM2.5 from wood-burning and other major sources. Measurements of levoglucosan will be taken at the air-quality monitor at Hawthorne Elementary School. This analysis will help:
    a. Determine the contribution of wood-burning to PM2.5, particularly during PM exceedance days.
    b. Compare wood smoke contribution to PM2.5 to that of other major sources such as vehicles, soil, secondary nitrate and sulfate, and possibly industrial sources.
2. Use results to derive emission ratios specific to wood-burning in Utah. Use these derived ratios, along with measurements of levoglucosan, to look at the amount of pollution that is coming from the wood burning stoves and fireplaces measured at four other monitors along the Wasatch Front and in Cache Valley.
3. Investigate whether EPA-certified wood burning stoves significantly impact pollution levels if their use is allowed on “voluntary no-burn” days when pollution levels are just beginning to rise. This includes:
    a. Considering a hypothetical scenario where existing wood-burning devices are replaced by low-emission models such as EPA-certified stoves and inserts.
    b. Using a combination of emission inventory data and air-quality modeling to estimate the potential reduction in PM2.5 from the change-out.
    c. Evaluating the number of exceedance days that could be avoided under this scenario.

Expected Outcomes

- Determine whether wood-burning is an important contributor to elevated PM2.5 levels.
- Analyze the impact of a program to encourage people to replace older stoves and fireplaces with EPA-certified and other low-emission devices in their homes.
- Reduce PM2.5 levels by establishing more effective control regulations that target significant contributors to PM2.5.

Key Drivers of Ozone Formation along the Wasatch Front

The Wasatch Front experiences elevated ozone levels during the summer. A stricter federal health standard for ozone was enacted this fall. Because of this new standard, counties along the Wasatch Front may be required to prepare a State Implementation Plan (SIP) to reduce ozone levels. Volatile organic compounds (VOCs) and nitrogen oxides (NOx) play an important role in the formation of ozone.

Purpose

To develop effective ozone control regulations, DAQ needs to determine the relative importance of NOx and VOC emissions in ozone formation along the Wasatch Front.

Research Plan (January-July 2015)

Analyzed VOC, NOx, and ozone measurements that DAQ collected in Salt Lake City over the past several years. This consisted of:

1. Investigating the variation of these species in time.
2. Identifying the most important VOC species driving ozone formation.
3. Investigating the sensitivity of ozone formation to changes in NOx and VOCs levels.

Results

- Ozone levels did not significantly decrease over the last 20 years in Salt Lake City.
- Ozone levels slightly increased on weekends, although levels of NOx and VOCs decreased. This is because ozone production depends on the relative availability of these gases rather than their levels.
- Ozone levels are not very sensitive to large changes in NOx emissions, suggesting that reducing on-road NOx emissions will not lead to ozone reduction.
- VOCs, specifically light alkanes, are the most important species driving ozone formation in Salt Lake City.
- The most effective strategy for reducing ozone is to reduce light alkanes such as ethane and propane.
- Further work is needed to characterize the sources of alkanes along the Wasatch Front.

Impact of Wildfires and Dust Events on Utah's Air Quality

Wildfires and dust storms sometimes lead to PM2.5 and ozone exceedances along the Wasatch Front. The Division of Air Quality (DAQ) can exclude data affected by these exceptional events when determining compliance with the National Ambient Air Quality Standards (NAAQS) if it can demonstrate that the observed exceedances are due to these events.

Impact of Wildfires and Dust Events on Utah's Air Quality (continued)

Purpose

DAQ needs a method to determine the direct contribution of wildfire and dust storms to exceedances of the PM2.5 and ozone health standards. The key difficulty is the ability to separate the contribution of these events from pollution that comes from automobiles, industrial, commercial, and household sources.

Research Plan (July 2014-January 2016)

1. Researchers are developing a computer model to determine the impact of wildfire and dust emissions on air quality along the Wasatch Front. The model combines wildfire emission inventory data and a method for estimating dust emissions with a model for predicting wind trajectories.
2. While the model can accurately reproduce PM2.5 concentrations from wildfires, more work has to be done for ozone modeling. This includes:
    a. Running the model without consideration for wildfire emissions.
    b. Running the model with consideration for wildfire emissions.
    c. Comparing the results to quantify the impacts of wildfires on ozone concentrations.
3. Determine contributions from wind-blown dust to springtime PM2.5 exceedances, when dust storms take place. This includes incorporating a dust emissions component into the model.

Interim Findings

Model results suggest that PM2.5 exceedances during summer 2012 were due to wildfires. These exceedances would not have taken place without contributions from wildfire emissions.

Expected Outcomes

- Determine whether wind-blown dust caused exceedances of PM2.5 during March and April 2011 dust storms.
- Use this tool in future analyses to demonstrate the occurrence of exceptional events and their contribution to NAAQS violations.

Ozone Measurements near the Great Salt Lake

Scientists suspect that high ozone concentrations over the Great Salt Lake may contribute to elevated summer ozone levels along the Wasatch Front when lake breezes carry the pollutant to urban areas. Ozone, an odorless constituent of smog, can trigger a wide range of health problems. The federal health standard for ozone was tightened up this fall. Counties along the Wasatch Front may be required to prepare a State Implementation Plan (SIP) to reduce ozone levels in the coming years.

Ozone Measurements near the Great Salt Lake (continued)

Purpose

DAQ needs to have a better understanding of ozone formation during the summertime to guide the agency's emission reduction efforts.

Research Plan (July 2015-January 2016)

1. Improve the prediction of ozone levels both near the ground and aloft. Air quality scientists from DAQ, the University of Utah, Utah State University, and Weber State University deployed a large suite of sensors this summer near the Great Salt Lake.
    a. Air quality monitoring stations were established near the Lake.
    b. UTA provided space on a TRAX light rail car for a mobile air quality monitor.
    c. An unmanned aerial vehicle (drone) was instrumented and flown over the lake.
    d. Tethered and free-flying weather balloons were employed.
    e. KSL-TV provided space on their traffic helicopter for ozone measurements. These measurements provided considerable information on ozone levels above and near the Great Salt Lake at different times of the day. Information about the study, data, and discussions are available online (http://meso2.chpc.utah.edu/gslso3s/).
2. Examine key factors controlling ozone levels over the Great Salt Lake. For example, the drop in recent years in the level of the Great Salt Lake might contribute to higher ozone levels because the exposed dry beds surrounding the lake are highly reflective and provide more sunlight for the chemical reactions that form ozone. Other factors include:
    a. Impacts of morning land breezes carrying precursor pollutants towards the lake.
    b. Afternoon lake breezes carrying ozone back towards the Wasatch Front.
    c. Vertical distribution of ozone at different times of the day.

Interim Findings

Ozone concentrations are low in the morning then increase rapidly in the afternoon during poor air quality periods.

Expected Outcomes

- Improved understanding of the impacts of ozone levels at the Great Salt Lake will help DAQ predict episodes of poor air quality along the Wasatch Front.
- Better information will assist DAQ in developing ozone SIPs that will satisfy new federal standards that are more stringent than the current ozone standards.

Residential Wood-Burning Inventory Survey

Northern Utah experiences elevated levels of PM2.5 during wintertime inversions. Estimates of emissions from residential wood-burning heating appliances are uncertain and more information about these sources is needed.

Purpose

To better determine wood-burning emissions and areas of high wood-burning activity, DAQ contracted with ICF, a private research firm, to conduct a survey on residential wood combustion in Northern Utah.

Research Plan (January-August 2015)

1. Design a survey to provide detailed information on the wood-burning practices of residents in the seven northern counties that currently fail to meet federal air quality standards for PM2.5 during wintertime inversions. Questions included:
    a. The type, age, and number of wood-burning appliances.
    b. The amount of wood burned in each appliance in a typical year.
    c. The time of day and months during which residents use their wood-burning appliances.
2. Use the data to estimate county-wide wood-burning emissions for each type of wood-burning appliance (i.e., wood stove, fireplace, etc.).
3. Compare the survey results to those obtained through the EPA method for estimating residential wood-burning emissions.

Results

- The most popular primary home heating sources are natural gas and electricity. These are collectively used by 96.2-percent of households, while wood is only used by 0.9-percent of households as a main heating source.
- 25- to 38-percent of households in Northern Utah own a wood-burning appliance.
- Fireplaces are mostly used for enjoyment, while inserts, wood stoves, and other wood appliances are mainly used as a backup heating source.
- Data from the survey and the EPA method on wood-burning emissions and amount of wood used were generally in agreement.
- Survey data will be used in future analyses on wood-burning activity in order to determine the contribution of wood smoke emissions to PM2.5 levels in Northern Utah.

Uinta Basin

Winter Ozone Chemistry and Snow Cover in Air Quality Models

The Uinta Basin in northeast Utah, as well as the Upper Green River Basin in southwest Wyoming, experiences high ozone levels during winter. Prior to 2010, when these episodes were first observed in Wyoming, atmospheric scientists had assumed that exceedances of the ozone health standard only occurred during the summer. These periods of high ozone occur under extremely cold conditions and require adaptations to the chemical and meteorological mechanisms within the air quality models. These updates to the models will improve DAQ's ability to regulate winter ozone in the Uinta Basin.

Purpose

To control the wintertime ozone problem in the Uinta Basin, DAQ needs an air quality model that accounts for the influence of snow cover and cold conditions on ozone formation in the Basin. Scientists at Ramboll Environ, Inc. were contracted to adapt the Comprehensive Air Quality Model with Extensions (CAMx) to account for winter ozone conditions.

Research Plan (August 2014-July 2015)

Researchers modified the CAMx air quality model. This consisted of:

1. Improving the characterization of snow cover and its influence on:
    a. Sunlight reflection
    b. Pollutant deposition onto ground surfaces
    c. Formation of ozone-producing species on the snowpack
2. Modifying the ozone chemistry component of the model to account for the influence of low-temperature conditions on ozone-forming species.
3. Evaluating these modifications by comparing the updated model results to observations and baseline model results (i.e., without any updates).
4. Testing the model with modified emissions to identify needed improvements in the emissions inventory.

Results

- DAQ will use model updates in the development of future State Implementation Plans (SIPs).
- Updates to the model improve ozone prediction in the Uinta Basin but are insufficient to reproduce the observed high ozone levels.
- Improvements to the oil and gas emissions inventory are needed to better predict and control ozone in the Basin. Improvements include accounting for missing sources, such as flanges, valves and storage tanks, and better representation of emission sources such as engines, compressors, and pumps, in the inventory.

Formaldehyde and Other Carbonyl Emissions from the Oil and Gas Industry

The Uinta Basin experiences ozone levels above EPA health-based standards during wintertime inversions. Emissions of carbonyls, a group of chemical compounds from the oil and gas industry, contribute to the formation of winter ozone.

Purpose

A better understanding of these emissions and how they contribute to ozone formation will help DAQ develop effective ozone-control regulations in the Uinta Basin.

Research Plan (August 2014-July 2015)

1. Measure carbonyl emissions from several oil- and gas-related sources during winter 2015. Sources include glycol dehydrators, liquid storage tanks, pneumatic devices, and pump-jack engines.
2. Use emission measurements in an air quality model to recreate ozone formation.

Results

- Emissions from all measured sources were very low, suggesting that emission controls that specifically target these sources may not be effective.
- Studies to improve model performance and measurements of carbonyl emissions from sources that were not considered in this work, such as natural gas burners, compressor stations, and gas processing plants, are needed to resolve discrepancies between the observations and model results.
- Better information will help improve understanding of oil- and gas-related emissions that impact Utah's air quality and will assist DAQ in developing more cost-effective emission control strategies.

Future Emissions Predictions from Oil and Gas Operations in the Uinta Basin

Emissions from oil and natural gas activities are one of the primary causes of high wintertime ozone levels in the Uinta Basin. The levels of these emissions vary over time. Large, one-time emissions occur when a well is drilled, followed by a long period during which emissions decline as production rates decrease.

Purpose

DAQ needs a method to estimate how much oil and gas can be produced from wells to better estimate the one-time emissions and emissions decline over time. This will identify emission controls that improve air quality in the Basin while minimizing the impact on the area's economy,

Research Plan (January-October 2015)

1. Conduct research to develop a model to predict emissions from oil and gas operations:
    a. Forecast the number of wells that might be drilled at any time in the future in the Uinta Basin using an economic model that uses past drilling activity and energy (oil and natural gas) prices in the Basin.
    b. Use a decline curve analysis based on local historical production data to estimate the decline over time in oil and natural gas production from wells. The production rate from new wells will also be estimated using this method.
    c. Estimate the likelihood that oil and gas drilling activity will occur by accounting for the variability in energy price forecasts.
2. Continually update emissions estimates using the most recent information on prices and production rates.

Expected Outcomes

- Estimate the number of wells that might be drilled in the Uinta Basin in the future.
- Estimate production rates from both existing and new wells.
- Use this information to estimate emissions from oil and gas operations that lead to high ozone levels in the Uinta Basin during winter.
- Set the most cost-effective emission regulations that help maintain regulatory ozone standards while minimizing the economic impact on the oil and gas industry.

Adaptation of the Chemistry Component of Air Quality Models to Utah-Specific Conditions

The Uinta Basin experiences high ozone levels during winter. To reduce these levels, it may be necessary to regulate emissions from the oil and gas industry. Computer models help scientists at DAQ understand the science behind ozone formation and pre-assess the impact of any given regulation. However, all the existing ozone computer models were designed to measure summer ozone and have not been well tested for the wintertime conditions under which ozone forms in the Uinta Basin.


Image by Sheri Trbovich, Weber State University, Physics Department

Purpose

This project was the second of two model chemistry improvements undertaken. Researchers analyzed and made subsequent improvements to an additional chemistry solving mechanism for use in the Community Multi-scale Air Quality model (CMAQ).

Research Plan (September 2014-September 2015)

1. Adapt the chemistry-related component of the air quality model to address wintertime conditions in the Uinta Basin by incorporating the low-temperature and low-humidity behavior of chemical reactions important to ozone formation into the model.
2. Run the computer model to gauge the impact of the updates made to the model.

Expected Outcomes

- Improvements to the model will help DAQ evaluate the impact of oil and gas emissions on wintertime ozone formation in the Uinta Basin.
- Improvements will assist DAQ in the cost-benefit analysis for new regulations.

Acknowledgements

The Utah Department of Environmental Quality gratefully acknowledges the support and funding from the Governor's Office and the Utah State Legislature.

In addition, DEQ would like to acknowledge the cooperation and collaboration of the state's research universities that were integral to the success of these projects:

- Brigham Young University
- University of Utah
- Utah State University
- Utah State University, Bingham Entrepreneurship and Energy Research Center
- Weber State University
- Weber State University, National Center for Automotive Science and Technology

UTAH DEPARTMENT *of*
ENVIRONMENTAL
QUALITY

Issued January 2016

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