The AQUARIUS (Air QUAlity Research In the western US) Workshop

Project Summary

In recent decades, overall particulate matter (PM) concentrations have declined in the U.S. as a result of regulatory policies. However, in several basins in the western U.S., wintertime PM concentrations have not experienced similar levels of improvement. This suggests that current regulatory actions may not be effectively targeting the appropriate precursor emissions and that there is a gap in our understanding of how the unique boundary layer meteorology and complex chemical processes interact to produce these elevated PM conditions. In addition, the PM precursor emissions are co-emitted with greenhouse gases (GHGs) that are of interest to urban policy makers and for which cities have active mitigation plans in place. It is vital to understand how the atmospheric chemistry, boundary layer meteorology, and GHG gas mitigation plans will impact air quality in the future.

This project will support a workshop focused on a future aircraft campaign in the winter of 2021/2022 to investigate wintertime PM in mountain basins of the western U.S. The workshop will be held in Salt Lake City during two days in April 2019. The goals of the workshop will be to identify the current state of knowledge surrounding chemical processes of wintertime PM formation, the meteorological conditions that affect PM formation, distribution and transport, as well as the chemical species such as GHGs that are co-emitted with PM precursor emissions.

Intellectual Merit
This workshop will:

- Identify measurements and the robust critical core airborne capabilities needed to enhance the fundamental understanding of wintertime PM within persistent cold air pools (PCAPs) including the oxidation chemistry, aerosol thermodynamics and interactions between atmospheric chemistry and meteorology within wintertime PCAPs.
- Identify measurements needed to constrain the emission ratios between PM precursors and GHGs across western basins with different levels of urbanization and agriculture.
- Identify emission inventories in need of constraint to improve and evaluate chemical transport models of wintertime PCAPs.
- Organize the community of researchers to develop a plan of action to coordinate efforts to address these needs.

These workshop goals will support development of a campaign centered around the research questions discussed below. After the workshop, the organizing committee will write a white paper outlining the scope and plan for the future aircraft and ground-based field campaign.

Broader Impacts
Understanding the emissions, atmospheric chemistry, and meteorology contributing to persistently elevated wintertime PM will have broad interest for policy makers, stakeholders, and the general public. The knowledge would lead to improved mitigation strategies, improved air quality and reductions in the associated health impacts. Some of these measures could be part of formal “State Implementation Plans” that would help several areas in the western U.S. reach attainment of National Ambient Air Quality Standards. The study will provide decision support to policy makers interested in how GHG emissions and their relationship to local air quality. Finally, the combination of aircraft and ground-based measurements will provide context and interpretability for long-term monitoring networks.

Introduction

This proposal is a request for NSF support for a focused science workshop dedicated to developing a major interdisciplinary aircraft and ground-based field campaign over the western U.S. driven by the need to better understand air quality, meteorology, and urban carbon cycle. The first half of this proposal briefly summarizes the key science motivation for why a study is needed. The second half of this proposal outlines the workshop goals, participants, venue, and organization.

Science Background

Fine particulate matter with aerodynamic diameter less than 2.5 microns ($PM_{2.5}$) is a major, regulated secondary pollutant that is prevalent across the U.S. and the world. Due to reductions in emissions of $PM_{2.5}$ precursors, such as sulfur dioxide, nitrogen oxides and VOCs, $PM_{2.5}$ levels in the U.S. have been decreasing for more than two decades (e.g., [1-3]), leading to improvements in visibility [4] and human health [5]. The 2006 U.S. National Ambient Air Quality Standard (NAAQS) for $PM_{2.5}$ of 35 μg m^{-3} (24-hr average) is now exceeded in a relatively small number of locations. Figure 1 shows that non-attainment areas (NAAs) for $PM_{2.5}$ are concentrated in basins of the western U.S.

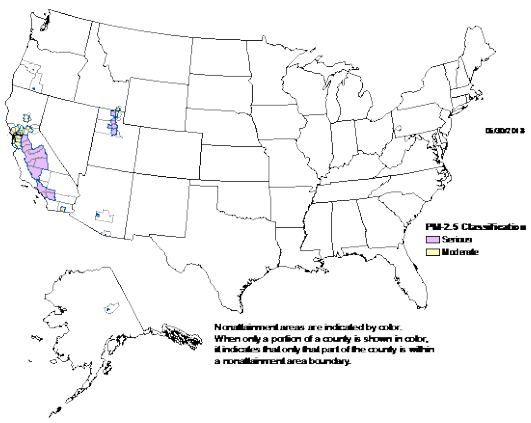

Figure 1. Non-attainment areas for the 2006 $PM_{2.5}$ National Ambient Air Quality Standard (35 μg m^{-3}, 24-hr average). Source: US EPA.

Mountain basins of the western U.S. interact with wintertime meteorology to confine air below the height of the surrounding terrain, events that are termed persistent cold air pools (PCAPS) [6]. These PCAP events lead to accumulation of local and regional emissions and secondary chemistry that transforms these emissions into particulate matter. A recent, NOAA-led study (the 2017 Utah Winter Fine Particulate Study, UWFPS) documented high wintertime particulate matter episodes in the mountain basins of northern Utah using the Twin Otter research aircraft [7]. Prior to UWFPS, multiple ground-based studies in that region had documented the long history of high $PM_{2.5}$ levels in northern Utah [8-14]. The 2013 NASA-led DISCOVER-AQ study used an instrumented P-3 aircraft to investigate the structure and composition of the winter polluted boundary layer in California's San Joaquin Valley (SJV) [8, 15-17]. This study was also preceded by a history of ground-based measurements that established the temporal characteristics and composition of $PM_{2.5}$ in that region (e.g., [18-21]). Although California and Utah stand out on the non-attainment map in Figure 1, they are not unique in being subject to winter air pollution. Basins throughout the western U.S. with larger (e.g., Las Vegas, NV and Phoenix, AZ) and smaller urban centers (e.g., Spokane WA, Boise ID, Missoula MT and Reno NV) are subject to similar phenomena [22]. A major component of aerosol mass in these winter, polluted basins is ammonium nitrate, NH_4NO_3 [7]. Under less polluted conditions, organics are the largest fraction of aerosol mass, but as mass loading increases above 10 μg m^{-3}, ammonium nitrate dominates, reaching 74% of the total under the highest pollution levels in Salt Lake City. Sources of ammonium nitrate, as well as control strategies to best mitigate its formation, are an ongoing area of research [16, 32] for which

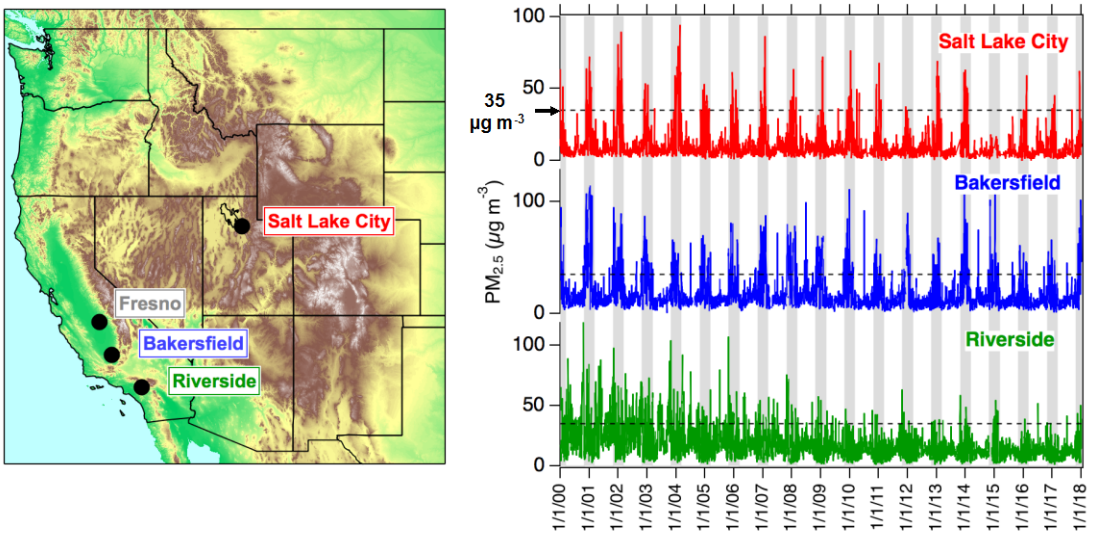

Figure 2. Daily $PM_{2.5}$ mass at Salt Lake City Utah, Bakersfield (California, SJV) and Riverside-Rubidoux (California, South Coast). Grey shading indicates November – February, and dashed line indicates 2006 NAAQS.

further detailed characterization of aerosol composition are required. Studies that also include investigation of boundary layer structure and its interaction with atmospheric chemistry are also essential (e.g.[15, 33]). Figure 2 shows a long-term record of $PM_{2.5}$ at two sites in California, one in the SJV (Bakersfield) the South Coast basin (Riverside-Rubidoux), as well as the Hawthorne monitoring site in Salt Lake City. The seasonal pattern in the SJV is apparent and is shown for two different intervals in Figure 3 for Bakersfield. The decreasing trend in $PM_{2.5}$ mass in the South Coast basin is apparent from Figure 2, in contrast to the SJV sites, whose trends are also decreasing in average mass but are less visually apparent. The right panel of Figure 3 shows that the seasonal pattern at Riverside has shifted from one that is relatively invariant with time of year to one that has higher average mass loadings during winter. Thus, the South Coast Air Basin would also be a target for aircraft investigations as part of a broader western U.S. initiative.

The interactions between atmospheric chemistry and complex boundary-layer meteorology during wintertime PCAPS have not been extensively studied within urban basins across the western U.S., and many scientific questions remain unanswered. Previous large meteorological boundary-layer field studies during PCAPS (e.g., The Persistent Cold-Air Pool Study 2011, Lareau et al. 2013) were missing key atmospheric chemistry components, whereas many large atmospheric chemistry studies only involved limited meteorological observations (e.g., Uintah Basin Wintertime Ozone Study, Utah Wintertime Fine Particulate Study). Furthermore, the precursor emissions that contribute to wintertime PM also co-emit greenhouse gases such as CO_2 and CH_4. Since many cities currently have climate action plans in place and are actively

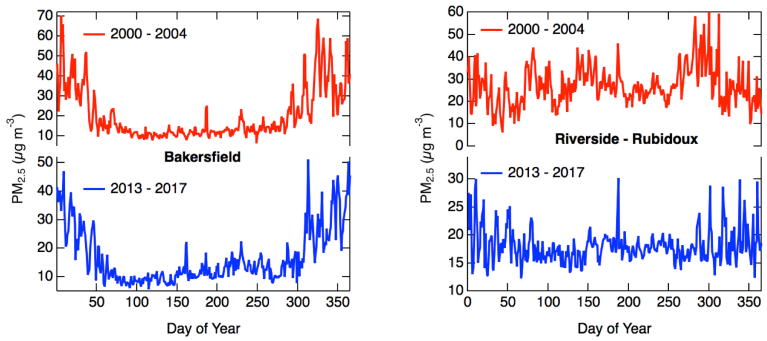

Figure 3. Seasonally averaged $PM_{2.5}$ for 2000-2004 (upper, red) and 2013-2017 (lower, blue) for Bakersfield (SJV, left) and Riverside-Rubidoux (right).

engaged in reducing greenhouse gas emissions, the relationships between PM precursor emissions and greenhouse gases are important to understand so that policymakers understand how air quality will change in the future given currently planned actions. A key objective of this workshop will be to bring together research leaders and young scientists in boundary-layer meteorology, atmospheric chemistry, and urban carbon cycle communities to develop joint and complementary science objectives for a large campaign in the western U.S.

Workshop Topics and Goals

We propose a 2-day workshop to plan interdisciplinary science goals toward a joint NSF- and NOAA-supported field study involving both aircraft and ground-based sampling to investigate wintertime PM in mountain basins of the western U.S. in the winter of 2021-2022. The specific goals of the workshop would be to identify the science objectives and develop the research plans to address the following questions:

- How do agricultural emissions impact wintertime air quality in basins with varying levels of agriculture and urbanization?
- How does biomass burning associated with residential wood combustion affect wintertime air quality?
- What is the role of volatile chemical products and VOCs on wintertime air quality?
- What data streams and parameterizations are needed to improve and validate models of wintertime persistent cold air pools (PCAPs)?
- How do inter-basin transport and vertical stratification of PCAPs impact the spatial distribution and atmospheric chemical processes?
- What are the emission ratios between PM precursors and GHGs?
- How will current and future GHG mitigation actions affect wintertime air quality?

Recent Meetings

While a number of recent meetings have been conducted on cold-season air quality, none of these meetings have addressed the key scientific issues to be addressed at this meeting. The ALPACA workshop (May 2018, Fairbanks, AK) addressed a different set of meteorological (extreme Arctic boundary-layers which are much colder and shallower) and air quality (primarily wood smoke emissions) science topics. The recent CO_2-USA workshop (October 2018, Salt Lake City, UT) focused on urban carbon cycle science but did not have an extensive discussion of air quality. A data meeting following the completion of the UWFPS study (August 2017, Salt Lake City, UT) facilitated the white paper summary of the study but did not address the next steps needed. Data meetings (Seattle, 2015) and special sessions at the AGU meeting (San Francisco 2015, New Orleans 2017) for the WINTER 2015 campaign explored process level chemistry relevant to the winter season, but did not explore western U.S. $PM_{2.5}$. Finally, the Air Quality Science for Solutions meeting (March 2018, Ogden, UT) is an annual meeting in Utah presenting research on air quality research topics being investigated by investigators only within the state.

Workshop Organizing Committee

The organizing committee from the University of Utah will be Gannet Hallar, John Lin, Logan Mitchell, and Erik Crosman. In addition, Steve Brown (NOAA) and Chris Cappa (UC-Davis) will also be on the organizing committee.

The organizers of this workshop (including representatives from U. of Utah, NOAA CSD, and University of California, Davis) have existing relationships with both the California Air

Resources Board (CARB) and the Utah Division of Air Quality (UDAQ) to facilitate studies in California and Utah. The state of Utah has recently allocated funds for future air quality research projects and the organizers are actively engaged in advising UDAQ on the best use of these funds. A western winter $PM_{2.5}$ study would assist both states with the development of State Implementation Plans (SIPs) to meet National Ambient Air Quality Standards (NAAQS) in the future.

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