

## **Routes to Sustainability for Natural Gas Development and Water and Air Resources in the Rocky Mountain Region**

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The AirWaterGas project is an NSF Sustainability Research Network (<http://airwatergas.org>) which endeavors to elucidate pathways to preserve air and water quality in the midst of significant natural gas and oil extraction in the Rocky Mountain region. The effort is being led by investigators at the University of Colorado Boulder with academic and national laboratory partners across the state and country. To highlight the breadth of the project, it encompasses the development and implementation of a social-ecological system model, the evaluation of impacts of natural gas development on air and water resources, and the communication of these findings to a wide variety of stakeholders.

Within this context, detailed atmospheric chemical transport modeling for the Rocky Mountain region will be conducted to evaluate health effects of ozone influenced by oil and gas extraction and to forecast the implications for air quality of a range of energy production scenarios in the next two decades (McLeod et al., 2014). The primary endpoints of interest are recent historical and potential future ozone concentrations and their associated health impacts in population centers throughout the Rocky Mountain region.

Specifically, we aim to establish a recent historical episode by running CMAQ for 2011 with revised estimates of the emissions of oil and gas operations for the Rocky Mountain region. We are particularly interested in complementing the sensitivity analysis work undertaken by the Three State Air Quality Study (3SAQS) team by employing the adjoint of CMAQ to evaluate the relative influences of emissions in the region on health impacts in selected population centers. The 2011 Modeling Protocol document available at the Western Air Quality Data Warehouse (WAQDW) has been instructive in the design of the 3SAQS study, and the majority of the input developed for this endeavor seems very appropriate for translating to the CMAQ modeling platform for this episode. We would like to request the opportunity to build upon the extensive work conducted by 3SAQS in establishing revised estimates of anthropogenic emissions in the region and in developing the emissions and meteorological input for the chemical transport modeling framework.

Similarly to 3SAQS, we intend to model the continental US domain at 36-km resolution and subsequently nest to 12-km resolution over the western US and 4-km resolution over the Rocky Mountain region. The WRF runs conducted and evaluated by 3SAQS are ideal meteorological input. If the 3SAQS team has not yet produced emissions for the CMAQ framework, we would be interested in acquiring the SMOKE input files in order to process them for a chemical mechanism available in the CMAQ v.5.0.2 framework (i.e., other than CB6r2). Additionally, if available, we would be interested in acquiring initial and boundary conditions for CMAQ or GEOS-Chem or MOZART data from which boundary conditions could be created. We would also be interested in learning from the methods selected by the 3SAQS team for calculating inline emissions with CMAQ. Finally, if the team has compiled a single database from the many sources of ozone concentrations available for evaluating the model, access to this would expedite comparison of results to those achieved by the 3SAQS team.

After evaluating the 2011 results, we anticipate disseminating data through the WAQDW. Furthermore, as we proceed with projecting energy market allocation modeling results into chemical transport modeling emissions and simulating these future scenarios, we will look forward to sharing those insights as well. This opportunity to build upon work of the states in the Rocky Mountain region to identify pathways to sustainable development of oil and gas operations is unprecedented. As prioritized by the AirWaterGas project, we will aim throughout the process to communicate clearly with the states as key stakeholders in the outcomes.

McLeod, J. D., Brinkman, G. L., & Milford, J. B. (2014). Emissions Implications of Future Natural Gas Production and Use in the U.S. and in the Rocky Mountain Region. *Environmental Science & Technology*. doi:10.1021/es5029537

## Timeline of Executing Modeling Work

<b><i>Time (months)</i></b>	<b><i>Anticipated output</i></b>
Initiation	Receipt of model input data from 3SAQS
3	Translation of emissions input for SMOKE into CMAQ-ready emissions
6	Execution of CMAQ test case (brief episode) with nesting at 12 km and 4 km
12	Evaluation of CMAQ 2011 results at 4 km against CAMx results and monitor data
15	Publication of results of 2011 modeling scenario with comparison and evaluation
21	Link between MARKAL scenarios and CMAQ emissions established
30	Execution of multiple CMAQ scenarios based on McLeod et al. (2014) results
36	Publication of results of scenario-based investigation