Four Corners Air Quality Related Studies/Research
September 2022

Ozone Studies

- The Colorado Department of Public Health and Environment conducted a summer 2019 ozone study in southwest Colorado to help determine if monitoring in the area is appropriate. One short- term site was added to the north of Cortez and five were added in the Animas Valley around Durango.

- The Southern New Mexico Ozone Study (SNMOS) was completed in early November 2016. The SNMOS assessed 2011 base year and future projection year ozone impacts and contributing source categories/regions in and around Doña Ana County, NM.

- The New Mexico Ozone Attainment Initiative Modeling Study developed a 2014 base year photochemical grid model (PGM) modeling platform and conducted 2028 future year modeling for a Base Case and an Oil and Gas (O&G) Control Strategy scenario that implemented proposed controls on 2028 New Mexico O&G sources. The NM OAI Study leveraged the 2014 PGM modeling platform developed by the Western Regional Air Partnership (WRAP) in the WAQS and enhances it by adding a 4-km grid resolution modeling domain covering New Mexico and adjacent regions.

- WESTAR/WRAP worked with Dr. Dan Jaffe and a team of federal and university scientists to publish a paper in the scientific journal *Elementa* on the state of the science of background ozone in the U.S.: http://www.wrapair2.org/pdf/BOSA_O3_Elementa2018_Jaffe_et_al.pdf.

- WESTAR/WRAP staff had a paper published in AWMA *Environmental Manager* September 2018 issue on the topic of addressing background ozone and transport: http://www.wrapair2.org/pdf/moore.pdf.

- The Ute Mountain Ute Tribe (UMUT) Air Quality program deployed an ozone field monitoring system at Tribal Lands north of Kirtland, NM July-Dec. 2021. The data show generally that the NM and Towaoc ozone concentrations are similar with NM highs being higher and lows being lower. The UMUT monitors ozone at Towaoc, CO, which meets regulatory requirements. Data since 2019 has been uploaded into EPA's Air Quality System Database. Staff posts current daily AQI via email and social media.

- National Park Service (NPS) and Colorado State University researchers measured volatile organic compounds (VOCs) which are known ozone precursors at four national parks in the southwestern United States: Carlsbad Caverns (CAVE), Great Basin (GRBA), Grand Canyon (GRCA), and Joshua Tree (JOTR), for five months in 2017. CAVE had the highest levels of light alkanes by approximately an order of magnitude. At the other three Parks, VOC concentrations were similar to each other. Measurements in and around CAVE showed an oil and gas influence: https://www.sciencedirect.com/science/article/abs/pii/S135223102030515X.

- NPS and State University of New York researchers examined decadal (2005- 2015) ozone trends for 13 rural & remote sites in the Intermountain West. No trends were observed at two

reference sites while widely varying trends were observed at the other 11 sites. Decreasing trends were observed at Mesa Verde and Canyonlands National Parks, attributed to a 37% decrease in natural gas production in the San Juan Basin and 25% emission reductions in coal-fired electricity generation, respectively. Findings suggest that emissions from oil and natural gas extraction likely played a significant role in shaping long-term ozone trends near or within oil and gas basins and warrant consideration in designing efficient ozone mitigation strategies for the Intermountain West: https://acp.copernicus.org/preprints/acp-2019-164/

- In 2016, NPS researchers conducted assessments of ozone foliar injury at Arches, Canyonlands, Mesa Verde National Parks and Colorado and Dinosaur National Monuments. The levels of ozone in 2016 were low during this time and prevented the development of foliar injury on bioindicator species in spite of moderate to high levels of precipitation in some parks. More research is needed: https://irma.nps.gov/DataStore/DownloadFile/640216

Mercury Studies

- Two years of follow-up gaseous oxidized mercury (GOM) dry deposition measurements in the Four Corners Area 2017-2019 completed in August, 2019. Results published in journal Atmospheric Pollution Research at the following link:https://doi.org/10.1016/j.apr.2020.08.030 Two years of follow-up gaseous oxidized mercury (GOM) dry deposition measurements in the Four Corners Area 2017-2019 completed in August, 2019. Results published in journal Atmospheric Pollution Research at the following link:https://doi.org/10.1016/j.apr.2020.08.030

- Mark E. Sather, Shaibal Mukerjee, Kara L. Allen, Luther Smith, Johnson Mathew, Clarence Jackson, Ryan Callison, Larry Scrapper, April Hathcoat, Jacque Adam, Danielle Keese, Philip Ketcher, Robert Brunette, Jason Karlstrom, and Gerard Van der Jagt, “Gaseous Oxidized Mercury Dry Deposition Measurements in the Southwestern USA: A Comparison between Texas, Eastern Oklahoma, and the Four Corners Area,” The Scientific World Journal, vol. 2014, Article ID 580723, 14 pages, 2014. Doi:10.1155/2014/580723. The article can be accessed at the following link: http://www.hindawi.com/journals/tswj/2014/580723/ .

- Sather, M.E., Mukerjee, S., Smith, L., Mathew, J., Jackson, C., Callison, R., Scrapper, L., Hathcoat, A., Adam, J., Keese, D., Ketcher, P., Brunette, R., Karlstrom, J., Van der Jagt, G., 2013. Gaseous oxidized mercury dry deposition measurements in the Four Corners Area and Eastern Oklahoma, U.S.A. Atmospheric Pollution Research, doi: 10.5094/APR.2013.017. https://www.sciencedirect.com/science/article/pii/S130910421530386X

- The Mesa Verde NPS Mercury Deposition Network (MDN) monitor. NADP-MDN website http://nadp.sws.uiuc.edu/mdn/ includes a temporal trend graph for mercury. Total Hg in wet deposition has been monitored at Mesa Verde NP since 2002.

- As a surrogate for mercury (Hg) risk, dragonfly larvae have been collected and analyzed for total Hg concentrations from NPS units in the Four Corners region including Valles Caldera National Preserve (Jemez Springs, NM) and Glen Canyon National Recreation Area (Page, AZ). Samples were collected from nine unique sites in these two parks across three years (2015, 2018-2019); 27% of the dragonfly Hg data fall into the moderate (100-300 ng/g dw) and 36% fall into the high or severe (>300 ng/g dw) impairment categories for potential Hg risk. An index of moderate impairment or higher suggests some fish species may exceed the US EPA benchmark for protection of human

health. There are also recent dragonfly Hg data from other NPS units that fall close to the Four Corners region including those in UT (Capitol Reef NP, Zion NP), CO (Colorado NM, Great Sand Dunes NP&P), and AZ (Grand Canyon NP, Montezuma Castle NM, Tuzigoot NM). New dragonfly Hg data are expected from parks in the Four Corners that sampled over the 2021 field season, including Yucca House NM (Cortez, CO) and nearby FWS refuges Valle de Oro (Albuquerque, NM) and Bosque del Apache (San Antonio, NM). Those data are anticipated in spring 2022. References below:

- Eagles-Smith, C.A., J.J. Willacker, S.J. Nelson, C.M. Flanagan Pritz, D.P. Krabbenhoft, C.Y. Chen, J.T. Ackerman, E.H. Campbell Grant, and D.S. Pilliod. 2020a. Dragonflies as biosentinels of mercury availability in aquatic food webs of national parks throughout the United States. Environmental Science and Technology 54(14):8779-8790. https://doi.org/10.1021/acs.est.0c01255

- Eagles-Smith, C.A., J.J. Willacker Jr., S.J. Nelson, C.M. Flanagan Pritz, C.S. Emery, B.L. Johnson, K. Ko, D.P. Krabbenhoft, C.Y. Chen, J.T. Ackerman, E.H. Grant, and D.S. Pilliod. 2020b. The Dragonfly Mercury Project- A citizen science framework for monitoring mercury pollution in US national parks using dragonfly larvae as biosentinels. USGS Story Map. https://doi.org/10.5066/P9SUMI7P

- Eagles-Smith, C.A., S.J. Nelson., C.M. Flanagan Pritz, J.J. Willacker Jr., and A. Klemmer. 2018. Total Mercury Concentrations in Dragonfly Larvae from U.S. National Parks (ver. 6.0, June 2021): U.S. Geological Survey data release. https://doi.org/10.5066/P9TK6NPT

- Johnson, B., C.A. Eagles-Smith, J. Willacker, C. Emery, C. Flanagan Pritz, K. Ko, and S. Nelson. Dragonfly Mercury Project Data Visualization Dashboard. In Review.

Methane Studies

- EPA will be conducting a special Methane Study at the NMED Air Quality Bureau's monitoring site located in Carlsbad, New Mexico. This is to commence either the summer of 2020 or 2021 depending on budget availability. The study will consist of a continuous monitor along with summa-canister sampling. The continuous monitor will be solar powered to measure for Methane while the summa-canisters will be used to capture VOC's (grab samples). A contractor will be hired by EPA to set-up the equipment. AQB's responsibility will be solely to set-up and collect the summa canisters and ship them to the respective laboratory for analysis. This study is to last for 4 months in duration.

- Riley Duren (University of Arizona/NASA-JPL/Carbon Mapper) conducted methane overflights during August & September, 2021. Carbon Mapper has also been working in the San Juan and Piceance basins in the fall of 2022 and those data will be available in coming months. Data for detections are available at https://carbonmapperdata.org/. Future data will also be posted at Carbon Mapper.

- Smith, Mackenzie L., Alexander Gvakharia, Eric A. Kort, Colm Sweeney, Stephen A. Conley, Ian Faloona, Tim Newberger, Russell Schnell, Stefan Schwietzke, Sonja Wolter, 2017. Airborne Quantification of Methane Emissions over the Four Corners Region. Environmental Science & Technology. Abstract at: http://pubs.acs.org/doi/abs/10.1021/acs.est.6b06107.

- Frankenburg, Christian, Andrew K. Thorpe, David R. Thompson, Glynn Hulley, Eric Adam Kort, Nick Vance, Jakob Borchardt, Thomas Krings, Konstantin Gerilowski, Colm Sweeney, Stephen Conley, Brian D. Bue, Andrew D. Aubrey, Simon Hook, Robert O. Gree, 2016. Airborne methane remote measurements reveal heavy-tail flux distribution in Four Corners region. Proceedings of the National Academy of Sciences of the United States of America. http://www.pnas.org/content/113/35/9734.full

- Kort, Eric A., Christian Frankenburg, Keeley R. Costigan, Rodica Lindenmaier, Manvendra K. Dubey, Debra Wunch, 2014. Four Corners: The largest US methane anomaly viewed from space. Geophysical Research Letters, an AGU Journal. http://onlinelibrary.wiley.com/doi/10.1002/2014GL061503/full

Multiple Pollutant and Other Deposition Studies

- Colorado 2019 Final Report: Human Health Risk Assessment for Oil & Gas Operations in Colorado. This includes both HHRA's for Denver-Metro North Front Range and Garfield County.

- The Western Regional Air Partnership (WRAP) has a 2018-19 workplan led by the Technical Steering Committee in place and has continued operation of five technical work groups on key western issues: Regional Technical Operations; Oil and Gas; Fire and Smoke; Regional Haze Planning; and Tribal Data. Each work group is implementing tasks under the workplan and all work groups have contractor analysis support activities underway. The WRAP workplan can be found at: https://www.wrapair2.org/TSC.aspx along with related materials and progress reports.

- The Intermountain West Data Warehouse – Western Air Quality Study (IWDW-WAQS), sponsored by EPA Region 8, NPS, USFS, BLM, and the States of CO, NM, UT, and WY have completed approval of the Cooperator workplan in September 2018 for the next three years of activities related to monitoring, emissions, and air quality modeling. The next regional modeling platform will be for the calendar year 2014 based on the NEIv2, with projections to 2023 and 2028 for use in regional air quality planning studies by the Cooperators while also supporting Regional Haze planning described in the WRAP 2018-19 Workplan. Work on the 2014 platform will include detailed model performance evaluation for year-round ozone, $PM_{2.5}$, nitrogen deposition, and visibility. The IWDW data are accessible at: http://views.cira.colostate.edu/tsdw/. The IWDW-WAQS provides air quality data and analysis tools to support regulatory, research, and academic applications. Available datasets include emissions inventories, meteorological data, monitoring data, and air quality modeling platforms. Modeling platforms available through the IWDW support consistent AQ/AQRV photochemical grid modeling (PGM) for NEPA projects and other modeling studies.

- 2014 BLM Drill Rig NO_2 Impacts Study: Effort to better predict 1-hour NO_2 impacts from drill rigs through a field study. Monitoring NO_2 concentrations at multiple locations near operating drill rights combined with stack testing and modeling. Data analysis, model evaluation and reporting happened in late 2016. Project website: http://www.wrapair2.org/DrillRig.aspx.

- BLM released a photochemical modeling analysis termed the Colorado Air Resource

Management and Modeling Study (CARMMS) 1.5 in March 2016, with updated Mancos Shale modeling in northwestern New Mexico. The CARMMS predicts impacts from future federal and non-federal energy development in Colorado and parts of New Mexico.

- Western Regional Air Partnership (WRAP) Oil and Gas Phase III inventory for the San Juan Basin was completed in 2009. http://www.wrapair2.org/PhaseIII.aspx . An update to this inventory for the year 2014 was completed in September 2018. The new project also updates the Permian Basin emissions in west TX and southeast NM. The project website is at: http://www.wrapair2.org/SanJuanPermian.aspx.

- NPS and University of Colorado Denver researchers found that lichen species richness has improved at Chaco Culture National Historical Park, Curecanti National Recreation Area, and Black Canyon of the Gunnison National Park while conditions have deteriorated at Nez Perce National Historical Park. The rate of species richness loss attributed to N deposition decreased for 88% of national parks between 2001 and 2016, and yet in 2016 89% of CONUS I&M National Park Service units (149 national parks) remained above the critical load of N for a decline in species richness (CLN-SR) of 3.5 kg-N ha−1 yr−1 . The total forested area in the 168 parks that was in exceedance of the CLN- SR decreased from 2001 to 2016, indicating that the health of forests is improving (McCoy et. al. 2021): https://irma.nps.gov/DataStore/DownloadFile/663435

- The study “Muted Responses to Chronic Experimental Nitrogen Deposition on the Colorado Plateau” found that simulated nitrogen deposition did not affect plant diversity or increase an invasive annual grass (*Bromus tectorum*). More work is needed to determine nitrogen critical load thresholds for plant community and biocrust dynamics in semi-arid systems: https://link.springer.com/article/10.1007/s00442-020-04841-3

- Southern Ute Southern Ute Indian Tribe Air Quality Program operates two State and Local Air Monitoring Stations (SLAMS) and a mobile monitoring station (MMS) within the exterior boundaries of the Reservation. The SLAMS and MMS are configured and operated consistent with EPA requirements and report to the EPA Air Quality Systems and AirNow databases. Real time air quality data, meteorological data and AirNow health forecasts for the Reservation are available for SLAMS on the Tribe’s Website at: https://www.southernutensn.gov/justice-and-regulatory/epd/air-quality/ambient-monitoring/. The Tribe also operates Thermo 55i analyzers at the Ute 3 SLAMS and MMS to measure ambient concentrations of methane and non-methane hydrocarbons.

- UMUT Air Quality Program maintains an air quality station at White Mesa, UT. In the past, total suspended particulate (TSP) monitoring occurred, which was analyzed for radioactive HAPs. A new TSP monitor is currently being installed and monitoring is planned to be resumed.

- USFS New Mexico Kerry Jones (Air & Water Quality Specialist) assisting New Mexico State Climatologist Dave Dubois with some weather/meteorological data and event analysis for an upcoming presentation at the American Meteorological Society’s annual meeting in Denver in January 2023. Review of recent high impact air quality events across New Mexico and thoughts on future partnerships (confex.com)

UTAH DAQ STUDIES

- Emissions of Reactive Organics from Natural Gas-Fueled Engines
    - The Utah Division of Air Quality (UDAQ) funded a Utah State University study to improve estimates of the magnitude and composition of emissions from natural gas-fueled artificial lift ("pumpjack") engines in the Uinta Basin. The study found that inventoried emissions from natural gas-fueled pumpjack engines are too high for oxides of nitrogen (NOx) and too low for organic compounds. Accounting for actual engine emissions would change established emissions inventory values completely. This study provides measurements of the magnitude and composition of emissions from natural gas-fueled pumpjack engines that can be implemented in future photochemical modeling efforts. More information and a final report can be found at: https://deq.utah.gov/air-quality/emissions-of-reactive-organics-from-natural-gas-fueled-engines
- Vertical Ozone Profiles in the Uinta Basin and Validating Drones as an Air Measurement Platform
    - The Utah Division of Air Quality (UDAQ) funded a collaborative University of Utah and Weber State University study to better understand drones as a vertical ozone measurement platform in the Uinta Basin. Ozone sensors were placed on the drone with guidance from a computational fluid dynamics (CFD) model. Drone measurements were validated against balloons launched concurrently with the drones. The study found that drones are easier to deploy than balloon systems, have a more controlled flight path, and provide excellent agreement with balloon borne sondes. The study also suggests that drones are more reliable for vertical ascent but not descent, no matter where the intake part of the ozone sensor is located. It was observed that ozone evolution starts at higher altitudes and progresses downward. Ozone becomes uniformly stratified around midday. However, the evening mixout of ozone was random in altitude and featured strong ozone titration. More information and a final report can be found at: https://deq.utah.gov/air-quality/vertical-ozone-profiles-in-the-uinta-basin-and-validating-drones-as-an-air-measurement-platform
- Composition of Volatile Organic Compound Emissions From Oil and Gas Wells in the Uinta Basin
    - The Utah Division of Air Quality (UDAQ) led a study to improve estimates of the composition of organic compound emissions from Uinta Basin oil and gas wells. As part of the study, Utah State University conducted an extensive sampling campaign at 78 oil and gas wells in which pressurized liquids and raw gas samples were collected from the liquid separator at each facility. These samples were then analyzed to quantify the hydrocarbon species present in each gas sample. Several sample collection and analysis methods were tested to determine best practices when working with Uinta Basin heavy crude. The results included four organic gas profiles describing the composition of: i) flashed gas from oil wells, ii) flashed gas from gas wells, iii) raw gas from oil wells, and iv) raw gas from gas wells. The two remaining profiles describe flashed gas from oil and gas wells including carbonyls. The composition profiles developed in this study will impact photochemical modeling exercises, the triennial oil and gas emissions inventory, and oil and gas permit application processes. More information and a final report can be found at: https://deq.utah.gov/air-quality/composition-of-volatile-organic-compound-emissions-from-oil-and-gas-wells-in-the-uinta-basin

- Improving Volatile Organic Compound Emission Estimates for the Uintah Basin
    - The Utah Division of Air Quality (UDAQ) funded a Utah State University study to further our understanding of the composition of volatile organic compound (VOC) emissions from oil and gas wells in the Uinta Basin. Comparisons of modeled vs. observed VOC and top-down emissions inventory estimates suggest that VOC emissions from oil and gas facilities in the Uinta Basin are probably underestimated. The study found that using VOC compositions and NO/NOx ratios from pumpjack engine measurements had significant impacts on modeled ozone. More information and a final report can be found at: https://deq.utah.gov/air-quality/improving-volatile-organic-compound-emission-estimates-for-the-uintah-basin
- Development of Top-down Hydrocarbon Emission from Oil and Gas Production in the Uintah Basin
    - Utah State University and the University of Utah will use a method known as top-down emission estimation to refine volatile organic compound emissions from oil and gas production based on long-term surface level measurements of methane and hydrocarbons in the Uintah Basin. The objective of this project is to improve the Utah Division of Air Quality (UDAQ) bottom-up Uintah Basin Emission Inventory (UBEI), which is critical information for developing a regulatory model for UDAQ's State Implementation Plan to attain the 8-hour federal ozone standard. This study is ongoing; more information about this study can be found at: https://deq.utah.gov/air-quality/development-of-top-down-hydrocarbon-emission-from-oil-and-gas-production-in-the-uintah-basin
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- Quantitative Attribution of Wildfires on Summertime Ozone Concentrations along the Wasatch Front
    - The Utah Division of Air Quality funded a study led by San Jose State University and the University of Utah to assess the contribution of regional fires and long-range smoke transport to poor air quality in the Salt Lake Valley. For this study, researchers developed the very first coupled fire-atmosphere-chemical transport model to account for all sources of atmospheric pollution including fires, anthropogenic emissions, background sources, and biogenic emissions. The study found that regional smoke events increased ozone across the western U.S. by upwards of 5-30 ppb. Ozone production was found to be sensitive to aerosol radiative feedbacks (e.g. smoke shading) that can inhibit ozone production if there is a sufficient amount of particulate matter in the atmosphere. More information and a final report can be found at: https://deq.utah.gov/air-quality/quantitative-attribution-of-wildfires-on-summertime-ozone-concentrations-along-the-wasatch-front
- Characterizing Air Quality Impacts from Exceptional Events along the Wasatch Front
    - This study, led by researchers at Brigham Young University (BYU), used particulate matter (PM) sampling to identify regional dust sources that impact local air quality and public health, as well as model how dust sources might change in the future. BYU's modeling showed that shrinking the Great Salt Lake (GSL) by 50-60% increased simulated dust concentrations by 15% with peak dust concentrations increasing by 22 ug/m3. Also, the addition of solar farms increased simulated dust by 14%. More information and a final report can be found at: https://deq.utah.gov/air-quality/characterizing-air-quality-impacts-from-

exceptional-events-along-the-wasatch-front