

Temporal and Spatial Measurements of Surface-to-Boundary Layer Ozone using Uncrewed Aerial Systems (UAS)

Dr. Randy Martin (PI), (435) 797-1585, randy.martin@usu.edu

Dr. Cal Coopmans (Co-PI), (435) 797- 8340, cal.coopmans@usu.edu

Utah Water Research Laboratory

Utah State University

1600 Canyon Road

Logan, UT 84321

USU/UWRL Sponsored Programs officer:

Ms. Norma (Nan) Buxton, Grant and Contract Officer

1415 Old Main Hill

MAIN 64

Logan, UT 84322-0001

(435) 797-1659

nan.buxton@usu.edu

Requested Budget: \$99,586.23

(M.S. graduate student to be supported via separate UWRL funding; \$34,038.58)

Project Period: July 1, 2024 – June 30, 2025

SCOPE OF WORK

Abstract

The work proposed herein would produce surface to 700-1000 ft agl pollutant concentration, primarily O₃ and select meteorological parameters, “curtains” up to 4 km in horizontal length using AggieAir’s arial drone platforms coupled with 2B Technologies Portable Ozone Monitors (POMs) and other appropriate sensors. This work will dovetail into the spatial void between USOS’s planned ground and aloft measurements. The field measurements will be conducted in areas around and over the Great Salt Lake, at sites to be discussed and finalized with UDAQ and NOAA personnel. As much as possible flights will be coordinated in time with NOAA’s Twin Otter flights as part of the 2024 Utah Summer Ozone Study (USOS). We propose to fly 3-4 flights daily spaced throughout the target days, approximately once per week during the USOS campaign. Besides key support to USOS, the drone flights will help directly address the RFP’s Goals and Priorities of (1f.) Measurements of O₃ and its Precursors, as well provide information on (3a.) Vertical Oxidant Exchange (profiles). The PIs involved in this project have experience in similar air-borne vertical and horizontal O₃, meteorological, and PM determinations using in-house modified sensors (e.g. 2B’s Model 205 O₃ monitor and Plantower 5003 sensors) mounted into both drone and tethered balloon systems.

Basis and Rationale

The primary focus of the work proposed herein is to compliment the planned NOAA campaign targeting the understanding of the multifaceted urban air composition and behavior along the Wasatch Front. Specific to the Science for Solutions FY 2025 RFP, this proposal will address sections of Goals and Priority #1: Summertime Ozone Chemistry and Sources, subpart (f.) Measurements of “background” ozone (O₃) and ozone precursors. The vertical and horizontal O₃ data collected data from this proposed project would also give insight into Priority 3a: Meteorology-Chemistry Coupling: Vertical oxidants exchange. As described in the draft plan for the 2024 Utah Summertime Ozone Study (USOS), the NOAA-led Utah Summer Ozone Study (USOS) aims to address complexities of ozone behavior along Utah’s Wasatch Front. Numerous

methodologies are planned to assess the spatial and temporal pollutant behaviors at ground-level (stationary and mobile) and aloft; with the latter being accomplished via NOAA's Twin Otter platform equipped with a suite of in-situ chemical and meteorological packages. However, a potentially critical region absent from the campaign's characterization plan is the region between ground-level and the allowable lower ceiling of the NOAA Twin Otter aircraft platform (approx. 1000 ft AGL). We propose to temporally and spatially characterize this intermediate region as close as possible to parallel in time with the larger project flights using uncrewed aerial systems (UAS) and portable ozone and meteorological monitoring systems.

Technical Approach

We propose to measure and analyze vertically stair-stepped, horizontal transects, or O₃ "curtains", essentially 2-D contour maps, at select locations near the Great Salt Lake as close to the same time periods as the USOS campaign from the near surface up to 1000 ft (305 m) AGL with a horizontal component out to as far as 4 km. We will use AggieAir (uwrl.usu.edu/aggieair/), a USU-affiliated UAS service center, to provide the air-borne platform, coordinate with the Federal Aviation Administration (FAA), and perform the selected flights.

The recommended system is AggieAir's new GreatBlue hybrid Vertical Take Off and Landing (VTOL)/Fixed Winged UAS (Figure 1).

The system is capable of remaining air-borne for up to one hour, has a payload capacity of up to five (5) kilograms, with a native velocity of 50 mph (22.4 m/s). The imaging systems typically carried in the payload bay will be removed and



Figure 1. AggieAir's Great Blue UAS

replaced with a pair of 2B Technologies Personal Ozone Monitors (POMs) – each weighing approximately 0.5 kg (see Figure 2). With the platform flying at 50 mph and the POMs minimum data acquisition of two seconds, the O₃ data collection will represent a concentration integrated over approximately 45 m. Further, although the dual POMs will each be individually calibrated, the proposed dual system is planned for redundancy. The Co-PIs, along with other USU personal, have successfully used a similar approach previously over land and water off of the Great Salt Lake's (GSL) north arm's Promontory Point (see Figure 3) and in the oil and gas fields of Utah's Uinta Basin.



Figure 2. 2B Technologies Personal Ozone Monitor (POM)

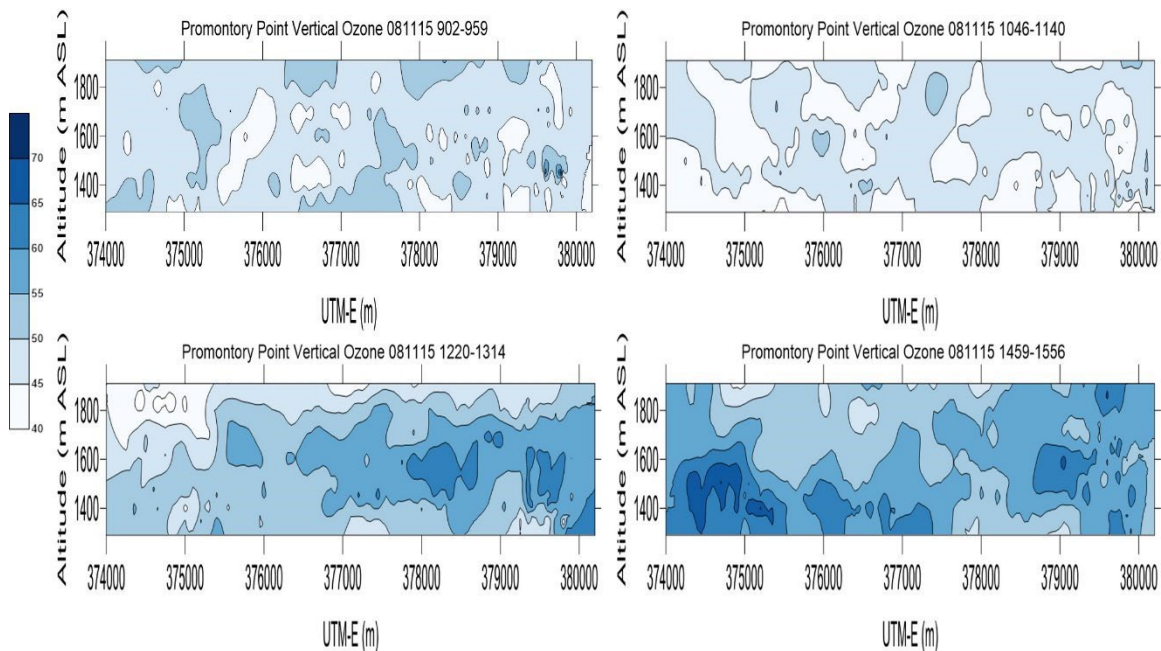


Figure 3. O₃ “curtains” (ppb) extending WSW from GSL’s Promontory Point in Aug. 2015. As can be seen, morning O₃ concentrations were 40-50 ppb and indistinct. As the day progressed, the overall O₃ increased and seemed to push in from the east (Wasatch Front). This was also supported by predominant easterly wind patterns throughout the day and throughout the air column. Further, the late afternoon flight showed increased O₃ at lower elevations over the GSL’s open water.

This light, dual POMs payload leaves room for possible inclusion of other instrumentation if geometric size and weight requirements can be met. Additionally, as we will likely still have available payload capacity in the AggieAir Great Blue, we plan to research integrating available light-weight, low-cost NO_x and total VOC sensors such as those indicated with moderate reliability via California's South Coast Air Quality Management District's Air Quality Sensor Performance Evaluation Center (AQ-SPEC; <https://www.aqmd.gov/aq-spec/home>). The PIs realize, that unlike the 2B POM units, these secondary sensors are not of EPA-Equivalent status; however, with proper calibration and understanding they can at least give relative concentration information. A portable meteorological sensor/datalogger, such as Kestrel's DROP D3 system will also be included as part of the payload package. The investigators have found the D3's to give acceptably fast and accurate temperature, relative humidity, and barometric pressure data to adequately map the vertical and horizontal profiles of these parameters. This would give added insight into the thermal stratification and mixing parameters of the observed air masses.

As indicated above, we propose to characterize O₃ curtains and supporting parameters ideally once per week, as close as possible in time with the NOAA flights, across the five-week study, with three-to-four flights each test day to capture diurnal behaviors. At present, we plan to characterize the atmospheric concentrations shortly after sunrise to capture the profiles before significant photochemistry and transport, followed by roughly flights equi-spaced in time, until the final flight shortly before sunset. It is anticipated that more than one location could be examined; the final locations will be determined after wider discussions with Division of Air Quality personnel and other USOS investigators. Of course, due to possible areas of flight restrictions, perfect geographical overlap may not be possible. Potential flight locations, include the GSL south shore, Badger Island, Stansbury Island, Antelope Island, Farmington Bay, SLC Foothills, and/or Jordan Narrows. Although obtaining FAA Certificate of Authorizations (COAs) in such areas can be problematic, AggieAir has historically obtained such COAs and conducted flights in similar areas, including multiple locations in California's air-traffic heavy San Joaquin Valley, and owing to another project, currently holds an open COA for the entire

33-mile (53.1 km) length, ± 2.5 mile (4.0 km) width, along the railroad causeway separating the north and south arms of the GSL.

Given consideration to short-timing funding windows (discussed below under “Schedule”), in early December 2023, the PIs and the AggieAir team preemptively sought FAA approval for a COA encompassing assumed UAS flight paths. FAA COA #2023-WSA-13496-COA was granted, valid through Dec. 7, 2025 to fly AggieAir’s unmanned aircraft system within the operational areas shown in Figure 3. Following the approved COA, Ops Area A has an approved flight ceiling of 700 feet above ground level (AGL), with the exception of the Ogden Class E area where the ceiling is 400 ft AGL, and Ops Area B has an approved flight ceiling of 1000 ft AGL. These potential flight areas, along with the previously mention railroad causeway window, would give the researchers ample opportunity for unique atmospheric vertical and horizontal ozone characterizations.

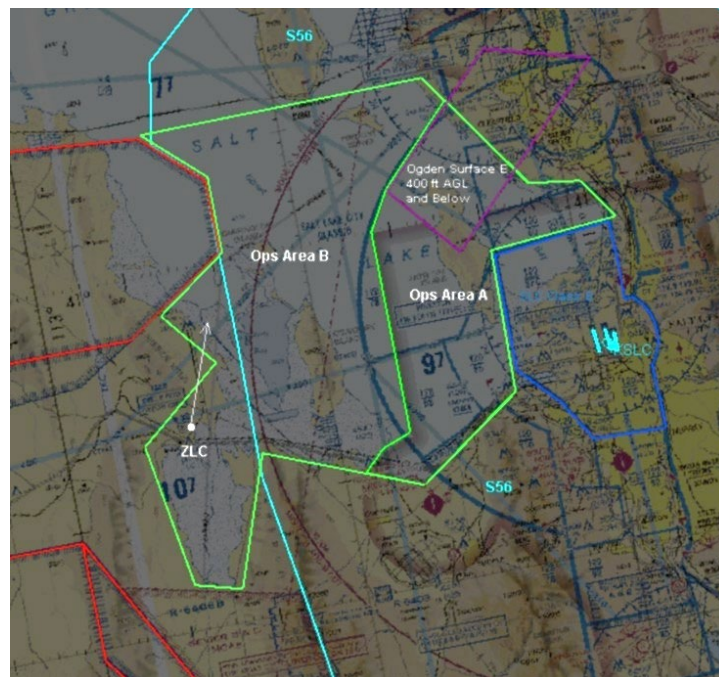


Figure 3. AggieAir’s approved COA for the GSL area.

As an added benefit to this proposed work, USU/UWRL colleagues of the proposal PI’s, Drs. Sierra Young and Alfonso Torres-Rua, have been award a UWRL-internal grant “Drone

meteorology: Developing accurate, mobile environmental sensors to accelerate information gain from remote sensing”. In short, the project will integrate a hex-prop drone platform with fast response ($< 1s$) meteorological technology including temperature, relative humidity, barometric pressure, 3-D wind speed and direction. The goal of this secondary project is to develop a system not only to characterize the thermal/moisture structure of the atmosphere, but also microclimate movement within the local air masses. Successful develop of such a system could lead to new techniques for local measurement of important environmental parameters such as surface/vegetation evapotranspiration, pollutant surface fluxes and/or deposition. The system is currently in development and is scheduled to be ready for flights in summer 2024. Although not guaranteed, recent personal conversations with these additional PIs, suggest it will likely be possible to test this new drone-based system in parallel with the AggieAir Great Blue flights proposed herein, thereby providing point validation data for both projects.

Expected Outputs and Outcomes

Successful completion of the proposed work will result in numerical and graphical maps of the distribution of ozone and select meteorological parameters from the ground surface up to 1000 feet agl (above ground level). The specific geographical locations will be finalized after discussions with UDAQ and NOAA personnel, and will fill in the spatial niche between mobile and stationary surface measurements and NOAA Twin Otter aircraft measurement. Aside from the required UDAQ quarterly and final reports and Science for Solution conference presentation, the data from the project will be used as an Environmental Engineering Master’s thesis project and is anticipated to be submitted to a peer-reviewed journal (e.g. JAWMA, ES&T, Environment, etc.) and likely presentation at broader conferences.

Deliverables

As per Section D, Awardee Requirements, the specific products deliverable to UDAQ will include the following:

- *Quarterly Reports.* Quarterly reports will be delivered on the schedule and the formatted template to be specified by UDAQ upon awarding of the grant or as included in the RFP packet.
- *Final Report.* As required, a draft final report will be submitted to UDAQ no later than Sept. 28, 2025 or 90 days after the end of the grant period. After draft submission, UDAQ will have up to one month to submit reviewed comments to the investigators, who will, in turn, address those comments within one additional month, followed by a final submission.
- *Conference Presentation.* As an original and continuing member of the S4S steering committee, I can assure UDAQ a poster or platform presentation will be delivered at the appropriate annual meeting, most likely the Spring 2025 meeting. Additionally, owing to the proposals cooperative nature with NOAA's USOS program, it is anticipated that the results would be shared at a broader meeting such as those of the American Geophysical Union (AGU) or the Association of Air and Waste Management (AWMA).
- *Data Sharing.* During the study, tabulated data in the form of Excel spreadsheets, including all flight profile information (date/time, longitude, latitude, elevation) and collocated pollutant concentrations (O₃ in ppb, other resultant compounds) and meteorological parameters (temperature, relative humidity, barometric pressure) will be supported as part of Utah State University Box cloud storage system. Generated figures and graphs, along with project photographs will also be include in the cloud storage. The PIs, USU/UWRL AggieAir technicians, USU graduate and undergraduate students, and appropriate UDAQ personnel will be given access to the Box project folders. Additionally, as the proposed work is to be conduct in support of the NOAA USOS, the PIs will work with NOAA personnel to make the data available to the NOAA database in the appropriate format (e.g., <https://www-air.larc.nasa.gov/missions/etc/lcarttDataFormat.html>). Finally, as suggested in the UDAQ RFP, within eight months of the project completion, if not before, the complete dataset will also be made available to UDAQ for publication on its website.
- *Additional Deliverables.* None applicable.

Schedule

The specified timing of the awarding of the funds (July 1, 2024) and the planned implementation of the NOAA study (July 15 - August 18, 2024) makes timely implementation of the field activities somewhat problematic. However, we propose to focus our flight activities on the final 2-3 weeks of the NOAA test period, depending on the actual NOAA flight plans. Instrument preparation and calibration is expected to only require a few weeks advanced notice, with the most time-sensitive concern really being advanced notice for scheduling of the AggieAir UAS platform and personnel. Although the actual funding availability date seemingly provides a tight window, historically USU PIs have been able to initiate pre-spending date activities as long as the contracts are authorized and both parties, USU's Sponsored Programs Office (SPO) and the funding agency (UDAQ), are in signed agreement.

Data compilation and analysis will continue through Fall 2024 and Spring 2025. During Spring 2025 the final report will be completed and the thesis and to-be-published manuscript will also be processed, although these components may extend beyond the proposed project completion date.

BUDGET

The total, 1-yr, UDAQ-requested funds, \$99,586.23, are shown in the table below. As shown, the requested funds are nearly equally split between personnel and supplies/services costs. As stated in the RFP, matching or in-kind funds are not required; however, Dr. David Tarboton, the Director of the Utah Water Research Laboratory (UWRL), has committed to up to two years of support for an Environmental Engineering M.S. graduate student, if the project is awarded. These additional funds equate to an annual contribution of \$34,038.58, approximately 34% of the requested UDAQ funds. The total project costs, including the request UDAQ and committed UWRL contributions total \$133,642.81.

	Effort	Requested UDAQ Funds	UWRL Funds
PERSONNEL			
Dr. Randy Martin	0.75 mo	\$8,647.44	
Dr. Cal Coopmans	0.5 mo	\$5,816.57	
Ian Going	1 mo	\$8,710.26	
UAS Pilots	48 hrs	\$772.10	
UG students	1080 hrs	\$16,205.28	
MS graduate student			\$26,660.00
FRINGE BENEFITS		\$11,307.25	\$713.16
USU Fees & Insurance			\$3,571.00
SUPPLIES			
Misc. Expendables		\$5,000.00	
UWRL Env. Quality Lab Fee		\$5,039.95	
AggieAir Flight Charges		\$14,170.68	
AggieAir Equipment Usage		\$12,060.80	
TRAVEL			
6 RTs to SLC, 2 vehicles		\$2,880.00	
TOTAL DIRECT COSTS		\$90,532.93	\$30,944.16
TOTAL INDIRECT (10%)		\$9,053.30	\$3,094.42
TOTAL PROJECT COSTS		\$99,586.23	\$34,038.58
COMBINED UDAQ & UWRL FUNDS		\$133,642.81	

PERSONNEL ROLES AND RESPONSIBILITIES

The project will be managed by Dr. Randy Martin, Associate Research Professor and Environmental Engineering Program Head. Dr. Martin will be in charge of guiding the research and ensuring that all deadlines and deliverables are met. Dr. Calvin Coopmans, Assistant Research Professor in USU's Department of Electrical & Computer Engineering and Director of AggieAir Services will handle coordination of the overall UAS logistics. Additionally, Dr. Coopmans will help electronically integrate the meteorological and pollutant measurement instrument with the UAS's on-board avionics to provide system-wide data collection coordination. Mr. Ian Going, Research Engineer III and the AggieAir Service Center Manager, will function as the lead in actual flight preparation and coordination both at UWRL (USU's Utah Water Research Laboratory) and in the field. One each flight day, an FAA Part 107-certified pilot from AggieAir will perform the actual flight duties.

As discussed under the budget section, the proposed project will also be managed as an M.S.-level research project. However, in order to optimize project budget, no requested monies are directly budgeted for this student support. Rather all M.S. stipends, tuition and other fees have been secured as voluntary matching through the Utah Water Research Laboratory. This expected 1-year contribution totals \$34,038.58. Finally, some project funds have been budgeted to include up to 1080 hours of undergraduate support. Besides the needed hands-on help in the lab and field, the project will give students in the Departments of Civil and Environmental Engineering and/or Electrical and Computer Engineering the opportunity to participate in a relevant and cutting-edge campaign, as well allowing exposure to the wider investigators of the USOS program.