Quality Assurance Project Plan

Project 14-006
Characterization of Boundary-Layer Meteorology During DISCOVER-AQ Using Radar Wind Profiler and Balloon Sounding Measurements

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Summary of Project

QAPP Category Number: III
Type of Project: Meteorological Research

QAPP Requirements: This QAPP includes descriptions of the project and objectives; organization and responsibilities; data analysis approach, data interpretation, and management; reporting; and references.

QAPP Requirements:
Audits of Data Quality: 10% Required
Report of QA Findings: Required in final report

May 29, 2014

Distribution List

David Westenbarger – TCEQ Project Liaison

Gary McGaughey – AQRP Project Manager, University of Texas

Clinton MacDonald – Principal Investigator, Sonoma Technology, Inc.

Gary Morris – Co-Principal Investigator, Valparaiso University

Approvals

QAPP was approved electronically on April 24, 2014 by Gary McGaughey, The University of Texas at Austin.________________________________

Gary McGaughey, Project Manager, Texas Air Quality Research Program

QAPP was approved electronically on April 23, 2014 by Cyril Durrenberger, The University of Texas at Austin.

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Cyril Durrenberger, Quality Assurance Project Plan Officer, Texas Air Quality Research Program

QAPP was approved electronically on April 22, 2014, by Clinton MacDonald, Sonoma Technology, Inc.

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Clinton MacDonald, Principal Investigator

1. Project Description and Objectives

1.1 Describe the process and/or environmental system to be evaluated.

Boundary-layer meteorological processes have a strong impact on the spatial and temporal characteristics of air quality in and around the greater Houston area. To provide data to help characterize these processes during the DISCOVER-AQ project, radar wind profilers (RWPs) were operated at seven sites. The radar wind profilers provided hourly vertical profiles of winds and reflectivity data that can be used to identify mixing heights. In addition, daily meteorological and ozone soundings were taken at several sites on most days during the study.

1.2 State the purpose of the project and list specific project objectives.

The primary goal of this project is to use the RWP measurements and balloon soundings to characterize the atmospheric boundary layer (ABL) processes that were occurring during DISCOVER-AQ. The study will focus on vertical and spatial structure of aloft winds, transport patterns, the diurnal and spatial characteristics of daytime mixing heights, the influence of large-scale meteorological conditions on these characteristics, and the influence of ABL meteorology on the general air quality in the greater Houston area. A second goal is to provide context to the DISCOVER-AQ boundary layer characteristics by comparing them to characteristics (1) observed on days of high ozone concentrations during the Texas Air Quality Study II (TexAQS-II) and (2) observ over the past 10 years (specifically in regard to the vertical ozone structure and general meteorological conditions). A third goal is to provide a data set of ABL measurement results for use by other researchers. Details on the data analysis and subtasks needed to achieve these three goals are shown in Section 5.3.

2. Organization and Responsibilities

2.1 Identify all project personnel, including QA, and related responsibilities for each participating organization, as well as their relation to other project participants.

This project will be conducted collaboratively by Sonoma Technology, Inc. (STI) and Gary Morris from Valparaiso University (VU). Clinton MacDonald from STI and Gary Morris from VU will serve as Principal Investigators. The personnel working on this project and their specific responsibilities are listed in **Table 1**.

Table 1. Project participants and responsibilities.

Participant	Project Responsibility
Clinton MacDonald (STI)	Principal Investigator. Oversee and perform quality assurance review for analysis and reporting tasks assigned to STI.
Gary Morris (VU)	Principal Investigator. Oversee and perform quality assurance review for analysis and reporting tasks assigned to VU.
Daniel Alrick (STI)	Project Manager. Oversee day-to-day project activities, communicate with staff at VU and TCEQ, and perform data analysis and reporting tasks.
Charley Knoderer (STI)	Perform data analysis and reporting tasks.
Natalie LaGuardia (STI)	Perform data analysis and reporting tasks.
Undergraduate student(s) (VU)	Perform data analysis tasks.
Publications department (STI)	Technical editing and quality assurance of reporting tasks.

2.2 Project schedule with key milestones.

The key milestones associated with this project are summarized in **Table 2**. More specific information regarding the project tasks can be found in the project Work Plan. The project schedule assumes a contract start date of May 1, 2014.

Table 2. Summary of project schedule and milestones.

Milestone or Deliverable	Party Responsible	Completion Date
Work Plan, budget justification, and QAPP; finalize with revisions from TCEQ	STI and VU	April 30, 2014
Contract start date	—	May 1, 2014
Analysis for Task 1: Characterizing the atmospheric boundary layer	STI and VU	June 30, 2014
Analysis for Task 2: Determine representativeness of meteorological conditions	STI and VU	June 30, 2014
Analysis for Task 3: Derive continuous mixing heights	STI	June 30, 2014
Monthly technical reports	STI	8th day of each month
Monthly financial reports	STI	12th day of each month
Quarterly reports	STI and VU	Last day of each quarter
Draft final report	STI and VU	July 31, 2014
Final report	STI and VU	August 31, 2014
End-of-project presentation	STI and VU	June 2015

3. Scientific Approach

3.1 Identify the secondary data needed to meet the project objective(s). Specify requirements relating to the type of data, the age of data, geographical representation, temporal representation, and technological representation, if applicable.

Two main data sets will be used for this project: (1) Boundary layer wind data from seven RWPs, and (2) meteorological and ozone data from soundings.

The RWP data are available from August 22, 2013, through October 22, 2013. The RWPs are listed in **Table 3** and their locations are shown in **Figure 1**. The 915 MHz RWPs collected continuous (hourly) vertical profiles of boundary layer winds from about 100 m above ground level (agl) to 3,500 m agl. The RWP backscatter data can be used to estimate continuous (hourly or sub-hourly) daytime boundary layer heights up to 3,500 m above ground level. The three-dimensional meteorological velocity components (u, v, w) and wind speed and direction can be calculated using appropriate trigonometry. For each hourly average, a minimum of 60% of the data collected during the hour must fall within a 3.0 m/s consensus window to be included in the hourly average. Consensus windows are determined for each velocity component.

Table 3. Radar wind profilers in the Houston area and their operator(s).

Radar Wind Profiler	Operator(s)
Smith Point	STI
College Station	STI/NOAA
Round Top	STI/NOAA
Wharton	STI/NOAA
Houston Coastal Center	University of Houston
LaPorte	TCEQ
Beaumont	TCEQ

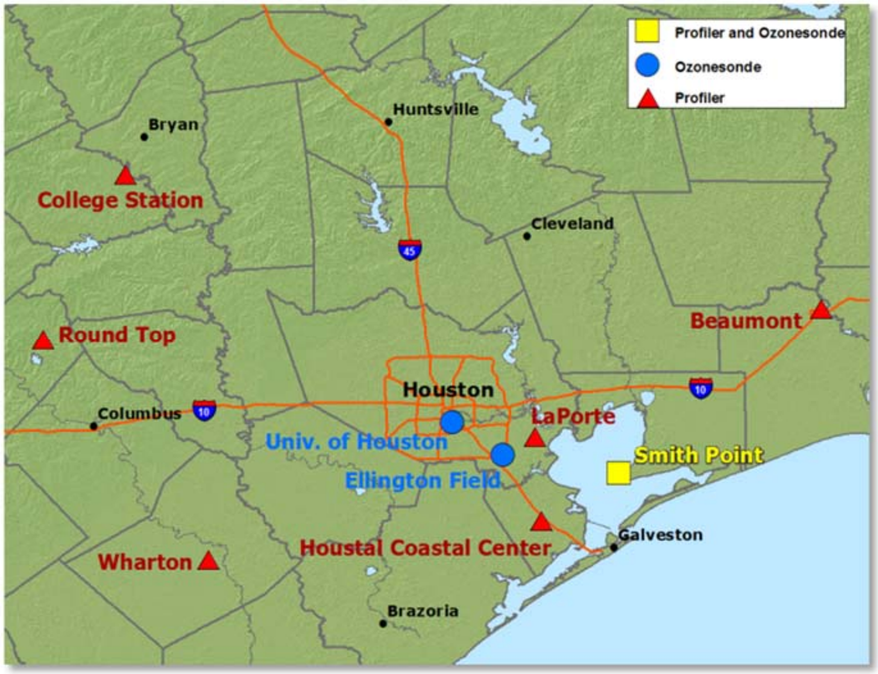

Figure 1. Locations of upper-air sites that we will use to characterize ABL processes

Balloon sounding data are available for almost all days during the DISCOVER-AQ project. The balloon sounding system consisted of the Electrochemical Concentration Cell (ECC) type En-Sci 2Z ozonesonde instruments (Komhyr, 1969) with 0.5% buffered KI cathode solutions (prepared by B. Johnson, NOAA Climate Monitoring and Diagnostics Laboratory), as recommended by the Jülich Ozone Sonde Intercomparison Experiment (JOSIE) (Smit et al., 2007). Meteorological measurements are provided by the InterMet system. On-board global positioning systems (GPS) provided latitude, longitude, altitude, wind speed, and wind direction data. The effective vertical resolution of ozone features is about 125 m. All data were processed with Holger Voemel's STRATO software or NOAA's SkySonde software, and data for all nominal flights are posted on the project website (physics.valpo.edu/ozone).

3.2 Identify the source(s) for the secondary data. Discuss the rationale for selecting the source(s) identified. If a hierarchy of sources exists for the gathering of secondary data, specify that hierarchy.

As part of the DISCOVER-AQ project, STI and National Oceanic and Atmospheric Administration (NOAA), with support from the University of Texas at Austin, operated RWPs at four sites in the greater Houston area to collect boundary layer wind data (Table 3). In addition, a permanent network of three RWPs also provided data during that study. Pennsylvania State University (Smith Point), NASA/USRA (Ellington Field), and the University of Houston/Valparaiso University partnership (University of Houston) conducted daily meteorological and ozone soundings on most days during DISCOVER-AQ. Gary Morris and student(s) at Valparaiso University will provide and analyze the ozonesonde data for this study.

In addition to the usefulness of these data for the boundary layer characterization analysis, these data sets were also selected because the data have already undergone a high level of quality control and because of STI's and VU's considerable experience with these data sets.

4. Quality Metrics

4.1 Specify the quality requirements of the secondary data. These requirements must be appropriate for the intended use of the data. Address accuracy, precision, representativeness, completeness, and comparability, if applicable.

Quality requirements for this project are standard for a meteorological and air quality analysis project. The ozonesonde and RWP data sets already underwent quality control and assessment as part of previous projects; documented in a data report (Knoderer and MacDonald, 2013). The ozonesonde data were collected by Valparaiso University, and the University of Houston under AQRP project number 13-016. The Smith Point and Ellington Field data were collected by Pennsylvania State University and NASA/USRA respectively and followed the same protocols as the AQRP-funded sites. Quality control requirements for the ozonesonde data can be found in that project's QAPP.[1]

4.2 Describe the procedures for determining the quality of the secondary data.

As mentioned in Section 4.1, the ozonesonde and RWP data have already undergone quality control and assessment. Please refer to the QAPP from AQRP project 13-016 for more information on the quality control measures used on the ozonesonde data. An RWP, like all radar, is sensitive to reflections from other targets and to electromagnetic radiation from sources other than the atmosphere. For instance, aircraft, birds, or insects may generate spurious radar echoes that can be mistaken for an atmospheric return. Migrating birds are a well-documented source of wind measurement errors, especially in Texas. For DISCOVER-AQ, the RWPs produced data with good height and time coverage (Knoderer and MacDonald, 2013); thus, those data will be very useful for characterizing wind patterns within the ABL. During data quality control performed under a separate contract, STI staff removed spurious data values due to bird interference, which primarily occurred at night. At the Wharton Airport RWP site, a nearby rotating radar caused interference of the RWP at night; under these circumstances, these data values were removed from the data set.

During this project, analysts will be monitoring the ozonesonde and RWP data sets for outliers or other abnormalities. The Radio Acoustic Sounding System (RASS) and backscatter data from the RWPs were already quality controlled under a separate, previous contract. As part of that quality control, the data were compared to data from nearby sites and to external data sources. Should any outliers or abnormalities be found during the current analysis, our analysts will assess the data and determine whether the data are accurate or inaccurate. Data accuracy will be assessed primarily through comparison of time-series plots at all monitoring sites, comparison to external data sources, and comparison to the conceptual understanding of

[1] http://aqrp.ceer.utexas.edu/projectinfoFY12_13%5C13-016%5C13-016%20QAPP.pdf

surface and aloft weather patterns. The data, quality control procedures, data analysis methods, and analysis results will be reviewed by an STI senior scientist who was not directly involved in the data analysis.

4.3 If no project-specific data quality requirements exist, state this in the QAPP. If the quality of the secondary data will not be evaluated by EPA, require that a disclaimer be added to any project deliverable to indicate that the quality of the secondary data has not been evaluated by EPA for this specific application. Provide the wording for the disclaimer.

Not applicable.

5. Data Analysis, Interpretation, and Management

5.1 Identify the data reporting requirements, including data reduction procedures specific to the project and applicable calculations and equations.

The ozonesonde data were collected by Valparaiso University and the University of Houston under AQRP project number 13-016. Data reporting requirements for the ozonesonde data can be found in that project's QAPP. Quality controlled ASCII text formatted data files with all ascending flight data for each ozonesonde launch during the DISCOVER-AQ period are provided.

The data reporting from this project will include (1) a discussion of meteorological conditions and interrelation among meteorological conditions and air quality on specific DISCOVER-AQ study days, (2) a comparison of the boundary layer characteristics noted during the DISCOVER-AQ study days to boundary layer characteristics observed on days with high ozone concentrations during the TexAQS-II project and more generally to boundary layer characteristics observed in September over the past 10 years, and (3) numerical estimates of hourly daytime mixing heights for all seven RWP sites and non-continuous mixing heights using the balloon sounding data from three sites over the entire DISCOVER-AQ period. The numerical estimates of daytime mixing heights will be provided in an Excel file. Time series plots of the hourly mixing height estimates will also be provided.

5.2 Describe data validation procedures used to ensure the reporting of accurate project data.

As mentioned in Section 4.1, the ozonesonde and RWP data have already undergone quality control and assessment. Please refer to the QAPP from AQRP project 13-016 for more information on the quality control measures used on the ozonesonde data. QC procedures for the RWP data are described in Knoderer and MacDonald (2013). During this project, analysts will be monitoring the ozonesonde and RWP data sets for outliers or other abnormalities. Should any outliers or abnormalities be identified in either the secondary data or from our analysis of the secondary data, we will assess the data and determine whether the data are accurate or inaccurate. Comparisons of spatial and temporal plots of the ozonesonde and RWP data and surface and aloft basic weather conditions will be used to validate our analysis and identify random or systematic anomalies. The data, quality control procedures, data analysis methods, and analysis results will be reviewed by an STI senior scientist who was not directly involved in the data analysis.

5.3 Describe how the data will be summarized or analyzed (e.g., qualitative analysis, descriptive or inferential statistics) to meet the project objective(s).

Data summary and analysis is described below by project task.

Task 1: Characterize the atmospheric boundary layer. STI and VU will qualitatively characterize the meteorological conditions present on all NASA aircraft flight days and on days when 8-hour average ground-level ozone exceeded 75 ppb in the Houston area during the DISCOVER-AQ study period. The end product will be a description of the meteorological characteristics for each day, as well as a discussion of the interrelation among the meteorological phenomena and the general air quality conditions. We will assess the vertical and spatial structure of aloft winds, transport within the ABL, the diurnal and spatial characteristics of daytime mixing heights, how the large-scale meteorological patterns influence these processes, and general relationships between the above and surface air quality. In particular, we will describe and report the following for each day:

- *Boundary Layer Winds.* We will characterize the diurnal and spatial changes in the boundary layer wind patterns by reviewing RWP and ozonesonde data. The existence, timing, and strength of synoptic winds and land/sea breezes will be reported, along with their relationship to the vertical mixing and the large-scale weather pattern.
- *Boundary Layer Transport.* For selected receptors, we will run 24-hour back-trajectories for several altitudes within the ABL, starting near the time of peak hourly ozone concentrations. We will use NOAA's trajectory tool (esrl.noaa.gov/psd/programs/2013/texaqs/traj/) to run the trajectories using the RWP wind data.
- *Vertical Mixing.* We will use mixing height data to determine the characteristics of the daytime mixing layer, including the period of CBL growth, the maximum height of the CBL, the time of maximum height of the CBL, and any undercutting of the CBL by land/sea breezes. The mixing height data used for this analysis will be estimated as part of Task 3.
- *Vertical Ozone Structure.* To characterize the vertical distribution of ozone, we will examine plots of the vertical ozone profiles from the three sites. We will determine mixing heights, vertical ozone structure, and the relationship between the boundary-layer winds and transport patterns (via the RWP trajectories).
- *Large-Scale Aloft Weather.* We will use the height of the 500-mb constant-pressure level and winds as depicted on the National Weather Service (NWS) Daily Weather Maps to characterize the aloft large-scale weather patterns that existed at 0600 CST on each day. Locations and strengths of ridges, troughs, and circulation patterns will be noted, along with their probable influence on mixing and cloud cover in the Houston area.

- *Large-Scale Surface Weather.* We will use the large-scale surface pressure pattern and regional winds as depicted on the NWS Daily Weather Maps to characterize the large-scale surface flows that existed at 0600 CST on each day. General locations of surface highs and lows will be noted, along with their probable influence on ABL winds in the Houston area.
- *General Ozone Patterns.* We will analyze spatial and temporal ozone patterns by reviewing hourly spatial plots of ozone data collected at routine monitoring sites in the Houston and Galveston Bay area and the ozonesondes. We will review the ozone data in conjunction with the meteorological data discussed above.

Task 2: Determine representativeness of meteorological conditions. We will provide a narrative and supporting figures comparing boundary layer characteristics observed during the DISCOVER-AQ period to characteristics (1) observed on days of high ozone concentrations during TexAQS-II, and (2) observed over the past 10 years (specifically in regard to the vertical ozone structure and general meteorological conditions). The dates of comparison from TexAQS-II will include June 22 to 25, 2005; July 31 to August 2, 2005; and August 31 to September 2, 2006. These dates were selected because a detailed analysis of boundary conditions has already been performed for these dates, and high ozone concentrations were reported on these dates (MacDonald and Knoderer, 2008).

For the TexAQS-II comparison subtask, we will

- analyze the diurnal and spatial characteristics of the boundary layer winds and mixing heights. We will note similarities and differences between the selected TexAQS II days and the selected DISCOVER-AQ days (see Table 1).
- analyze general transport patterns and note similarities and differences between TexAQS II days and the selected DISCOVER-AQ days.
- analyze aloft ozone patterns using the sounding data and note similarities and differences between TexAQS II days and the selected DISCOVER-AQ days.
- identify any days that have very similar meteorological patterns; then, for these days, determine how the boundary layer meteorological conditions explain differences in observed ozone concentrations.

For the 10-year data comparison subtask, we will put the DISCOVER-AQ ozone profiles and general meteorological conditions in context by

- comparing profiles during DISCOVER-AQ to the September average profiles for each of the last 10 years and to selected profiles from days with high ozone concentrations (days with 8-hr ozone concentrations above 75 ppb).
- examining the meteorological variability over that 10-year period to understand the context for the meteorological conditions observed during DISCOVER-AQ.

Task 3: Derive and deliver continuous mixing heights. STI will produce hourly daytime mixing heights for all seven RWP sites and non-continuous mixing heights using the balloon sounding data from three sites for the entire DISCOVER-AQ period. The resulting data will be made available to other researchers. To determine mixing heights from the RWP data, we will analyze time-height cross-sectional plots of the RWP signal-to-noise ratio (SNR), vertical velocity, spectral width data, and wind data. At times, the peak SNR may not always define the surface-based mixed layer and may depict some other aloft layer, such as a subsidence inversion or a cloud layer. The mixing heights will be provided in an Excel file. Time series plots of the hourly mixing height estimates will also be provided.

5.4 If descriptive statistics are proposed, state what tables, plots, and/or statistics (e.g., mean, median, standard error, minimum and maximum values) will be used to summarize the data.

Not applicable.

5.5 If an inferential method is proposed, indicate whether the method will be a hypothesis test, confidence interval, or confidence limit and describe how the method will be performed.

Not applicable.

5.6 Describe data storage requirements for both hard copy and electronic data.

No hardcopy data will be generated by this project except as printouts of electronic documents. The mixing heights derived in Task 3 will be provided in an Excel file. Basic analysis of the RWP and ozonesonde data and overall meteorological conditions will require minimal electronic storage space. Electronic data will be stored on hard drives for a minimum of three years. All data files will be delivered to the University of Texas for storage at the Texas Advanced Computing Center.

6. Reporting

6.1 List and describe the deliverables expected from each project participant.

The project team will produce and deliver monthly technical and financial reports, quarterly reports, a draft final report, a final report, and a final presentation. The parties responsible for these deliverables and the schedule of deliverables are shown in **Table 4**. Please note that we would like to perform this work in a short time frame so that the data can quickly be provided to other researchers to support their analyses. Monthly Technical Reports, a Draft Final Report, and a Final Report will be written in third person and will follow the State of Texas accessibility requirements as set forth by the Texas State Department of Information Resources.

Table 4. Deliverables and work schedule.

Deliverables	Party Responsible	Completion Date
Monthly technical reports	STI	8th day of each month
Monthly financial reports	STI	12th day of each month
Quarterly reports	STI	Last day of each quarter
Draft final report	STI and Valparaiso University	July 31, 2014
Mixing heights spreadsheet	STI	July 31, 2014
Final report	STI and Valparaiso University	August 31, 2014
End of project presentation	STI and Valparaiso University	June 2015

6.2 Specify the expected final product(s) that will be prepared for the project (e.g., journal article, final report, etc.). Specify the source(s) of the secondary data in any deliverable.

A draft final report and a final report will be prepared and submitted on the schedules appearing in the QAPP and the Work Plan. The final report will include a section with a summary of our secondary data sources. Monthly technical reports will be prepared and submitted by the 8th of each month, with accompanying financial reports submitted by the 12th of each month. Quarterly update reports will be prepared by the end of each calendar quarter. The results of this analysis will be presented at the end-of-project meeting in Austin, Texas, in June 2015.

7. References

Knoderer C.A. and MacDonald C.P. (2013) Summary of data quality control of data collected by four 915-MHz RWP stations for DISCOVER-AQ Houston, from August 22 through October 22, 2013. Technical memorandum prepared for the University of Texas at Austin, Austin, TX, by Sonoma Technology, Inc., Petaluma, CA, STI-913045-5831-TM, November 21.

Komhyr W.D. (1969) Electrochemical concentration cells for gas analysis. *Ann. Geophys.*, 25, 203-210.

MacDonald C.P. and Knoderer C.A. (2008) Spatial and temporal characteristics of winds and mixing during TEXAQS-II. Final report prepared for Texas A&M University, College Station, TX by Sonoma Technology, Inc., Petaluma, CA, STI-907101-3344-FR, April.

Smit H.G.J., Straeter W., Johnson B.J., Oltmans S.J., Davies J., Tarasick D.W., Hoegger B., Stubi R., Schmidlin F.J., Northam T., Thompson A.M., Witte J.C., Boyd I., and Posny F. (2007) Assessment of the performance of ECC-ozonesondes under quasi-flight conditions in the environmental simulation chamber: Insights from the Juelich Ozone Sonde Intercomparison Experiment (JOSIE). *Journal of Geophysical Research: Atmospheres*, 112(D19), D19306, doi: 10.1029/2006jd007308. Available at http://dx.doi.org/10.1029/2006JD007308.