MONITORING AND QUALITY ASSURANCE PLAN

for the

UPPER GREEN RIVER WINTER OZONE STUDY - 2008

Prepared for

State of Wyoming
Department of Environmental Quality, Air Quality Division
122 West 25th Street
Herschler Building, 2nd Floor East
Cheyenne, WY 82002-006

February 15, 2008

Prepared by

T&B Systems
environmental research associates

MSI

ENVIRON

TABLE OF CONTENTS

SECTION 1

INTRODUCTION AND PROJECT OVERVIEW

This monitoring and quality assurance plan provides the basis for the collection of air quality and meteorological data for the Upper Green River Winter Ozone Study (UGWOS), sponsored by the Wyoming Department of Environmental Quality (WDEQ). While research in nature, the monitoring methods and objectives described in this plan are consistent whenever possible with EPA quality assurance guidance for the collection of air quality and meteorological data (US EPA 1995, and 1998) and the most recent guidance for the collection of meteorological data for regulatory modeling applications (US EPA, 2000).

Recent high ozone events observed in this area have raised concerns regarding potential adverse health and ecological effects associated with monitored concentrations greater than the U.S. Environmental Protection Agency's ozone standard (set at an 8-hour average concentration of 0.08 ppm) and the significantly increased federal regulatory requirements that would be associated with any potential future violation of the EPA ozone standard. The situation is made even more critical by the fact that EPA's Science Advisory Board is currently considering the need to lower the ozone standard between 0.060 and 0.070 ppm which would make a violation (currently defined as a three year average of the annual fourth highest daily maximum 8-hour ozone above 0.08 ppm) considerably more likely: preliminary measurements from the Jonah monitoring site show an average fourth highest 8-hr ozone of 0.071 ppm for 2005 – 2006.

Ozone formation in the Upper Green River Basin is unusual in that the highest concentrations have been recorded during the late winter and early spring (February to April) when sun angles are relatively low and temperatures are generally below freezing. This is in stark contrast to ozone exceedances in other areas, which occur during the warm summer months when abundant solar radiation and high temperatures act to increase precursor emissions and enhance the atmospheric reactions that result in ozone formation near the earth's surface (i.e., within the planetary boundary layer).

Due to the pressing need to manage ozone air quality in the Upper Green River Basin and the limited amount of information currently available about the nature and causes of these unusual events, the WDEQ funded a comprehensive field study during the 2007 late winter – early spring season. This study was described in detail in an original QA plan entitled *Monitoring and Quality Assurance Plan for the Upper Green River Ozone Study* written in March 2007. Atypical meteorological conditions during this initial study period resulted in only limited monitoring, and a second effort was organized using remaining funds to conducted monitoring during the winter of 2008, during which hopefully more favorable meteorological conditions will occur. This QA plan describes the 2008 effort.

Data from this study will be used to develop a conceptual model of ozone formation. The conceptual model will be used along with the field data to develop accurate meteorological and air quality numerical simulations of the ozone events. Both the conceptual and numerical models will in turn be used to develop effective air quality management strategies needed to adequately protect public health and the environment in accordance with applicable State and Federal laws.

SECTION 2

SAMPLING PROGRAM DESCRIPTION

There are two levels or modes of field measurements in UGWOS: *continuous* and *intensive*. Continuous measurements will be ongoing from the start of the field study January 15, 2008 and continue until the scheduled end date, anticipated March 30, 2008. More extensive measurements will be conducted when the meteorological conditions are conducive to producing high ozone levels. These periods are hereafter referred to as Intensive Operational Periods (IOPs). IOPs will be initiated on a forecast basis and, as such, the field crew is committed to the project for its duration. Each IOP can last up to four days, and three such IOPs will be conducted over the study period. IOP measurements comprise the main core of the study in which the three-dimensional air quality and key meteorological features will be described. The surface ozone measurements are expanded to bound the major well field development, and measure the maximum air quality impacts.

2.1 Operational Forecasts and Readiness Protocol

The current conceptual model of the meteorological conditions conducive to the formation of high ozone levels in the Pinedale-Jonah fields during the winter and early spring is characterized by clear skies, light winds and a stable atmosphere. These conditions occur during periods when the synoptic weather is dominated by high pressure over the western Rockies, Intermountain area and the northern Great Basin. The primary broad scale characteristics dominating the Green River basin during the high probability events are weak pressure gradients within the context of a subsidence-dominated air mass.

In an effort to formulate the conceptual model, the synoptic scale weather patterns prior to occurrences of escalated ozone values in the study area during the winters of 2005 and 2006 were examined. Although many different nuances of the general pattern were encountered, the basic characteristics of the conceptual model did emerge. Figures 2-1 through 2-4 present composite views of the 700 mb and 500 mb configurations for all of the days with surface 8-hour averaged ozone concentrations greater than 60 ppb. Figure 2-1 shows the ridging pattern of the 500 mb height contours; Figure 2-2 presents the wind speed isotachs at 500 mb; Figure 2-3 shows the ridging pattern of the 700 mb height contours; and Figure 2-4 demonstrates that there was warmer air aloft just above the surface, indicating air mass subsidence.

Recognition of the onset and establishment of the conceptual model characteristics in advance is the key to the operational forecasting solution for the UGWOS field measurements operations. National Weather Service numerical synoptic-scale models such as the North American Mesoscale model (NAM) and the Global Forecast System model (GFS), coupled with regional NWS Forecast Discussion guidance, will provide the experienced MSI and T&B Systems weather forecasters with the basis for daily long and medium range operation forecasts. An additional factor that may prove critical in operational forecasting is the presence of sufficient snow cover to provide the radiation component needed for ozone chemistry. Local observations will provide this information on a day-to-day basis.

The effects of day-to-day variability in local-scale meteorological factors on ozone levels are not clearly understood due to the limited measurements in the project area. Our knowledge and ability to refine the forecasts will improve as the program progresses. Discussions with local DEQ and BLM personnel and our initial observations suggest that high levels of ozone may occur more frequently than the current monitoring network is capable of detecting. The mesonet being deployed for the study will provide significant expanded areal ozone coverage.

A number of products and data will be routinely archived. Products include: the daily Riverton NWS rawinsondes, the GOES sounding data for Afton and Rock Springs, the Weather Modification, Inc. project soundings from Farson, and the NAM and GFS model generated simulated soundings for points within the Pinedale area. Short-term daily operational forecasts will be aided and refined as all this near real-time information is obtained. We will also be evaluating the usefulness of the Rapid Update Cycle model (RUC), the Weather Research and Forecasting model (WRF) and the RAMS model from CSU in our short-term operational forecasting mode and possibly incorporate them into our daily forecasts.

An operational forecast will be issued by 10 MST each day that will include both the short-term and long-term weather forecasts. All project participants will be required to provide any changes in their operational readiness daily to the Field Project Manager and that information will be included as well. This forecast will be posted on a project web site accessible to all participants. If conditions are developing that are conducive to the development of high ozone, an alert will be issued.

A “GO” alert will be issued at the 10 MST forecast at least 48 hrs before an IOP is to begin. Field crews will begin making preparations to debark to the field the following morning. A final GO or NO GO will be issued by 17 MST that afternoon. If the forecast remains a GO, the crews will deploy as scheduled.

The field crews will meet in Pinedale the following evening for a briefing and to coordinate setting up for the IOP. All equipment will be deployed and/or checked for readiness the following day. In this manner, an IOP can begin within 48 hours of the initial GO forecast. To aid in that critical operational forecast, we have contingency plans to launch a rawinsonde to measure local winds, temperature and humidity the first morning in the field before the complete network is deployed.

We do not anticipate having to deploy the field crew when inclement weather hampers travel to and from the project area. It should be noted that the major characteristics of the meteorology that can lead to high ozone levels in the Pinedale-Jonah area are a stable atmosphere, clear skies, and light low-level winds. These conditions take some time (at least 48 hours after a storm frontal passage) to develop. Moreover, we expect operational conditions to occur during periods when the synoptic weather pattern in the western states is relatively stationary as opposed to short-waves of high and low pressure patterns, so it will not be necessary to start operations on the heels of a storm system.

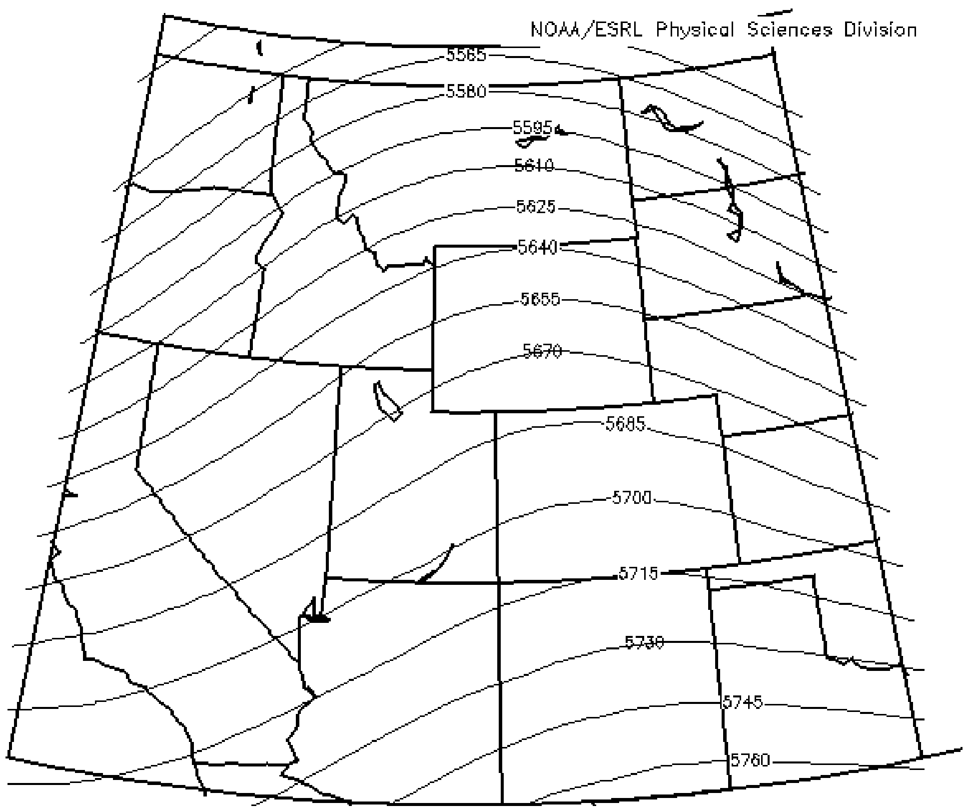


Figure 2-1 Composite 500 mb Heights During High Ozone Periods

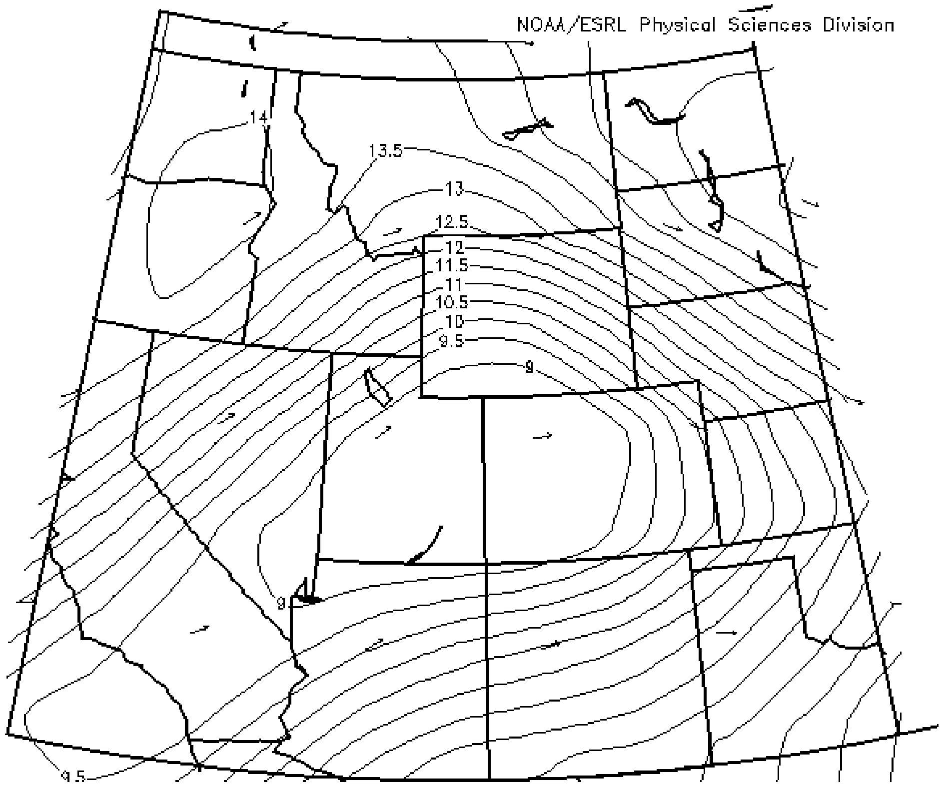


Figure 2-2 Composite 500 mb Winds During High Ozone Periods

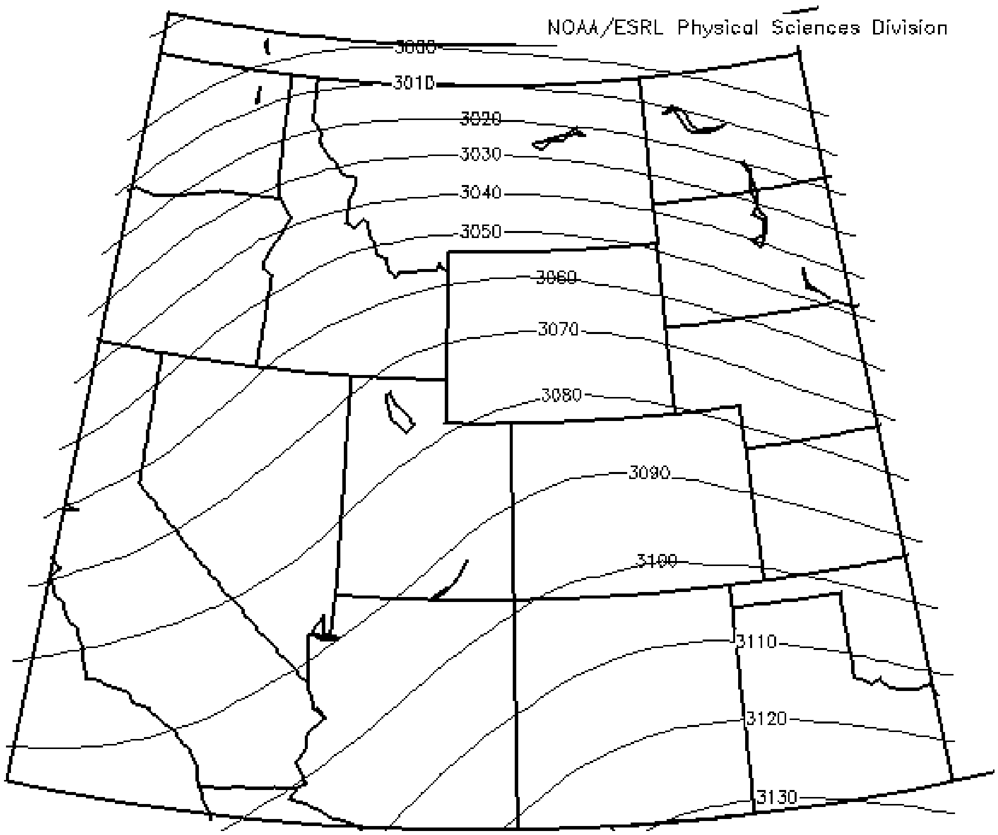


Figure 2-3 Composite 700 mb Heights During High Ozone Periods

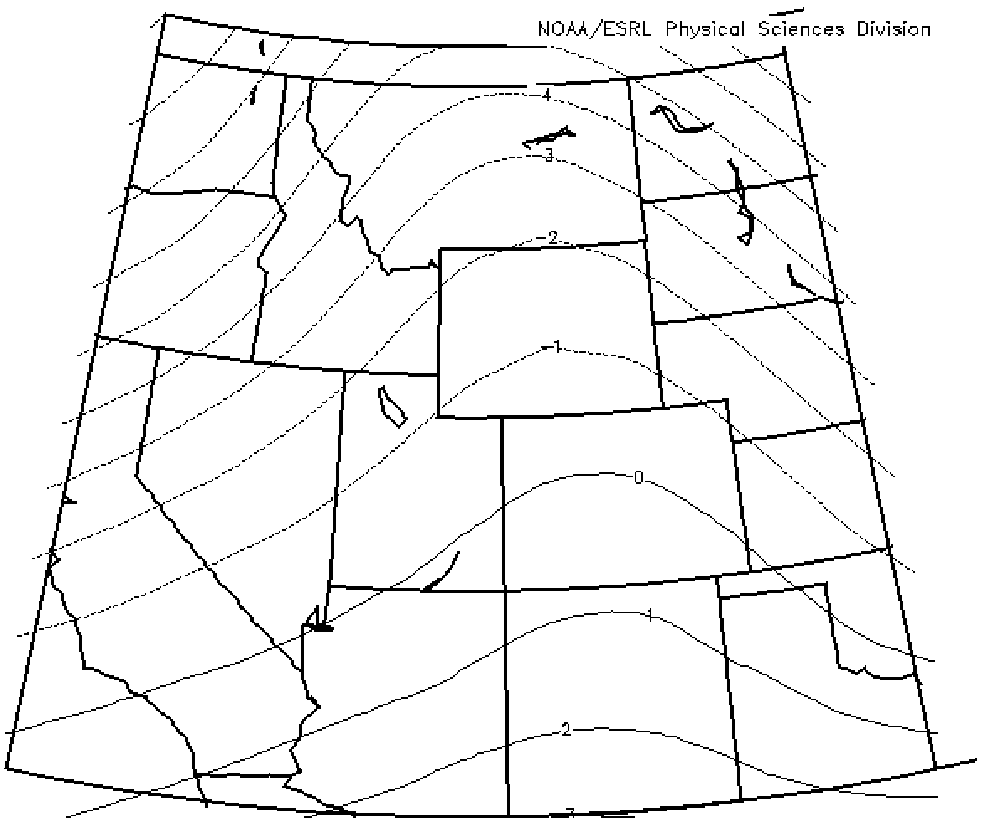


Figure 2-4 Composite 700 mb Temperature During High Ozone Periods

2.2 Continuous Measurements

Project-specific measurements to be continuously obtained over the complete field program period include surface and winds aloft, and supplemental surface ozone measurements. Surface ozone and wind measurements will be taken from a 5-site mesonetwork (mesonet) and from Wenz Field (Pinedale airport). At the latter site, continuous surface ozone measurements using a designated EPA equivalent analyzer will be made. Surface temperature and relative humidity will also be collected at the Pinedale site. At a site on the south mesa, both surface and aloft winds will be measured continuously employing a Sodar and surface meteorological station. Both incoming and reflected UV radiation will be measured using currently operating equipment at the Boulder site.

2.3 Intensive Measurements

During periods when high ozone levels are forecast, more intensive measurements will be initiated. The key components of the intensive monitoring periods (IOPs) are:

- VOC and carbonyl measurements
- Ozone/rawinsonde operations
- Aircraft measurements

2.3.1 Mesonet Ozone Measurements

Though the mesonet ozone analyzers will operate continuously over the course of the study, routine performance checks of the analyzers will only be conducted during the IOPs. MSI staff will deploy to the field from their office in Salt Lake City immediately following issuance of the final GO. The 2B ozone monitors will be span-checked prior to the first day of the IOP, if at all possible. Their operation on-site will be checked using the 2-B ozone generator and zero-scrubber, and any zero and span adjustments made. The data system time will be reset as required.

During the IOPs the sites will be visited every two to three days to download data and ensure appropriate operations. At these visits, batteries will be checked and the solar panels cleaned, as necessary. At the completion of each IOP, the ozone analyzers will be span and zero checked. All on-site operations will be documented and logged by the MSI technicians.

WDEQ will be responsible for servicing the sites in between IOPs, as time and resources allow.

2.3.2 VOC and Carbonyl Measurements

VOC and carbonyl measurements will be conducted at each of the three existing WDEQ monitoring sites within the study area – Jonah, Boulder and Daniel. The VOC and carbonyl measurements will be collocated and sampled simultaneously as three-hour integrated samples. On intensive study period days, samples will be taken from 0400-0700, 0900-1200 and 1400-1700 hours.

VOC measurements will be made using 6-liter SUMMA canisters connected to Xontech Model 910A canister samplers. Ambient air will be pumped to the canisters for a three-hour period. Carbonyl measurements will be made by pulling ambient air at 1 LPM through DNPH cartridges with an ozone scrubber inserted upstream of the cartridge. Both types of samplers are outfitted with timers that enable automatic start/stop operation. Ambient air needed for the samplers will be obtained from borosilicate glass intake manifold ports at each monitoring shelter.

Research team technicians will be responsible for loading canister/cartridge media into the samplers, confirming sample run times, removing samples and filling out the affiliated documentation. Exposed sample media will be collected at the end of each intensive study day and brought to the project field office at the Pinedale Airport for packaging and shipment to EAS laboratory for analysis. Field sample sheets will accompany samples and the required chain-of-custody documentation will accompany each shipment.

Samplers will be cleaned prior to the start of the measurement program and tested for contamination. A field blank will be submitted for each site during intensive study periods.

VOC/carbonyl samples will also be collected using the aircraft (see section below). Up to two samples can be collected each flight with the sample locations at the discretion of the on-board scientist based on observations during the flight. Samples will be collected during a five-minute spiral at the desired location.

While up to 150 sample pairs may be collected over the course of the 2008 study, only 100 pairs will be analyzed, based on their anticipated value for meeting study goals.

2.3.3 Aircraft Sampling

Ozone, fine particulate loading, and temperature will be measured using a single-engine airplane. A typical sampling flight will be comprised of measurements at constant levels and spiral ascents and descents to provide vertical profiles. Vertical profiles will be made from as near to ground level as safety permits to approximately 4000 ft-agl. If the daytime boundary level is shallower than 4000 ft, the spirals may be to a lower height.

Two three-hour sampling flights are planned each intensive sampling day, beginning the first day of an IOP. Preliminary flight plans will be developed prior to takeoff. The morning flight will take place approximately 07:30 -10:30 MST. The afternoon flight will take place approximately 13:30 –16:30 MST. An experienced T&B Systems air quality scientist will be onboard observing the measurements in real-time. Based on those observations and the winds aloft measurements, the flight plan may be modified. For example, if a polluted layer is observed the primary mission of that sampling flight may be to map the areal extent of the polluted layer.

Flight patterns will initially be as follows:

- The morning flights will concentrate on characterizing the near-surface ozone conditions, and will consist of a series of spiral soundings connected by relatively low level flight. Flights during both the morning and the afternoon will begin with a sounding near the radar profiler site. The study area will then be characterized by conducting a similar spiral sounding near at least the Jonah site, with connecting legs at a constant level below 500 ft AGL (7,500 ft MSL), to characterize as best as possible concentrations at or below the inversion layer.

- The goal of the afternoon flights will be to map the extent of any plume of high concentrations. The initial spiral sounding near the radar profiler site will determine the height of maximum concentrations, determining the flight level for the remainder of the flight. As and alternative, based on available upper level wind data from the ozonesonde measurements and sodar, as well as observations from the first flight, a series of constant level traverses perpendicular to the prevailing winds could be conducted at progressively farther downwind distances.

Figure 2-5 shows a basic flight pattern. Table 2-1 describes the basic elements of the flight, including waypoints. However, the flight patterns for the aircraft measurements are intended to be dynamic in nature, with changes made as data are collected and analyzer from all of the study measurement platforms.

This task is the responsibility of T&B Systems.

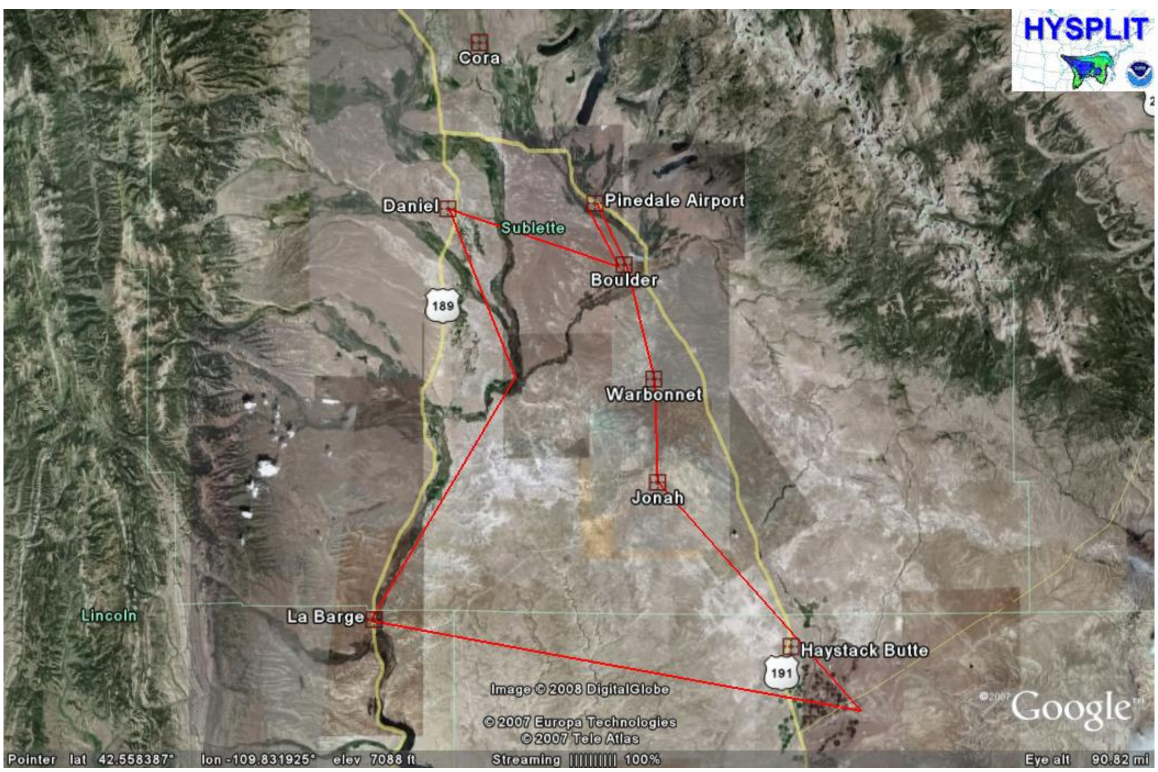


Figure 2-5. Basic Flight Pattern.

Table 2-1. Basic Flight Pattern

Waypoint	Latitude	Longitude	Comments
Pinedale Airport	42.7982°	-109.805°	Climb to 11,000' MSL in route to Boulder
Boulder	42.7187°	-109.754°	Spiral down to ~200' AGL, then up to 7,500' MSL (anticipated to be below inversion level)
Warbonnet	42.5702°	-109.702°	Maintain 7,500' MSL
Jonah	42.4364°	-109.696°	Proceed to Jonah at 7,500' MSL, descend to ~200' AGL, then spiral up to ~500' above inversion level
Hwy 28	42.1378°	-109.343°	Return to 7,500' MSL, and travel over Haystack Butte to Hwy 28 out of South Pass
La Barge	42.2585°	-110.194°	Maintain 7,500' MSL
Green River Drainage	42.5736°	-109.945°	As an option, fly back to any area of high readings noted along Boulder/Jonah path
Daniel	42.7914°	-110.065°	Maintain 7,500' MSL
Boulder	42.7187°	-109.754°	Maintain 7,500' MSL until approaching Boulder, then drop to ~200' AGL and spiral up to 11,000' MSL
Pinedale Airport	42.7982°	-109.805°	Descend and land

2.3.4 Ozone/Rawinsondes

Free ascending balloon-borne measurements of ozone, temperature, relative humidity, and winds will be made three-times daily from Wenz Field (Pinedale Airport) during IOPs. Scheduled rawinsonde sounding times are 07, 11, and 15 MST. The early morning sounding will document the vertical structure of the atmosphere during the most stable period over the diurnal cycle. This sounding will closely correspond to the 12 GMT world-wide sounding schedule and data set. The afternoon sounding will characterize conditions when the atmosphere is generally most unstable and the mixed layer has fully developed. The midday sounding will be document the timing of the growth of the boundary layer.

Soundings will extend to at least 500 mb or ~ 18,000 ft. Optimally, data will be gathered to 300 mb which is approximately 30,000 ft.

Ozonesondes will be incorporated for two of the soundings, most likely during the morning sounding to document initial conditions aloft, and the afternoon sounding when ozone concentrations are anticipated to be the highest.

This task is the responsibility of T&B Systems.

2.3.5 Supplemental Monitoring and Data Collection

UV Radiation

Direct and reflected UV radiation sensors (radiometers) initially installed during the 2007 effort at the WDEQ Boulder site will be an important part of the UGWOS data set. The sensors will be checked and the data downloaded at the beginning and end of each IOP. Sensor checks will consist of a zero reading and comparison of the sensors output while orientated the same. The radiometer will be operational but unattended between IOPs.

Archiving of NOAA Products

Archiving of data that is not already archived on the web and readily available will occur on a daily basis. The items that will be archived for the period from January 15 through March 31, 2008 are listed below:

- MSI routinely archives 00Z and 12Z surface and upper air maps for 700 mb, 500 mb and 850 mb.
- MSI routinely archives data from all rawinsonde sites in the United States for both 00Z and 12Z time periods.
- MSI routinely archives Visual and IR, US east and west satellite images every 15 minutes.
- Vorticity information provided by the NAM model will be archived twice daily. The 00Z and the 12Z analysis vorticity data will be archived for a 13 by 13 grid surrounding the Pinedale area. Additionally, all data from the analysis period will be archived for the data point nearest Pinedale. This will provide another point for which a sounding may be plotted.
- Vorticity graphics at 500 mb produced by NCEP from both NAM and GFS will be archived on a daily basis for the analysis runs at 00 and 12Z.
- GOES derived soundings will be archived on a daily basis. Archival will include plots and data listings.

In addition to the above, the following data are currently archived on the web and available for analysis:

- Snowpack - available at NOAA's National Operational Hydrologic Remote Sensing Center

- Total Column Ozone - A web site from NASA provides historical ozone global charts, and Dobson Unit measurements for any lat/long on any particular day.
- Local Camera Images - The current local camera images from Daniel, Jonah and Boulder can be viewed on line at the WDEQ site, and there is also a 2 week image archive here which consists of an image at 9:00 12:00 and 15:00 MST each day. Archived images can also be requested from Air Resource Specialists, Inc. or InterMountain Labs.

SECTION 3

MONITORING SITE DESCRIPTIONS

Figure 3-1 presents a map of the UGWOS site locations. Tables 3-1 and 3-2 present coordinates and site selection rational (monitoring objectives), respectively, for each of the sites. Photographs of the sites can be found in Appendix A.

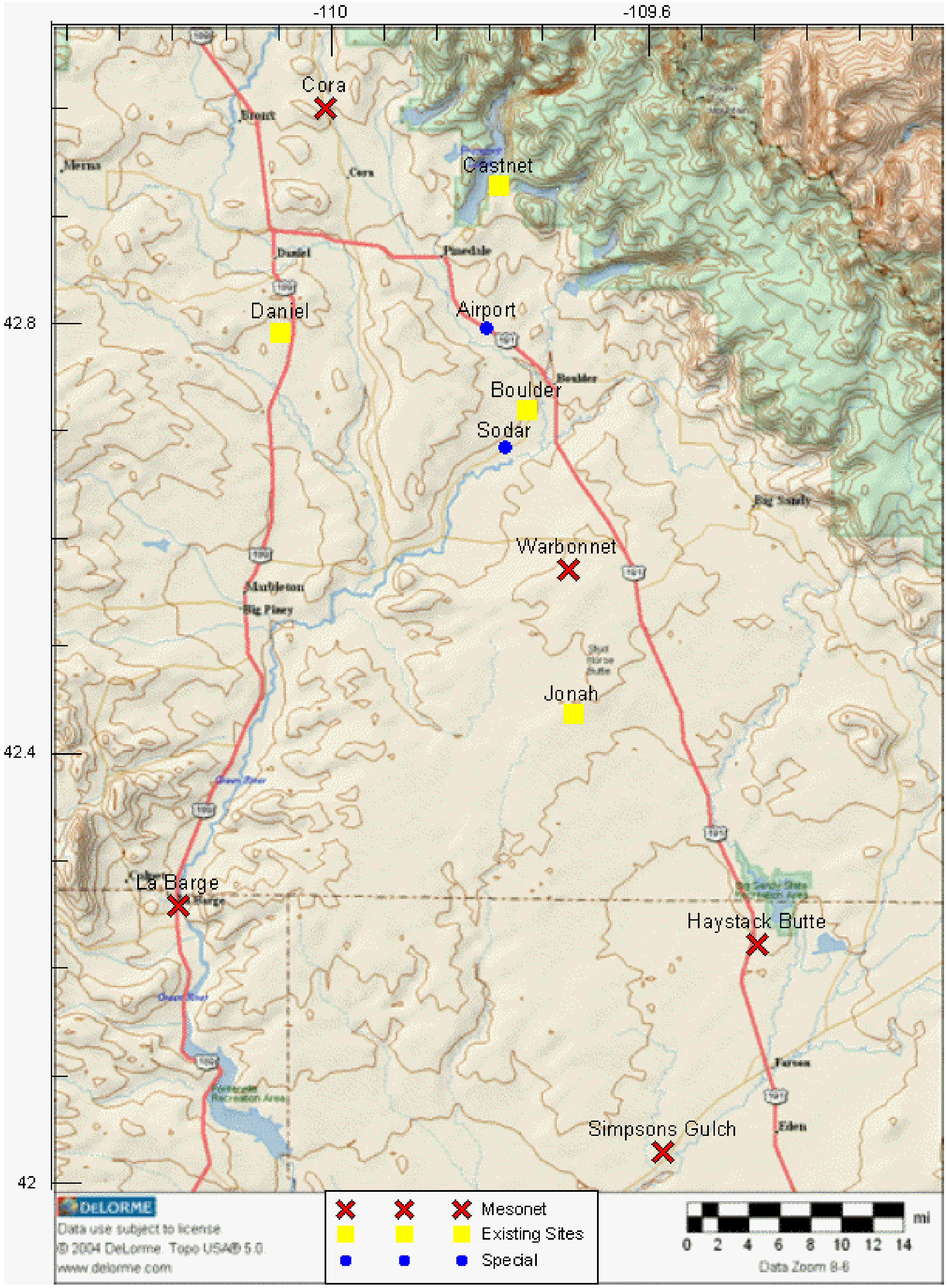


Figure 3-1. Map of UGWOS Site Locations

Table 3-1. Network Locations and Identifiers

All Lat/Longs are WGS 84	Latitude	Longitude	Elev.
OZONE/MET SITES			
Site 1: Cora Area (BLM)	43 00.399N	110 00.543W	7558'
Site 3: Warbonnet (BLM)	42 34.212N	109 42.125W	7425'
Site 4: Haystack Butte (WY)	42 13.323N	109 27.762W	6758'
Site 5: Simpson Gulch (BLM) (FAA Tower)	42 01.697N	109 34.914W	6691'
Site 8: La Barge (Private)	42 15.512N	110 11.638W	6609'
WIND PROFILER SITE			
Sodar: M&N Yard	42 36.420N	109 51.879W	6910'
SURFACE VOC/CARBONYL SITES			
Boulder	42 43.120N	109 45.225W	7078'
Daniel	42 47.484N	110 03.886W	7084'
Jonah	42 26.184N	109 41.754W	6848'
PINEDALE AIRPORT (WEINZ FIELD)			
Airport	42 47.890N	109 48.296W	7109'

Table 3-2. Major Objectives of Mesonet Sites

Cora	Northern boundary site upwind from prevailing winds
Warbonnet	Representative of middle and southern Pinedale Anticline
Haystack Butte	Southeastern boundary site. Highest readings during 2007.
La Barge	Southwestern boundary site
Simpsons Gulch	Southern boundary site

SECTION 4

MONITORING EQUIPMENT DESCRIPTION

The following section describes the monitoring equipment that will be used for UGWOS. Monitoring quality objectives (MQOs) are presented for each of the monitoring methods.

4.1 MESONET OZONE MONITORING

All equipment used at the mesonet ozone monitoring sites will be housed in a 70 to 100 quart portable cooler. This includes a 110 amp-hour deep cycle 12-Volt battery will power all equipment and allow continuous monitoring for a least one week. A small 5-watt light bulb will also be located in the cooler to provide sufficient heat to keep temperatures in the cooler within the operating ranges of all equipment.

The following equipment will be at each of the mesonet sites:

<u>2B Model 202 Ozone Analyzer</u>

The 2B Ozone Monitor will be used for the mesonet Monitoring. This monitor has a low power consumption (12v DC, 0.33 amp, 4.0 Watt) relative to conventional instruments allowing operation with deep cycle batteries. Additionally, it does not require a temperature-controlled environment.

The 2B Technologies Model 202 Ozone Monitor™ is designed to enable accurate and precise measurements of ozone ranging from low ppb (precison of ~1 ppbv) up to 100,000 ppb (0-100 ppm) based on the well established technique of absorption of light at 254 nm. "Absorption spectroscopy" is a chemical analysis technique made possible by the phenomenon that a given molecule absorbs light at selected wavelengths. The wavelengths absorbed are characteristic of each molecule's atomic features. The amount of light radiation absorbed by a substance depends on two factors: the number of molecules in the path of the light, and the characteristics of the molecule (e.g., absorption cross-section). Measurement of changes in the light intensity as it passes through the molecules, and the use of calibration and reference data, enable the determination of the number of molecules encountered.

Accuracy (performance checks)	±5%
Precision (performance checks)	±5%
Resolution	0.001 ppm
Lower Quantifiable Limit	0.002 ppm

RM Young Model 05305 Wind Monitor AQ

For surface monitoring of wind speed and wind direction at the mesonet sites, we will employ an RM Young 05305 Wind Monitor AQ wind speed and direction sensors. These sensors employ a propeller anemometer. The sensors can be mounted on existing structures or on 2-meter tripods, typically on the roof of existing buildings (Figure 4-1), resulting in measurement heights ranging form 2 to 10 meters. All sensors will be oriented to true north using either the GPS walkoff method or solar alignment method for orienting wind speed sensors.

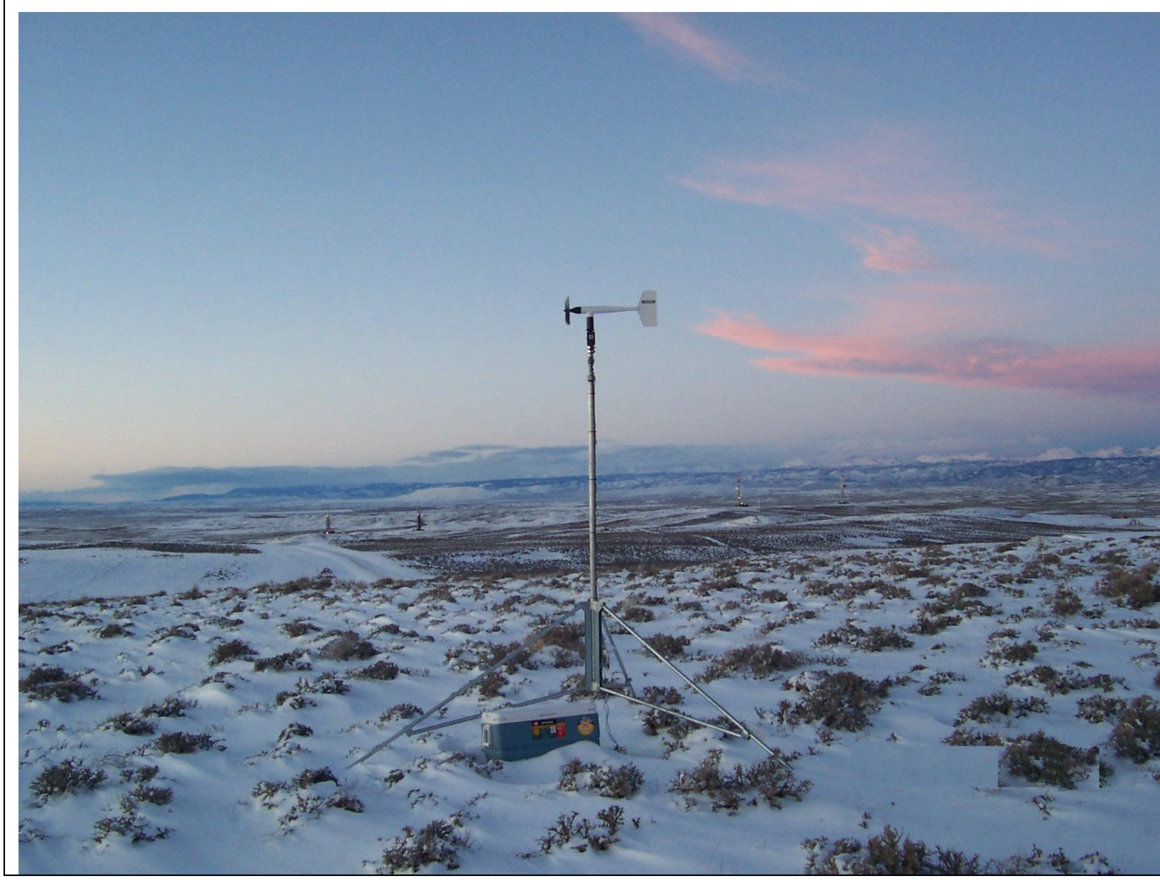


Figure 4-1. Tripod mounting of wind sensors.

Monitoring quality objectives for the supplemental surface wind measurements are presented below.

Accuracy (instrument specifications)	
Horizontal Wind Speed	±(0.2 m/s + 5% of observed)
Horizontal Wind Direction	±5 degrees
Precision (performance checks)	
Horizontal Wind Speed	±0.1 m/s
Horizontal Wind Direction	±2 degrees
Output Resolution	
Horizontal Wind Speed	0.1 m/s
Horizontal Wind Direction	1.0 deg.
Starting Threshold	0.5 m/s

Campbell Scientific 109-L Temperature Probe

The temperature within the cooler will be monitored using a Campbell Scientific 109 temperature probe. The 109-L Temperature Probe is a thermistor designed for use specifically with the CR200-series dataloggers and has a measurement temperature range of -50° to +70°C.

Campbell Scientific CR206 Data Logger

All data will be stored using a Campbell Scientific CR206 data logger. Both 5-minute and 60-minute averages will be stored, though the 5-minute data will be used primarily for QC purposes. Based on the number of measurements an statistics being record, the CR206 can operate for a period of up to approximately two weeks before it is necessary to download data. The CR206 data logger is equipped with a 915 MHz radio, allowing remote accessing and downloading of data.

4.2 OZONE/RAWINSONDES

To profile ozone concentrations from the surface to the tropopause, we will use balloon-borne ozonesondes, with measurements placed at the Pinedale airport. The ozonesonde systems has three primary components, described below:

Sippican W-9000

The Sippican W-9000 system consists of a SIPPICAN ZEEMET W-9000 GPS based navaid receiver/data system for measuring winds and the SIPPICAN Mark II Microsondes radiosonde packages.

The SIPPICAN ZEEMET W-9000 receiving station interfaces with a personal computer and printer. This is a state-of-the-art wind finding system employing GPS technology. The UHF receiver operates in the 400 MHZ range. SIPPICAN software enables the interface with the SIPPICAN W-9000 receiver and reduces the thermodynamic pressure, temperature and humidity (PTU) and navaid/wind data. During each flight, the technician is able to monitor both raw and reduced data in near real time. The software also includes graphics and plotting capabilities that allow the technician to review results during and at the end of each flight. Both raw and reduced data are stored on the hard disk in subdirectories identified by the flight name. All data files are copied to both primary and backup diskettes immediately after each flight.

SIPPICAN Mark II Microsondes

The SIPPICAN Mark II Microsondes are 10 x 19 x 15 cm and weigh 250 grams with a water-activated 18V battery. The radiosonde UHF transmitter sends its modulated signals in the 400 MHZ range. The Microsondes are calibrated at the factory in a computer-controlled environmental chamber. Calibration coefficients are stored in read-only-memory (ROM) within each sonde and are automatically transmitted to the receiver in 1.5 sec intervals. Temperature is measured using a bead thermistor and relative humidity using a carbon hygristor. The SIPPICAN W-9000 is an automatic wind finding system that is based on tracking the sonde using the GPS satellite network. The Microsonde incorporates a low-noise integrated circuit GPS receiver. Winds aloft are calculated from the change in balloon position (determined from navaid) with time. Height is obtained directly from GPS positioning and, unlike older systems, pressure is now a derived parameter, calculated from the hydrostatic equation, using measured height, temperature, and humidity.

Accuracy (instrument specifications)	
Horizontal Wind Speed	± 0.5 ms^{-1}
Horizontal Wind Direction	Unknown
Temperature	± 0.2° C
Relative Humidity	± 2.0%

Output Resolution	
Horizontal Wind Speed	0.1 m/s
Horizontal Wind Direction	1.0°
Temperature	0.1° C
Relative Humidity	1.0%

<u>EN-SCI Corporation KZ-ECC Ozonesondes</u>

EN-SCI Corporation KZ-ECC ozonesonde system will be used in conjunction with the SIPPICAN W-9000 Mark II Microsondes radiosonde package. The KZ-ECC atmospheric ozone sounding system is designed for ozone measurements from balloon platforms, but for this project will be used both from balloon platforms and, in a modified package, for continuous surface sampling at fixed locations (see Section 3.2.1.4). Ozone is measured with an electrochemical concentration cell (ECC) ozonesonde coupled through an electronic interface to a SIPPICAN W-9000 Mark II radiosonde (described in detail in the meteorological measurements proposal).

The ECC ozonesonde is of a simple design consisting of a rigid mainframe on which is mounted a motor-driven Teflon/glass air sampling pump, a thermistor for measuring pump temperature, an ozone sensing ECC, and an electronics box containing interface circuitry which couple the ozone sensor to the radiosonde. The mainframe is mounted in a lightweight weatherproof polystyrene flight box that is taped and wired to the radiosonde during flight.

The ozone-sensing cell is made of two bright platinum electrodes immersed in potassium iodide (KI) solutions of different concentrations contained in separate cathode and anode chambers. The chambers are linked with an ion bridge that, in addition to providing an ion pathway, retards mixing of the cathode and anode electrolytes thereby preserving their concentrations. The electrolytes also contain potassium bromide (KBr) and a buffer whose concentrations in each half-cell are the same. The driving electromotive force for the cell, of approximately 0.13 V, is provided by the difference in potassium iodide concentrations in the two half cells. Sample air is forced through the ECC sensor by means of a non-reactive pump fabricated from TFE Teflon impregnated with glass fibers. The pump is designed to operate without ozone-destroying lubricants. Pumping efficiency for each pump varies from pump to pump and is also dependent on ambient air pressure. The sampling flow rate is calibrated at the factory and checked in the field before launch. The ECC ozone concentration calibration is also determined prior to launch.

When ozone in air enters the sensor, iodine is formed in the cathode half cell according to the relation

$$2KI + O_3 + H_2O \rightarrow 2KOH + I_2 + O_2. \quad (1)$$

The cell converts the iodine to iodide according to

$$I_2 + 2e \rightarrow 2I^- \quad (2)$$

during which time two electrons flow in the cell's external circuit. Measurement of the electron flow (i.e., the cell current), together with the rate at which ozone enters the cell per unit time, enables ozone concentrations in the sampled air to be derived from

$$p_3 = 4.307 \times 10^{-3}(i_m - i_b)T_p t \quad (3)$$

where p_3 is the ozone partial pressure in nanobars, i_m is the measured sensor output current in microamperes, i_b is the sensor background current (i.e., the residual current emanating from the cell in the absence of ozone in the air) in microamperes, T_p is the pump temperature in Kelvin, and t is the time in seconds taken by the sonde gas sampling pump to force 100 ml of air through the sensor.

Sensitivity	2-3 ppb by volume ozone in air
Response Time	15 seconds for 67% of change; 60 seconds for 85% of change
Noise	less than 1% of full scale
Estimated Measurement Uncertainty	less than ± 10% of indicated value

As an integral part of the ozonesonde operations, a Dasibi EPA designated equivalent ozone analyzer and meteorological instrumentation will be installed at the ozonesonde launching site, within the hanger office building at the Pinedale Airport. This equipment is described below:

<u>Dasibi Model 1000 Series Ozone Analyzer</u>

Ozone at the Pinedale airport will be measured with either Dasibi Model 1003 or Model 1008 UV photometric ozone analyzers (EPA equivalent numbers EQOA-0577-019 and EQOA-0383-056, respectively). Sampling will made through Teflon lines, which will be of sufficiently short length to meet EPA requirements for sample residence time. Interior temperature will also be monitored.

Accuracy (performance checks)	±5%
Precision (performance checks)	±5%
Resolution	0.001 ppm
Lower Quantifiable Limit	0.002 ppm

RM Young Model 05103 Wind Monitor

For surface monitoring of wind speed and wind direction at the Pinedale airport site, we will employ an RM Young 05103 Wind Monitor wind speed and direction sensors. MQOs for this sensor are similar to those for the model 05305 sensor presented above with the exception of the starting threshold, which is 1.0 m/s.

4.3 AIRCRAFT SAMPLING

The sampling instrumentation for the aircraft that we are proposing is identical to that which used during the 2005 CCROPS (T&B Systems, 2006). Ozone sampling is based on the wet cell KI technique implemented by EN-SCI Corporation for tropospheric and stratospheric ozone profiling, as described in Section 4.2. The sample pump/cell system is housed in a small case with the output signal from the sampler recorded on a Campbell CR1000 data logger. This data logger allows the recording and parsing of a serial data stream from a Global Positioning System receiver as well as recording analog signals of pressure, ambient temperature, detection cell temperature and the calculated values of ozone based on the sampled parameters. Data are sampled and recorded at 2-second intervals. A set of AA batteries provides power and the capability for the entire system to measure ozone continuously for over 8 hours. The sample inlet is through a length of FEP Teflon tubing to a region of the aircraft in free airflow. The temperature probe will be placed near the sample inlet. The preparation time prior to a flight requires approximately 20 to 30 minutes to install, pre-flight and assure that the systems were operational. Figure 4-3 shows the installation of the package behind the pilot seat in the Piper Super Cub used for the 2005 CCROPS study, with the sample line is run out the open window to the mounting on the strut. For this study, we are using a Cessna 172 based out of the Pinedale airport.

In addition to sampling for ozone, $PM_{2.5}$ sampling will also be included in the aircraft measurements using a DustTrak 8520 optical light scattering instrument. Test flights of the system showed that the aircraft readings were in no way affected by the aircraft exhaust, as evidenced by $PM_{2.5}$ reading of zero.

VOC and carbonyl samples will be collected during 5-minute spirals in the desired sampling location. VOC canisters will be opened, allowing the sample to be drawn using the canister's vacuum. A Thomas 12-V portable pump operating at approximately 5 lpm will be used to draw sample air through the carbonyl cartridges. More details regarding the VOC/carbonyl sampling are discussed in the section below.

Figure 4-3. Ozone sampling package mounting in back seat of aircraft.

4.4 VOC SAMPLING

VOC samples will be collected using SUMMA canisters outfitted with flow controllers set up for 3-hour integrated samples. Carbonyl samples will be collected using DNPH-coated cartridges outfitted with ozone scrubbers and connected to constant flow pump systems over the same time period as the canisters. VOC samples will be analyzed using Method TO-14 with an expanded PAMS list of compounds (see Table 4-1). Carbonyl samples will be analyzed using Method TO-11 for the compounds listed in Table 4-2. Analysis will be performed by Environmental Analytical Services, Inc., Santa Barbara, CA.

Table 4-1. Target compound list for EPA Method TO-14 Toxics in Air (Expanded for PAMS).

Ethene	Cyclohexane	Total Petroleum Hydrocarbons:
Acetylene	2-Methylhexane	Total Non-Methane Hydrocarbons
Ethane	2,3-Dimethylpentane	Total Gas Non-Methane Organics
Propene	3-Methylhexane	Total Volatile Organic Compounds
Propane	2-Methyl-1hexene	TPH (gasoline)
i-Butane	Tert amyl methyl ether	TPH (diesel)
Methanol	2,2,4-Trimethylpentane	TPH (hexane)
1-Butene	n-Heptane	TPH (toluene)
1,3-Butadiene	Methylcyclohexane	TPH (methane)
n-Butane	2,5-Dimethylhexane	TPH (Jet A Fuel)
t-2-Butene	2,4-Dimethylhexane	TPH (Mineral Spirits)
c-2-Butene	2,3,4-Trimethylpentane	c6+ (hexane)
Ethanol	Toluene	Sample: Composition
3-Methyl-1-butene	2,3-Dimethylhexane	Total Identified
Acetone	2-Methylheptane	Paraffins
i-Pentane	4-Methylheptane	Isoparaffins
1-Pentene	3-Ethyl-3-methylpentane	Aromatics
Isopropanol	3-Methylheptane	Napthlenes
2-Methyl-1-butene	2-Methyl-1-heptene	Olefins
n-Pentane	n-Octane	Oxygenates
Isoprene	Ethylbenzene	Carbon Ranges:
t-2-Pentene	m,p-xylene	C2 (ethane)
c-2-Pentene	Styrene	C3 (propane)
Tert butyl alcohol	o-xylene	C4 (Butane)
2-Methyl-2-butene	1-Nonene	C5 (Pentane)
2,2-Dimethylbutane	n-Nonane	C6 (Hexane)
Cyclopentene	i-Propylbenzene	C7 (Heptane)
n-Propanol	n-propylbenzene	C8 (Octane)
Cyclopentane	a-Pinene	C9 (Nonane)
Methyl tert butyl ether	3-Ethyltoluene	C10 (Decane)
2,3-Dimethylbutane	4-Ethyltoluene	C11+ (Undecane)
2-Methylpentane	1,3,5-Trimethylbenzene	
3-Methylpentane	2-Ethyltoluene	
1-Hexene	b-Pinene	
n-Hexane	1,2,4-Trimethylbenzene	
Diisopropyl ether	n-Decane	
3-Methylcyclopentene	1,2,3-Trimethylbenzene	
Ethyl tert butyl ether	Indan	
Methylcyclopentane	d-Limonene	
2,4-Dimethylpentane	1,3-Diethylbenzene	
Benzene	1,4-Diethylbenzene	
	n-Butylbenzene	
	1,4-Dimethyl-2-ethylbenzene	
	1,3-Dimethyl-4-ethylbenzene	
	1,2-Dimethyl-4-ethylbenzene	
	Undecane	
	1,2,4,5-Tetramethylbenzene	
	1,2,3,5-Tetramethylbenzene	
	Napthalene	
	Dodecane	

Table 4-2. Target compound list for EPA Method TO-11 volatile organic compounds.

Compound
Formaldehyde
Acetaldehyde
Acrolein
Acetone
Propionaldehyde
Butyraldehyde
Methylethylketone
Benzaldehyde
Valeraldehyde
Cyclohexanone
Hexaldehyde

4.5 UPPER AIR METEOROLOGY

An ASC Model 3000 miniSodar, and a surface-based meteorological system will be used to collect the upper air meteorology data. These instruments provide vertically and temporally resolved boundary layer winds and boundary layer depth (i.e., mixing height) data. The Sodar provides continuous (hourly or sub-hourly) wind data with a vertical resolution of 10 m at heights from about 10 m up to about 400 m agl. The exact height coverage at any given time depends on atmospheric conditions. Continuous (hourly or sub-hourly) boundary layer depth can be derived from the Sodar reflectivity data. An example of this is shown in Figures 4-4.

As part of the operations, we will design and implement sampling strategies for the Sodar, including programming the data acquisition systems to operate the instruments under configurations that produce the highest quality data for the typical atmospheric conditions found in the Upper Green River Basin.

Accuracy (instrument specifications)	
Horizontal Wind Speed	0.5 m/s
Horizontal Wind Direction	±5°
Maximum Altitude	200 meters
Sampling Height Increment	5 meters
Minimum Sampling Height	15 meters
Transmit Frequency	4500 Hz.
Averaging and Reporting Interval	1 to 60 minutes

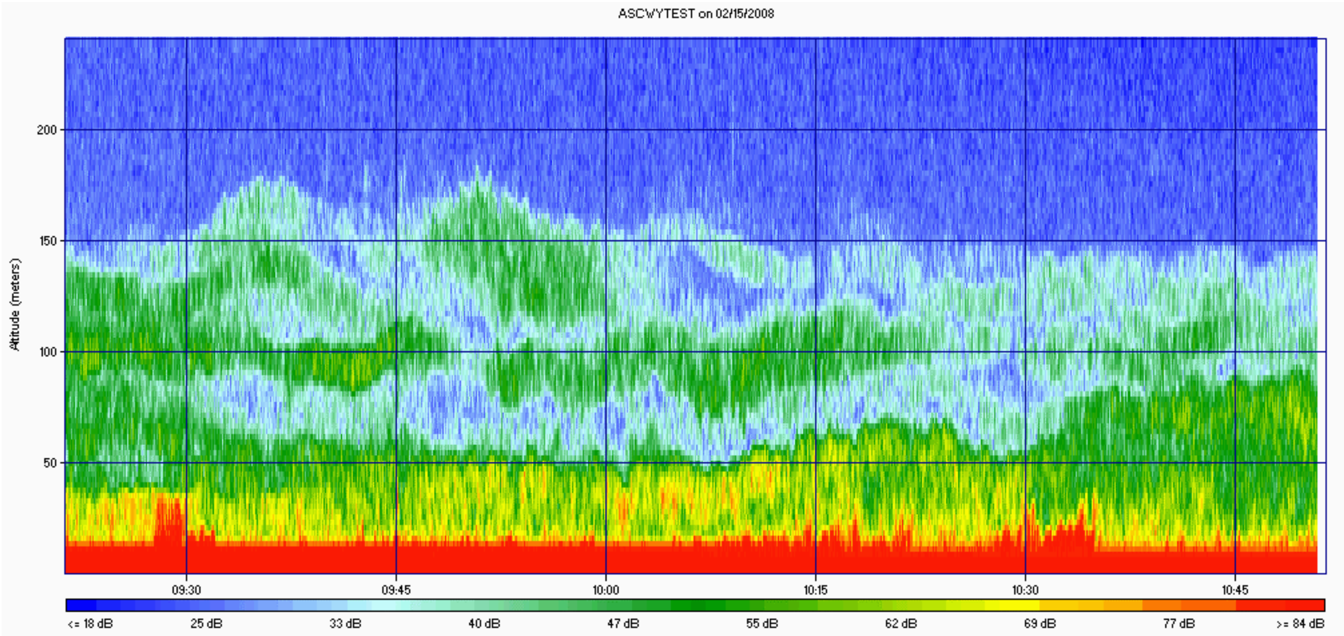


Figure 4-4. Example of sodar backscatter data capturing the daytime mixing height layers under cold wintertime conditions.

4.6 ADDITIONAL MEASUREMENTS

Total UV Radiation

UV radiation will be measured using two Eppley Total UV Radiation (TUVR) sensors – one facing upward to the sky and one facing downward to the ground. The Eppley Ultraviolet Radiometer consists essentially of a selenium barrier-layer photoelectric cell with a sealed-in quartz window, a bandpass filter to restrict the wavelength response of the photocell to the designed range, generally 295-385 nm (i.e. adhering closely to the generally accepted limits for solar ultraviolet radiation reaching the earth's surface, even at altitudes as high as l5,000 feet) and virgin Teflon diffusing disk. The purpose of this disk is twofold, - to reduce the light intensity at the filtered photocell (and thus to increase its stability with exposure time) and also to improve the adherence of the instrument to the Lambert cosine law (and is shaped with this object in view).

These sensors were installed at the Boulder site during the initial 2007 study.

SECTION 5

DATA REPORTING

5.1 DATA MANAGEMENT PLAN

A primary study objective is to produce an adequately validated data set from the field measurements that is well defined and documented within the desired completion time. The overall goal of the data management effort is to create a system that is straightforward and easy for users to obtain data and provide updates.

Each data provider will be responsible for reviewing and validating their collected data. The raw data will be validated to level 1 as described in "The Measurement Process: Precision, Accuracy, and Validity" (Watson, 2001) before being submitted to the database. This includes flagging values for instrument downtime and performance tests, applying any adjustments for calibration deviation, investigating extreme values and applying appropriate flags. Flags used for UGWOS are presented in Table 6-1. Each data provider will be responsible for documenting the validation process so that it could be provided to the data manager and other analysts if needed.

In addition, each data provider will be responsible for furnishing information regarding the monitoring equipment used in the field study and any additional site information to the data manager as requested to enhance the overall documentation of the study. In particular, participants will provide the Monitoring Quality Objective (MQOs) defining the quality of all data submitted as "valid." These MQOs contain the following:

- Accuracy
- Precision
- Lower quantifiable limit
- Resolution
- Completeness

If cases exist where data do not meet the primary MQOs but is still deemed useable and can be defined with a secondary set of MQOs, these additional MQOs and the dates to which they apply will also be submitted.

Flag	Description
V	Valid. Data meets primary MQOs.
S	Valid, but does not meet primary MQOs. Secondary MQOs in effect.
I	Data invalid.
M	Missing. Measurement not taken.

Table 6-1. Data Flags.

Once the data have been validated to level 1, the data will be prepared for submittal to the database in a form that clearly define the time reference, averaging period, parameter names and units. The time reference for the database is **local standard time (Mountain Standard Time)** and the averaging period reference will be standardized to **hour beginning (0 – 23)**. The data will be submitted as ASCII comma delimited text files or excel spreadsheet files, with data columns well defined to clarify site identification, parameters, instrumentation, units, and time reference.

Data will be submitted in a format similar to that of the final database structure, as outlined below. This basically has a second column for each measured value for an accompanying QC code. Data flagged as invalid or missing will be given a value of -9999. In the event that data for a given measurable is either all valid (meeting primary MQOs) or all missing, participants need not supply the flag column, though this must be specifically stated.

Database Management Design

T&B Systems will be responsible for assimilating the submitted data into an integrated relational Microsoft ACCESS database and is managing the data for subsequent distribution and analysis. The database will consist of both information and data files. The goal is to make the database very usable by data analysts and all participants.

The following describes design for the database that was implemented during the 2007 field study. The database includes an inventory spreadsheet file to help users track and ensure that all of the data were submitted and processed in a timely and consistent manner. All data files submitted will be examined to verify unique names for all sites, instruments, and parameters so that no orphan or duplicate records exist in any of the tables. A system is in place for identifying the version and or modification date of all data files.

The data have the following flat format:

Surface Hourly Meteorological Data

SITE, DATE, HOUR, WS, WS_QC, WD, WD_QC, TP, TP_QC, and any additional met parameters and QC codes, if collected.

Ozone 8-hour averaged:

SITE, DATE, HOUR, O3_8HR, O38HR_QC

Hourly Surface Air Quality:

SITE, DATE, HOUR, OZONE, O3_QC, NO, NO_QC, NOx, NOx_QC, NOy, NOy_QC, PAN, PAN_QC and any additional air quality parameters if collected and QC codes.

NMHC VOC:

SITE, DATE, HOUR, START_TIME, END_TIME, CANNISTER_ID, QC_CODE, PARAMETER1, PARAMETER2, PARAMETER3,..PARAMETERn, notes

Upper level meteorological and air quality data

The episodic rawinsonde, ozonesonde, pibal, and glider data will be stored together in a file with the following format:

SITE, DATE, TIME, HEIGHT, PRESSURE, PRESSURE_QC,

O3, O3_QC, WS, WS_QC, WD, WD_QC, TP, TP_QC, RH, RH_QC

Radar Profiler and SODAR data will be stored in both a flat file format and a CDF (common data format) or similar tabular format. CDF files are used for plotting the data. Participants should include both flat files and CDF files with their data submissions. The final flat format will be as follows:

SITE, DATE, HOUR, TIME, HEIGHT, WS, WS_QC, WD, WD_QC

The data will be formatted into the final database with the following unit configurations and naming conventions:

- Parts per million for O3
- Meters per second for wind speed (as a general rule, metric units will be used)
- Degrees Celsius for ambient temperature
- Percent for relative humidity
- Parts per Billion Carbon for non-methanated hydrocarbon species
- Watts/m^2 for radiation

- SITE = Alpha-numeric site code identifier
- DATE = (MM/DD/YY)

- HOUR= Nearest whole begin hour (HH) (MST)
- TIME, START_TIME or END_TIME = Time stamp of data (HH:MM:SS) (MST)
- HEIGHT = Elevation in meters above MSL
- QC_CODE, WS_QC, WD_QC, O3_QC, etc =
  "V" (valid), "M" (missing), "I" (invalid), "S" (secondary MQOs)
- NOTES = any additional information

The Level 1 data files along with the documentation files will be available for download on an FTP server.

5.2 DATA REPORTING

Data files of all data collected during the study will be transmitted to WDEQ by June 15, 2008.

The ENVIRON/T&B team will review the validated data collected during the field study and prepare descriptive summaries in a report format for delivery to WDEQ. We will prepare summaries of air quality and meteorological conditions during the study period. In addition, we will prepare more detailed descriptive analyses of the air quality and meteorology measured during each high ozone event captured by the intensive operating periods. As part of our Level 1 data validation procedures, we will carefully examine all of the measurements. This process typically provides insight into the critical processes that determine the extent of pollution loading such as atmospheric stability, wind shears (low-level jets, etc), layers aloft, and boundary layer development (growth rate, peak mixing heights), including the nocturnal boundary, convective boundary, and residual layer. The meteorology leading up to and during periods with high ozone levels and the diurnal behavior of ozone aloft during these periods will be characterized.

Supporting the analyses discussion, products that will be produced in this phase of the study include but are not limited to:

1. Time-series plots of continuous measurements such as ozone, ambient temperature, radiation;
2. Vertical profiles of ozone, temperature, and winds;
3. Horizontal mapping of ozone, precursors, ambient temperature, and winds—both at the surface and aloft;
4. Time-height cross sections of ozone, potential temperature, winds, and mixing heights.
5. Time-height cross sections of transport statistics including scalar transport distance, vector transport distance, and recirculation factors
6. Wind roses at the surface and select levels aloft,

7. Pollution roses at the surface and select levels aloft, and
8. Summary tables of 1-hour and 8-hour averaged ozone as well as statistical summaries showing hourly averages and maximums.

A final report will be prepared presenting:

- The above-mentioned information and associated analyses in an easy to digest format.
- A summary of field operations via tables showing the times of balloon-borne soundings, the times of ground and airplane sampling, VOC samples, and supplemental measurements. A measure of the associated data capture rates will be included. Problems encountered during the field operations will be discussed.
- Details of the database design including descriptions of the metafiles; field descriptors; and the accuracy, precision, lower limits, resolution, and completeness of each measurement.

A draft version of the report will be presented to WDEQ by June 30, 2008. Voluminous tables and figures will be incorporated into electronic appendices as appropriate. All report materials will be made available via a project web site with access restricted in accordance with WDEQ policies and procedures.

SECTION 6

QUALITY ASSURANCE PROGRAM

6.1 PROJECT MANAGEMENT

Mr. Till Stoeckenius will serve as overall project manager and co-principal investigator. Dr. Greg Yarwood will serve as ENVIRON's Principal in Charge for the proposed project, insuring that any and all ENVIRON resources needed for the timely and on-budget completion of the project are made available.

Mr. Don Lehrman will serve as manager of all field operations and co-principal investigator, overseeing the day-to-day project activities and providing the primary interface with team members on project related issues.

Additional key staff will be assigned to each project task as shown in Figure 3-1. Quality assurance will be lead by Mr. David Bush. Mr. Bush has extensive experience in this area, having served as the external quality assurance officer for a number of large air quality studies. He will also be closely involved in field study operations. Mr. Robert Baxter will also be involved in field study operations and will lead the data archiving task. Mr. Baxter has managed numerous field studies including the Clark County (Las Vegas) CO Saturation and PM_{10} studies. Key staff from T&B Systems, MSI and STI will be responsible for the deployment, operation, and data gathering from the specific instrumentation programs they are assigned to.

Study personnel responsibilities and contact information is presented in Table 6-1.

A UGWOS study web site has been developed to assist in communications between study participants. This web site can be found at http://70.133.103.202/UGWOS. The web site contains the following web pages:

- Study Overview - This page presents a brief overview of the study, the study objectives, and study schedule.
- What's New? – This page serves as "document control" for the web site, providing a complete history of all modifications to the web site. Anytime the web pages are expanded or modified, a brief summary and the date of the modification is posted.
- Project Status – This page provides information regarding the readiness of participants' monitoring efforts. The page is particularly important during the early stages of the study period for helping to maintain the study schedule.

- Study Forecast – This page provides for the communication of study-specific information regarding forecasted ozone conditions, and serves as the alert for IOPs and episode-mode monitoring efforts.

- Monitoring Sites – This page provides a description of the CCROPS measurements and a map of the measurement locations.

- Project Participants – This page provides a list of the CCROPS participants, a summary of each participant's study responsibilities, and contact information for key individuals.

- Planning Documents – This page requests and posts measurement quality assurance documentation. This is discussed in more detail below.

- Preliminary Analysis – This page provides participants with a means to present preliminary analysis of collected data. This in turn provides study management with feedback regarding collected data versus study goals, and the means of refining the monitoring effort, if needed.

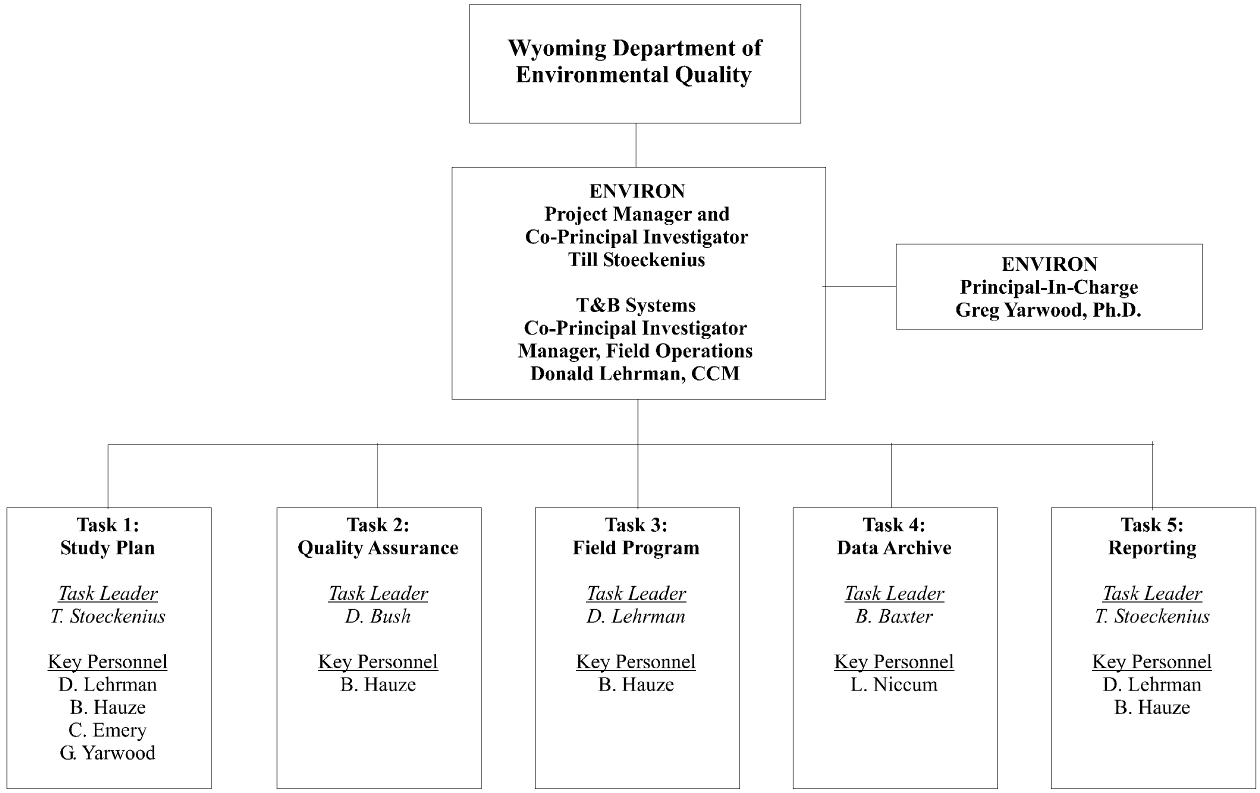


Figure 6-1. Project organization.

Table 6-2. Project Responsibilities and Contacts

Name	Organization	Key Responsibilities	Phone Numbers
Cara Keslar	Wyoming DEQ	Contract Manager	(307) 777-8684 (307) 421-9953 (cell)
Jennifer Frazier	Wyoming DEQ	Pinedale Support	(307) 231-2387 (cell)
Till Stoeckenius	Environ	Project Manager Principal Investigator	415-899-0709 415-717-0039 (cell)
Don Lehrman	T&B Systems	Field Project Manager Ozonesondes Principal Investigator	(707) 526-2775 (707) 975-4412 (cell)
David Bush	T&B Systems	Quality Assurance Aircraft Measurements	(530) 647-1169 (530) 903-6831 (cell)
Bob Baxter	T&B Systems	Overall Field Measurements Support Sodar Operations	(661) 294-1103 (661) 645-0526 (cell)
Bill Knuth	T&B Systems	Study Setup and Teardown Ozonesondes	(707) 279-1661 (707) 975-4413 (cell)
David Yoho	T&B Systems	Aircraft Measurements Field Support	(661) 294-1103 (661) 212-3008 (cell)
Bill Hauze	MSI	Field Support	(801) 474-3826 (801) 450-3776 (cell)
Dan Risch	MSI	Forecasting	(801) 474-3826
Tyler Ward	MSI	Mesonet Site Checks, VOC Sampling	(801) 450-8706 (cell) (928) 814-3926 (cell)
Michael Butler	IML	Daniel Site Operations	(307) 674-7506 (307) 751-3108
Lincoln Sherman	ARS	Boulder Site Operations	(970) 222-5362
Jim McLellan		Aircraft Pilot Pinedale Airport Support	(307) 367-4395 (307) 537-5488 (home)

6.2 DATA QUALITY OBJECTIVES

Specific monitoring quality objects have been presented for each measurement in Section 4 of this document. The overall objectives for the collection of valid data will be as follows:

Air quality data: 80% of the possible data

Meteorological data: 90% of the possible data

For the above calculation, data lost during calibrations, maintenance or audits are considered invalid.

6.3 ASSESSMENT AND OVERSIGHT

QUALITY CONTROL PROCEDURES

As part of the quality assurance program, detailed quality control procedures have been implemented to assess and maintain control of the quality of the data collected. All equipment will undergo complete checkout and acceptance prior to the start of monitoring on February 16, 2008. This checkout will occur during the week prior to the start of monitoring, during setup and installation of the equipment. This includes a dry run of all measurement methods, during which operating procedures can be refined and fully documented. Standard operating procedures (SOPs) for measurements will be completed prior to the start of monitoring. SOPs can be found in Appendix B.

A summary of key elements of the QC program for each measurement is presented below:

Ozone Analyzers and Samplers

All ozone analyzers and samplers will be routinely checked using a certified transfer standard, following operating procedures consistent with EPA guidelines. This will consist of zero and span checks conducted at the beginning and end of each IOP. These checks will be conducted using a transfer standard certified against T&B Systems primary standard maintained following EPA's guidelines at their office in Valencia, CA. For the mesonet equipment, a 2B model 306 (S/N 2) portable ozone calibrator will be used. Zero/span checks of the mesonet samplers will be conducted at least twice per week during the IOPS, providing precision data. A pass/fail criterion of +/-10% will be used when evaluating the span and calibration data. A zero check and ground truth comparison will be performed on all tethersonde and ozonesonde equipment prior to each flight.

Aircraft Samplers

QA/QC for the aircraft ozone sampler will be similar to that for the other ozone analyzers and samplers. This would include calibrations at the beginning and end of the study, as well as zero check and ground truth comparison each intensive day. In addition, we will periodically conduct soundings coincident with ozonesonde soundings, providing a QA comparison for both aircraft and ozonesonde measurements. In addition, soundings at each of the tethered sounding sites will be conducted each day, providing additional QC data. The DustTrak will be subject to zero and flow checks each intensive day.

MiniSodar

The status of the instruments will be checked daily via remote access of the data. If any problems are encountered that could affect data recovery, repairs will be made promptly. The data will be transferred hourly to T&B's server, using a cellular modem. Data can also be accessed in real time so that team members can use the data to assist in special monitoring and forecasting.

VOC Sampling

Field blanks totaling approximately 5% of the collected samples will be collected and analyzed. In addition, two of the samplers will be collocated periodically during the study to collect duplicate samples.

Radiation Sensors

The relative calibrations of the two radiation sensors will be periodically checked by aiming both sensors towards the sky and recording the responses. The ratio of the responses should be consistent with that obtained from the calibration certifications that accompany the sensors. In addition, the zero response of each sensor will be checked at the same time by covering the sensor with a UV blocking substance.

CALIBRATIONS

The purpose of a calibration is to establish a relationship between the ambient conditions and an instrument's response by challenging the instrument with known values and adjusting the instrument to respond properly to those values. The calibration method for each of the air quality and meteorological variables is summarized in Table 6-1.

Calibrations of the ozone instruments will be performed upon initial installation and at the end of the study period. Additional calibrations will be performed on an as-needed basis in the event of equipment repair or replacement. All calibrations will be performed in accordance with manufacturers recommendations and consistent with USEPA guidance (USEPA, 1994, 1995, 2000).

Calibrations and zero/span checks of all ozone monitoring equipment will be conducted using a transfer standard (2B Model 306, S/N 002) certified against a local ozone standard (Dasibi Model 1003-PC, S/N 2437) maintained at the Pinedale airport. This local standard in turn has been certified against T&B System's primary standard maintained following EPA's guidelines at their office in Valencia, CA, as well as against the US EPA Region 8 primary standard maintained at Boulder, CO prior to the initial 2007 monitoring. The two certifications showed very good agreement.

Ozone data will be adjusted if the calibration slope is off by more than ±5% or if the zero is off by more than ±5 ppb.

All meteorological sensors will be calibrated at the beginning and ending of the study. Wind speed sensors will be calibrated using an RM Young constant rpm motor simulating wind speeds at several points across the sensor's operating range. Wind direction sensors will be calibrated by checking responses in 30° to 45° increments. Calibration of the UV radiometers is provided by the manufacturer.

Table 6-1. Calibration methods for the monitored variables.

Measurement Variable	Calibration Method
Ozone (O_3)	Multipoint comparison of ozone concentrations with certified ozone transfer standard
Wind Speed	Rotational rate using a selectable speed anemometer drive
Wind Direction	Alignment using true north and linearity with a directional protractor
Temperature	Water bath comparisons to a certified transfer standard
Relative humidity	Collocated comparisons to a certified transfer standard

INDEPENDENT AUDITS

As part of the quality assurance program, an independent audit program will be implemented that will use an independent entity to verify the site operations and data accuracy. These audits will be performed using personnel independent of the measurement program. This will establish confidence in the data collected and allow the measurement processes to be supported through independent verification. Audits will be performed in accordance with the principles of the US EPA.

The principal audit tool will be system audits of the data collection operations. System audits will address the following:

- Siting
- Adherence to SOPs
- QA/QC procedures
- Documentation
- Data collection and chain of custody

Mr. David Bush and Mr. Bob Baxter will conduct the system audits of all measurement platforms, with audit responsibilities based on independence from the operations of the monitoring efforts. These audits will be conducted during or before the first IOP of the study. Comments and recommendations resulting from the audits will be discussed with measurement personnel at the time of the audit, with a written memo report provided to study management within 48 hours of the audit.

As discussed above, to further verify the accuracy of the ozone measurements, the T&B Systems ozone transfer standard will be compared against the US EPA Region 8 primary standard located in Golden, Colorado. This comparison will consist of a six-point comparison, per US EPA guidance for ozone transfer standards, and will be conducted prior to its use for the UGWOS.

6.4 DATA VALIDATION

All data collected for UGWOS be will validated to Level 1 validation (see Section 5). As part of the validation effort, participant's data will be evaluated to verify that they meet the stated MQOs. If data clearly do not meet MQOs, they will be removed from the database as invalid data. If, however, data miss meeting the primary MQOs in a definable way to the point where the data are still considered useful, secondary MQOs will be assigned to the data in question. This use of secondary MQOs will be specifically documented in metafiles associated with the data.

For the miniSodar, monthly reviews and editing will include Level 1 and Level 2 validation of wind, T_v, and mixing height data. Level 1 validation is a check of internal consistency and reasonableness for each site for each hour (or sub-hour, depending on measurement frequency). Level 2 validation is an external consistency check of the data and is achieved by comparing the data with those collected at nearby locations for each day, including comparisons of wind and temperature data to meteorological data from other sources (e.g., rawinsondes, synoptic weather charts). The final product will include electronic files containing Level 2-validated mini-sodar wind and mixing height data.

SECTION 7

REFERENCES

United States Environmental Protection Agency (1995). Quality Assurance Handbook for Air Pollution Measurement Systems Volume IV: Meteorological Measurements. Document EPA/600/R-94/038d. Office of Research and Development, Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, North Carolina.

United States Environmental Protection Agency (1998): Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II: Part I, Ambient Air Quality Monitoring Program Quality System Development. Office of Air Quality Planning and Standards. Draft Revision to Document EPA/600/R-94/038b.

United States Environmental Protection Agency (1999): EPA Requirements for Quality Assurance Project Plans. Document EPA QA/R-5. U.S. EPA Quality Staff Interim Final Report, Research Triangle Park, North Carolina. November.

United States Environmental Protection Agency (2000). Meteorological Monitoring Guidance for Regulatory Modeling Applications. Document EPA-454/R-99-005. Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina.

Watson, J.G., B.J. Turpin, and J.C. Chow (2001). The measurement process: Precision, accuracy, and validity. In *Air Sampling Instruments for Evaluation of Atmospheric Contaminants,* 9th ed., B. Cohen, Ed. American Conference of Governmental Industrial Hygienists, Cincinnati, OH, in press.

APPENDIX A

SITE PHOTOS

View to North

View to East

View to South

View to West

View of Site

Cora

View to North

View to East

View to South

View to West


View of Site

Warbonnet

 View to North	 View to East
 View to South	 View to West
 View of Site	

Haystack Butte

View to North

View to East

View to South

View to West

View of Site

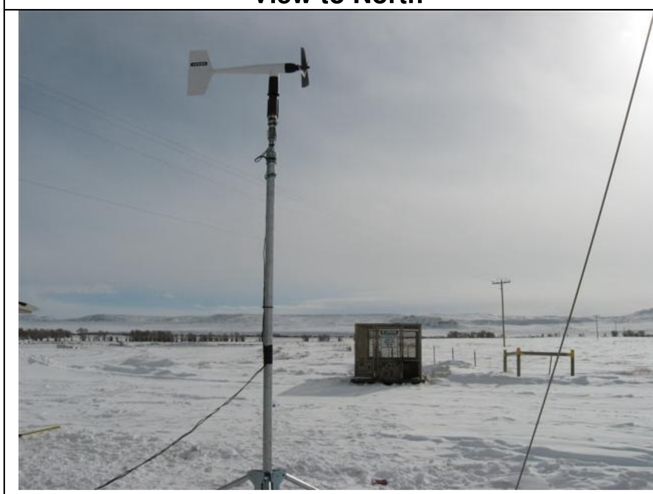
Simpson Gulch

 View to North	 View to East
 View to South	 View to West
 View of Site	

La Barge

View to North

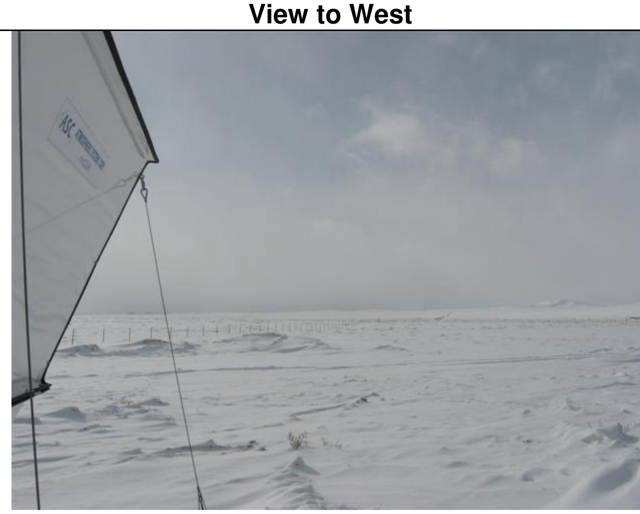
View to East



View to South

View to West

View along U Beam (345°)



View along U Beam (255°)

Mini-Sodar Site

APPENDIX B

STANDARD OPERATING PROCEDURES

1. STATION SETUP

This section to be executed only when installing equipment at a new site.

GPS Station Setup Elevation Procedures

VIZ Setup Program requires three elevation fields to be filled out. Those are:

1. DGPS Antenna Height (with reference to WGS-84 elevations)
2. Geoid Separation
3. MSL Station Height

Knowing any two of the three, the third can be determined using a variation of the following relationship:

DGPS Antenna height = MSL station height + Geoid Separation + Height of GPS antenna off ground level

Station Coordinates and MSL station height can determined from a very accurate site-specific survey.

If you know the Station Coordinates accurately before going to the field, you can obtain the Geoid Separation (from WGS-84 elevations) from the following website:

<http://www.nima.mil/GandG/egm84/intptW.html>

Otherwise the following procedure is recommended:

1. Run the program LOCATE

   To run LOCATE at the DOS prompt type "START LOCATE" (note that ground GPS antenna must be installed and W9000 system turned on). Allow the program to run for at least 10 minutes until stable readings are noted. When the "Escape" key is pressed, the resultant Latitude, Longitude, and Station Height relative to WGS-84 coordinates is shown on the monitor (which is the same as DGPS Antenna Height).

2. Using the surveyed MSL site elevation or the best estimate height with the results from LOCATE, you can calculate the DGPS antenna height in WGS-84 using the equation shown above.

3. Note that the last term in the equation is simply an estimate of the height of the GPS antenna above the ground release point (~2 meters unless mounted on a structure).

Some examples:

At Site A, we were able to determine beforehand the approximate Latitude and Longitude of the site. From the above web site, it was determined that the Geoid separation was -20 meters. Once at the site, LOCATE is run (for a minimum of 10 minutes). The height shown in LOCATE is "-20 meters", relative to WGS-84 coordinates that must be corrected to actual using the cited relationship.

Station Height = DGPS Antenna Height - Geoid Separation - Antenna height (~2 m)
= -20 meters - (-30 meters) - 2 meters
= 8 meters

At Site B, we had no prior knowledge of its location but the site documentation gives a height of 230 meters. LOCATE is run yielding a height of 210 meters. Again the antenna is mounted on a tripod 2 meters off the ground. From the referenced relationship:

Geoid Separation = DGPS Antenna Height - Station Height - Antenna height
= 210 meters - 230 meters - 2 meters
= -22 meters

For both examples above, it is preferred to use the coordinates obtained from the LOCATE program.

NOTE: if when running the W9000 Flight Program the first time at this site, the error "Base Coordinate Error" or something to that effect, it means the software can not reconcile the height and/or location input in Setup. Run Setup again, checking the input.

Also NOTE: that the last field in the Elevation Setup, **Height Adjustment**, is no longer used.

Special Note When **Using for Audits**: A special version of the post-flight processing programs are available, call finaud.bat and audver.exe. Features of this processing program is that heights output will be meters above ground level, and virtual temperature is included in each record.

T&B Systems processing header information (all radiosonde types)

The ASCII file "SSSinput." must be edited for new sites. This information is what is output in the .DAT header record. Use the DOS or any other editor to edit. Change the fields as necessary. keeping the spacing (blanks). The edited file be must renamed so that the SSS is station ID that is used in the VIZ software.

Wind Computation Setup

GPS : Wind Interval Selection

Select Invervals by Time

	Section Start (seconds)	Smoothing Length (seconds)	Minumum Inteval Samples	Computation Interval (seconds)
1	0	1	1	1
2	6	10	5	1
3	666	20	10	10

GPS : Wind Parameter Setting

Differential GPS Curve Fit Variance 0.90
Raw Wind Sampling Interval (seconds) 1.00

LORAN: Wind Interval Selection

Select Invervals by Time

	Section Start (seconds)	Smoothing Length (seconds)	Minumum Inteval Samples	Computation Interval (seconds)
1	0	60	15	15
2	180	120	30	15
3				

LORAN: Wind Parameter Setting

Loran Curve Fit Variance 0.90
Raw Wind Sampling Interval (seconds) 3.00

2. SONDE OPERATIONS

Prepare sonde and battery; remove humidity sensor's protective cap*; remove plastic cover from thermistor arm, and orient at a 45° upwards and out from the body of the sonde; soak the battery in water for 2 minutes, then shake excess water from battery by (with label facing down assuring water will not be trapped by the wax layer) extending arm and swinging over your head to an abrupt stop at your knees, and repeat this 5 times. Then visually inspect battery for any remaining excess water.

*(Once the humidity sensor's cap is removed, close the flap and tape it down. This is also per the manual (section 5 page 4).)

Place battery in the clear plastic bag provided. Place battery into the compartment that the battery was originally packed in on the front of the sonde *with the label facing out* from sonde.

Connect battery wires to those of the sonde. Always connect the negative (ground, black) wires first when connecting the battery to the sonde. This is necessary for proper initialization. This is actually straight out of the manual (section 5, page 3), not some voodoo superstition.

Once connected, **let sonde battery warm up** *until signal begins to emit*. Not doing so will almost assuredly result in having to re-initiate the sonde (which as we know is a likelihood anyways).

Also per the manual, once the battery is hooked up and placed into it's location in the sonde (with the "TOP" label facing out), **tuck the wires into the same compartment before closing the flap and taping**. To quote the manual (section 5, page 4) "failure to put all the wire for the battery inside the battery compartment may cause radio energy to fee back into the circuits of the radiosonde."

Meanwhile, **prepare balloon** as usual (keeping in mind that an ascension rate greater than 3 meters per second is necessary for the launch to be detected), and **turn on the system computer** booting in DOS mode. (The station set-up procedure should have already been completed when first installing the site. See "station set-up notes" above). Make sure that the 403 receiver has already been turned on for at least 15 minutes before proceeded with flight (this is necessary for proper GPS coordination). Depending upon the particular launch-schedule for your project, often it is prudent to **leave the receiver on between flights** to avoid having to wait the 15 minutes each time.

From the C: prompt, type "start" to open Zeemet software. The **flight identifiers screen** should now be displayed on the system computers monitor. Enter the 6-digit sonde serial number (located on bottom of sonde), and the new flight identifier. Escape from this screen, and accept the correct values entered. **The flight preparation screen** will now open, and you will be prompted to connect the initialization cable to the sonde.

Initialize the sonde. Plug the initialization cable into the plug attached to the sonde with the words "TOP" clearly displayed from (get this) on top (above). **Wait 15 seconds** and then press "enter" and the initialization process will begin. (the 15 second delay here "allows the radiosonde microprocessors time to complete their start-up sequences").
Note: There is no pattern in the initialization process. This means that an initialization with very faint or no clicks at all may be perfectly fine (usually not); that the signal may not modulate at all

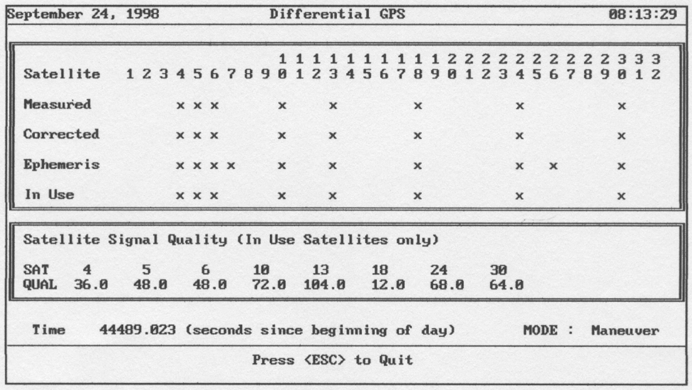
while hanging in it's static pre-flight position, but may pop in perfectly 2 minutes or 5 minutes or 30 seconds before arming for launch (or maybe not); that IN MOST CASES the sonde will need to be initiated at least twice, possibly 3 times, sometimes only once which brings up:
The 3 STRIKES YOU'RE OUT rule. The sonde may need to be re-initialized 1, 2 or 3 times, but if it hasn't happened by then, it probably will not happen; after 3 strikes (the point of diminishing returns), move onto a new sonde. 80% of the time the sonde successfully initiates on the 2nd try, but if not usually "the third time's a charm."

When initialization is complete (3-6 minutes approx.), you will be prompted that the "initialization is complete." Once the initialization is complete, the cable needs to be removed quickly and the sonde moved to it's (predetermined) static pre-flight position ***within one-and-a-half minutes*** according to the manual. The "two actions must be done quickly as they are time sensitive." (Section 5 page 4) " The radiosonde has been programmed to start acquiring satellites immediately after the initialization cable has been removed" (section 6 page 6).

A note on the "static pre-flight position": for the duration of the project, you should have selected and installed a stationary position outside of the inflation room/computer-receiver room (near the launch site) that allows you to hang the sonde from it's tie ring with the GPS antenna pointing upwards and leave it there as you proceed with other aspects of this flight's set-up. The view of the sky from here needs to be unobstructed, and **this stationary position is crucial** for the GPS capabilities of the sonde to be able to lock in to position and be of use. Also, through trial and error, Bill and I found that the static pre-flight position chosen to hang the sonde should be placed in a position that roughly forms a triangle with the two antennaes.

For more detailed information surrounding the initialization process, see Chapter 6 (page 6) "Pre-Flight and In-Flight Operating Instructions" in the GPS Supplement to the W9000 Operation Manual.

Once the sonde has been moved outside to it's stationary position, the sonde will now begin gathering and locking onto satellites. Depending on weather conditions and other variables, this process may take 10 minutes or more (but usually less). A minimum of 4 satellites need to be collected and locked onto for the GPS positioning of the sonde to be enabled.
After typing "1" from the flight preparation screen (the category of "Wind Finding Status, dgps"): the satellites will first start to appear on the "ephemeris" line, and then start to pop in along the "corrected" and "measured" lines just before finally appearing in the "in use" category (at which point also the "satellite signal quality" box will begin filling in with the satellites that are locking in**). It is only the "in use" category that we count when determining that the GPS satellites are adequately locked in.** See Figure 6-10 on the next page (copied from GPS Supplement).



September 24, 1998 — Differential GPS — 08:13:29

Satellite	Measured	Corrected	Ephemeris	In Use
4	x	x	x	x
5	x	x	x	x
6	x	x	x	x
7			x	
10	x	x	x	x
13	x	x	x	x
18	x	x	x	x
24	x	x	x	x
26			x	
30	x	x	x	x

Satellite Signal Quality (In Use Satellites only)

SAT	4	5	6	10	13	18	24	30
QUAL	36.0	48.0	48.0	72.0	104.0	12.0	68.0	64.0

Time 44489.023 (seconds since beginning of day) MODE : Maneuver

Press <ESC> to Quit

Figure 6-10. W9000 Differential GPS Screen(LOS, LOS-B, LOS High Resolution)

Note: once the satellites seem locked in while viewing this page and then you "escape"to get back to the flight preparation screen, you'll notice that the asterisk has not yet appeared or has disappeared next to the category of "Wind Finding Status, dgps." This is normal, but you'll need to now wait for a few minutes for the system to re-lock onto the satellites; for whatever reason, toggling back and forth to view the detailed satellite status information interrupts the GPS lock-up, and will thus result in delaying the launch.

If it becomes apparent that for whatever reason the sonde is unable to lock onto the satellites, then re-initialization will be required. However, keep the following in mind:

When you progress to the point of waiting for the satellites to start popping in, it will seem that it's taking forever with no apparent progress, but remember that **the "in use" satellites will usually *all appear at once*...** that while it appears as though nothing's progressing, it actually is. It just doesn't come in incrementally. So don't give up on it too quickly…

While the sonde is hanging in it's stationary position and you are waiting for the satellites to start locking in, by now you should also have a "match" between the sonde's broadcast signal and the receiver (or to put it differently, a match between the sonde's serial number and the serial number you entered), signified with an asterik now appearing next to the "receiver" field on the flight preparation screen, in the pre-flight menu box (number 4). The signal should be modulating strongly (an unmistakable sound that you will become very familiar with)* **Most often, when it's *going* to happen, the receiver will lock onto the signal (get a match) from the sonde almost immediately**. Before or as you walk the sonde out to it's static pre-launch position, the match should just pop right in (meaning that the asterisk will appear almost immediately next to the "Receiver" status in the window). Unfortunately, this is not always the case, so you can't use it as a general rule; it may take a few minutes to lock as it often did with the loran-sondes. But to spend too much time trying to hand tune (via the "alt-t") *unless it's already locked once (and you've **already** had a "match")* is not worth the effort; you'll most likely never get a match until you re-initialize. Essentially, **It'll happen or it won't without the need for hand-tuning.**

*(keep in mind that there are times when you've got "a match" but the signal is not yet modulating, or it's going in and out, but the signal will at some point become a steady modulation before you arm for launch).

If it is necessary to re-initialize the sonde (due to the lack of a "match" or of a modulating signal, or of the inability of the sonde to lock onto satellites, or perhaps other complications): both disconnect and re-connect the battery and also toggle 403 receiver power switch off and back on.

If you are within 10 to 15 minutes of launching, now is the time to **enter the surface data** using the flight preparation screen interface. An asterisk will appear next to the "surface data" category in the pre-flight menu box (number 2) once this is complete. *Note: (to quote from the manual) "the correct surface pressure, temperature, and humidity at the release point MUST be entered in the surface data display just prior to Arm for Launch. These values are used to initialize the pressure computation for differential GPS operation…The accuracy of the in-flight pressure data is dependent upon the surface pressure measurement recorded in the Surface Data Screen. Whereas the temperature and humidity are measured by the radiosonde in flight, the pressure is calculated by the W9000 system software based on the initial pressure entered (in the Surface Data Screen)".*

Once all of the necessary satellites are locked in, an asterisk will appear next to the "wind finding status" category in the pre-flight menu box (number 1). Assuming that there is an asterisk also appearing next to the "Calibration" category in the pre-flight menu box (number 3), and next to the Receiver category (number 4) you are now ready to **Arm for Launch**.

When the weather is permitting, let the train out all the way on the derailer. The tracking software is set to compensate for the sonde oscillating along an arc based upon the full length of the line.

Special note you can take to the bank: as Bill pointed out numerous times, the sonde will either be ready to go 40 minutes early if all goes smoothly, or 30 minutes late if not. This, at least, you can count on.

3. POST-FLIGHT OPERATIONS

From main menu select option to 'End Flight' and acknowledge when prompted.
Do not change the "L" or launch point in the record as we used to do with the loran-based sondes. First of all, it isn't necessary in general because using the GPS system results in this point being remarkably accurate (almost always only 1 or at the most 2 points off, usually dead-on), and secondly, if you change the "L" even though the computer will claim to be "averaging winds up to the current time," it never will, and all data will be lost.

From the main menu selection 'Utilities', select option to 'Save Flight'. If for some reason the flight name was not entered correctly or this was a repeat sounding, you will be prompted to enter a new flight ID or overwrite the existing one. If appropriate, enter the correct flight ID new.

Escape back to main menu and exit program. You will be at the DOS prompt at this time.

Insert diskette in drive A. Type "copy c:\flights\new*.rts A:". Next type "type *.rts and inspect data file to ensure sounding was successful.

Remove diskette and add flight ID to diskette label.

Lastly wipe the snot off your nose.

Launch Information

Station Name:________________________________Station ID (SSS):______________

Date (mm/dd/yy): _______________Flight Name (SSSmddhh): ___________________

Scheduled Launch Time (Local): __________Actual Launch Time (Local): ___________

Radiosonde Information

Serial Number: _____________________________Loran or GPS: _________________

Sonde Frequency (MHz):_____________________403 Signal Strength: ____________

Initial Sonde Pressure (mb):___________________Pressure Offset (mb): ___________

Surface Information

	Ambient Readings	Sonde Readings
Pressure (mb)	____________	____________
Temperature (C)	____________	____________
RH	____________	____________
WB Temperature (C)	____________	____________
Wind Direction	____________	____________
Wind Speed (with units)	____________	____________

Cloud Observation:____

Current Weather Conditions:____

Operational Information

Arm for launch Clock Time:____________________

Time Launch Detected: _______________________

First Time Value in Edit Launch Mode (mm.ss): _______________________

For GPS - Number of Satellites Found: __________ Number Used: ___________

Comments and Calculations Used:

The following are procedures for preparing, operating and data retrieval for the aircraft sampling systems.

Special Notes:

- First and foremost, safety is the number one priority. No operation should be performed that could pose a hazard to the operator or aircraft. If there are any questions regarding safety concerns for the flight, the Field Manger (Don Lehrman or Bob Baxter) should be contacted.
- When working with the ANODE and CATHODE solutions, take great care not to mix the syringes and solutions, otherwise all will be lost!
- When the samplers and spare cells are transported, never tip them as the fluids might leak.

1 Ozone Sampler Servicing – Laboratory Cell Preparation

- Prepare the initial sample cells. The following steps assume that the cells to be used have been previously flushed with distilled water and are dry (or been in storage since the last flushing and drying), and that the cells will be put into use within 24 hours of preparation.
    - Place an appropriate amount of CATHODE and ANODE solutions in their respective cups. As none of this solution should be returned to the original bottle, take care to only use what is necessary for the cells to be prepared.
    - Fill the CATHODE syringe and charge (fill) each of the CATHODE cells up to the bottom ridge line (approximately 1/3 of the way from the bottom of the cell).
    - Fill the ANODE syringe and charge each of the ANODE cells to the bottom ridge line on the cell. Place the cap with the short lines on the ANODE cell.
    - Using the CATHODE syringe, withdraw all CATHODE fluid from the CATHODE cell and discard. Take care not to damage or deform the platinum screen or Teflon rod. Immediately following the removal of the CATHODE fluid, fill the CATHODE cell with fresh fluid to the top ink-marked line.
    - Carefully place the cap with the long lines on the CATHODE cell. Make sure the Teflon rod on the bottom of the cell is inserted into the long tube and the long tube is not forced to deform the Platinum screen. Make sure that the long tube on top is aligned to have the arc toward the cell wires and Velcro strip.
    - Check the cell voltage. It should be positive and above about 25 mv. If the cell voltage is negative the start the preparation process over. If the repeated check is a negative voltage then the cell is bad.

- If the cells are used after 24-hours from initial preparation then the cathode solution should be replaced (anode is fine).

2 Aircraft Monitor Setup

- Install the sampling lines for ozone and $PM_{2.5}$, as well as the temperature sensor. The $PM_{2.5}$ sample line is ¼" copper tubing, providing a rigid base. Strapped to it is 1/8" Teflon tubing and the wiring leading to the temperature sensor. Using the Cessna cabin air vents, insert the tubing into the air vent such that the temperature probe and $PM_{2.5}$ sample tubing are just visible in the vent opening on the leading edge of the wing. The ozone sample tubing should bend and stick out of the vent opening about 1". Using duct tape, cover up a portion of the vent opening, leaving approximately a ¼" slit, in order to restrict the volume and velocity of the air going past the $PM_{2.5}$ inlet.
- At the beginning of each day, load fresh AA batteries (8 each) into the battery of the ozone/logger package and the GPS unit, and C batteries into the DustTrak; discard and DO NOT reuse any old batteries. Batteries will last for at least 6 hours of flight time.
- Prepare the ozone sample cell by removing the shorting clip and connecting the plug to the respective jack.
- Place ozone/logger package and DustTrak in the rear passenger area and connect the samplers to their respective sample lines. Connect the data logger plug jacks, making sure that the male and female labels match. Jacks must be connected for $PM_{2.5}$ and temperature. Connect the GPS using its cable to the serial port of the data logger and place it on the dashboard at the front of the cabin, with good exposure out the window.
- Connect the Campbell Scientific logger readout unit to the data logger and select the appropriate data screen for viewing the data.
- Connect the battery pack in the ozone/logger package and turn on the DustTrak. Using the logger readout unit, scroll to the Cessna data tables and check the ozone value. Initially, the ozone channel should be greater than 0 ppb and may fluctuate as the cell first starts sampling air. If the cell remains at 0 ppb then there is a problem. Either the cell is not connected, or the something has failed.
- Turn on the power for the DustTrak and GPS unit.
- Conduct a zero check of the ozone sampler by place a ozone scrubbing cartridge at the end of the sampling line. It should be less than 5 ppb. After removing the zero filter, compare the reading with ambient ozone readings from a reference analyzer, if available. Prior to connecting the sample line to the DustTrak, conduct a flow check and zero check of the sampler using the supplied rotameter and zero filter, respectively. The flow should be 1.7 lpm and the zero less than 5 $\mu g/m^3$. Record all check values. Verify that the temperature reading is representative of ambient conditions and that the GPS unit is reporting a location. All above checks are made using the logger readout unit.

3 In-flight Procedures

- Periodically review the logger readout unit to check for instrument performance. The ozone reading should not be noisy (variations greater than ±5 ppb). Noise may be an indication of drying cells. The spare cell can be used if problems are noted.
- Make sure that none of the GPS values (speed, heading, altitude, position) read zero or invalid. If zero or invalid readings are noted, the most likely cause is a poor cable connection most likely at the GPS unit. If bad readings are still noted after checking the cable, reposition the GPS unit in the window.
- Temperature readings should agree within a couple of degrees with the aircraft sensor.
- Extra batteries should be taken on all flights. Any of the batteries can be changed in flight if needed.

4 Procedures Following a Flight

- Verify that the pumps for the ozone sampler and DustTrak are still running.
- Turn of the DustTrak and GPS unit.
- Download the data logger as quickly as possible using the LoggerNet software version 3.3.1.
- Disconnect the battery pack in the ozone/logger package. This will prevent the data logger from continuing to log data, writing over existing data with null data.

The following are procedures for installing and operating the 2B Technologies model 202 ozone analyzers for the UGWOS Mesonet ozone monitoring network.

Ozone Analyzer Setup

1. Prior to the installation of the analyzer, condition all sample lines by drawing air with concentrations of at least 50 ppb ozone through the lines for a period of 24 hours.
2. Place the analyzer in the designate site cooler, making sure that the number on the analyzer matches the number on the cooler.
3. Connect the 47 mm filter holder, with filter, and the associated sample line onto the inlet port of the analyzer. Make sure that flow through the filter holder is in the correct direction - it should follow the arrows on the filter holder. Loop any excess line in the cooler.
4. Install a fully charged 12 V battery, with power cord adapter, in the cooler. If necessary, the 2B analyzer can be turned on its side.
5. Connect the 12 V power cord to the battery and to the 2B analyzer.
6. Turn on the analyzer and allow it to warm up for at least one hour prior to calibration in order to let internal temperatures stabilize. Note that analyzers can be powered up using a vehicle 12 V cigarette lighter receptacle in transit to the Mesonet sites in order to reduce or eliminate warm up time at the site.
7. Connect the analyzer to the Campbell Scientific CR206 data logger using the stereo jack connector labeled “1”.
8. Verify that the small heater light is connected and operating.

Ozone Analyzer Calibration

1. Position the 2B Model 306 ozone transfer standard near the station analyzer such that the calibration line reaches the sample inlet. Connect the sample inlet to the calibration line using a suitable connector.
2. Connect the calibrator’s power cord adapter to the 12 V lighter receptacle in your vehicle. Turn on the transfer standard and allow it to warm up. The calibrator display will read “Warming up …” while doing so. When the indicated delT reading is within 1°C, the display will read “Temperature Set Press Select”. The calibrator is sufficiently warmed up whenever the delT reading is within 1°C. Note that the calibrator may be kept running while in transit to the Mesonet sites in order to eliminate warm up time at the site.
3. Record the calibration “begin time” in the logbook. All calibration and check activity will influence the hourly averages, which will need to be invalidated.
4. The 2B Model 306 transfer standard has a single output port, with a venting tee contained within the transfer standard. Thus, no external vent should be used. Connect

one end of the calibration Teflon tubing to the transfer standard output port and the other to the analyzer sample inlet line, using an appropriate adapter.

5. If not already done, program the Model 306 transfer standard to produce the zero and two span points. Hold down the rotary switch until the main menu is displayed. Rotate the rotary switch to move the cursor under “Cfg” for the automatic calibration sequence configuration. Follow the menu prompts to create a five-point calibration, with points at 200, 150, 100, 50 and 0, spaced at 10-minute intervals.
6. Start the calibration sequence at approximately one minute after a five-minute clock division (e.g. 10:01, 10:06, 10:11, etc.). Since 5-minute averages are being recorded by the data logger, this will result in an approximately 4-minute stabilization period and a full 5-minute average of the calibration input for each input concentration. Start the calibration sequence by going to the main menu and selecting “Stp”.
7. Using the procedures presented in the SOP “Operating Procedure for Mesonet Data Handling”, connect to the data logger and download the most current 5-minute data. Record the resulting calibration values into the site logbook.
8. Contact Dave Bush for current ozone output concentrations for the 2B transfer standard settings and record these in the logbook.

Routine Station Checks

1. Station checks should be conducted every other day during IOPs, as well as at the beginning and end of each IOP.
2. Upon reaching the site, enter the date and time in the station logbook, along with the technicians initials.
3. Complete a visual inspection of the system. Note any anomalous situations both in the site’s logbook.
4. If not already done, program the Model 306 transfer standard using the procedures in the Calibration section above to produce a three-point calibration sequence, with points at 200, 50 and 0, spaced at 10-minute intervals.
5. Using the procedures in the “Calibration” section above, conduct the described three-point zero/span check.
6. Using the procedures presented in the SOP “Operating Procedure for Mesonet Data Handling”, connect to the data logger and download the most current data. Review the 5-minute data file and record the resulting calibration values into the site logbook.
7. Contact Dave Bush for current ozone output concentrations for the 2B transfer standard settings.
8. If either of the span checks deviated by more than 10% from the standard, or if the zero is off by more that 5 ppb, alert Dave Bush or Bob Baxter.
9. It is not anticipated that any inlet filter changes will be necessary during the study. However, if a filter change is required, use the following procedures. Record the current ozone reading from the analyzer display in the log book. Disassemble the filter holder and replace the filter. Reassemble the filter holder and record, wait approximately one minute, and record the ozone reading from the analyzer display. Note if the before and after readings change by more than 5 ppb. Note that any filter changes should be conducted after the scheduled zero/span/precision check.

10. Write down the current readings for the following measurements in the station log book: battery voltage, station temperature, ozone, WS, and WD. Verify that the WS and WD readings are consistent with current conditions.
11. Verify that the monitoring system is operating appropriately. Verify that the display on the analyzer is normal, that the red light on the Campbell Scientific Model 206 data logger is blinking, and that the heater light is on. Note in the logbook the period that the ozone analyzer was off-line for the checks.

The following are procedures for preparing, operating and data retrieval for the Mesonet monitoring network.

Special Notes:

- Data connections are made using the RF401 wireless connection module. Make sure power is provided to the module and that the serial connection is made to the proper connector on the RF401 and the antenna is connected.
- Each of the data loggers is assigned a PAKBUS address that is equivalent to the site number. You can only access the data logger by using the correct site program with the corresponding PAKBUS address, i.e., site 3 can only be accessed using the program/configuration configured for PAKBUS address 3. The following is a list of the site names/numbers:

  Cora Area – 1
  The Mesa – 2
  Warbonnet – 3
  Haystack Butte – 4
  Simpson Gulch – 5
  Speedway Pit – 6
  Big Piney – 7
  La Barge – 8

- Before proceeding to the field verify that the clock in the field computer is correct to within 1 minute of **true** Mountain Standard Time. This can be best performed using the integral Internet Time function in Windows and verifying that the time was truly set when it is complete. If not then find an appropriate time standard before leaving for the field and set the computer clock manually. Again, verify it has the proper time.
- The file naming convention for each site and data interval is critical and should not be changed. If a different computer is used for downloading data then the setup for data access and collection must be consistent with the following standard and example shown for site 3:

  Wy Site 3_min_5.dat
  Wy Site 3_min_60.dat

  Note that there is a space between ‘Wy’ and ‘Site’, as well as between ‘Site’ and ‘3’.

1.1 Data Download from Data Logger

- Enter the arrival time at the site in the site log.

- When parked within radio range of a desired site, press the "Connect" button and select the proper site.
- When connected, verify the time on the data logger is within 1 minute of the computer time. If the times differ by more than one minute then synchronize the data logger clock to the computer
- Press the "Collect Now" button and wait for the complete download. Sometimes the connection may take some time through the wireless connection.
- When the collection is complete use the view data mode for 5 minute and 60 minute files to verify all data to the present has been collected. Note the date and time of the data collection in the log.
- Review all the values for any anomalies during the period collected. In particular review the battery voltage to verify a proper battery charge. The battery voltage will read about 1.5 to 2 volts low. If you ask Bob why then be prepared for too long an explanation. However, if any values look suspicious then contact either Bob or Dave Bush regarding the operations.
- Press the "Disconnect" button, you are done at this site.

1.2 Data FTP Upload to the T&B Systems FTP Server

Special Notes: The FTP upload process should only be performed in the time window from 10 minutes past the hour to 10 minutes prior to the hour. This will minimize the chances of the server trying to process data that is in the middle of an upload. This server process will be running at the top of every hour. Additionally, any data downloads must be performed in a consistent manner. The file naming convention for the two indicated upload accounts below is critical. If a computer change is made then it is imperative that the assigned file naming convention is maintained.

- Use an appropriate FTP program such as Filezilla or you can use Internet Explorer. Be aware that FTP through Internet Explorer version 7 requires an additional step to view the FTP site in an Explorer window. This is not required in Internet Explorer version 6.
- Log into the proper account for the data uploads. If you log into the wrong account then the data may not be properly registered and a potential loss of data may occur. **Nobody else should upload data to these accounts! If you have data to be uploaded then contact Bob to set up an account and obtain the proper file naming convention. This file naming convention is critical to assure no data are lost!**
  - **Jennifer Frazier (Wyoming DEQ):**
    URL: ftp://70.133.103.202
    Username: wydeqdataup
    Password: ugwosdata
  - **MSI:**
    URL: ftp://70.133.103.202
    Username: msidataup
    Password: ugwosdata
- Copy the full files that have been downloaded from the data loggers into the FTP server. This includes both the 5-minute and 60-minute files. Do not attempt to create any new folders underneath the FTP root login, or edit, or rename the files in any way, as this will

disable the automated update process. However, it is OK to overwrite the existing files that were previously uploaded to the FTP server as those files are automatically backed up daily.

- If all goes well then the newly uploaded data will appear on the web site within an hour. Send an email to Bob (bbaxter@tbsys.com) to let him know that new data have been uploaded. He will verify that the new data have been registered properly in the database and will contact you as appropriate with any issues.

The following are procedures for checks and maintenance of the ASC miniSodar located on the M&N property. Included are the downloading notes for the surface meteorological sensor located at the same site.

Special Notes:

- The site is located on M&N property and care should be taken to not damage any of the surroundings. The minisodar Acoustic Signal Processor (ASP) and surface meteorological data logger is located in the shed adjacent to the antenna.
- Check both the minisodar and surface meteorological station cables for integrity.
- The sodar is powered by AC with an APC UPS to maintain power during short outages.
- Take care when leaving anything on the ground as there are hungry rabbits nearby. They particularly like cables and can run fast when you chase them in anger.
- There is a key hidden for entry in the shed. If you don't know the location of the key then ask Bob, Jennifer or Dwayne.
- Data downloading from the surface meteorological station should be conducted using the RF401 spread spectrum radio modem. The PakBus address is 7. If serial communications are required the data logger has a 9-pin connector cable already attached.
- The surface meteorological equipment is powered by the deep cycle battery located on the floor, below the sodar ASP.

Clearing the miniSodar antenna of snow

- Prior to the removal of the Antenna Array Box (AAB) assembly, the miniSodar must be powered off. The procedures for shutting down the system is as follows:
    - Remove the front cover from the ASP by unlatching the catches all the way around the front (8 places).
    - Press the "X" button on the front panel display and scroll using the "v" button to the "Control" menu. Select "Control" by pressing the check (√) button. Select shutdown system and again press the check (√) button. The display will ask: Power Down? "No", use the "^" to select "Yes", then press the check (√) button.
    - It is important to wait at least 30 seconds before powering down using the power switch. Wait 30 seconds before turning the power switch off (the switch is on the far left)! The power rocker switch is off when the top of the switch color is hidden. When the power is on, the top of the power switch is red
    - Turn off the front panel switch on the amplifier.
    - The system is now powered off.

- Removal of the AAB box assembly and cleaning
  - Disconnect both antenna cable connectors from the AAB taking care not to let the connectors fall in the snow. If water or snow gets into either of the connectors or the connections on the back of the array then the moisture must be removed by blowing it out.
  - Loosen each of the four Phillips head screws that hold the AAB to the enclosure. It is best to remove the bottom screws first so the array doesn't try to fall backwards. Take care in supporting the array when you loosen the screws to minimize the downward force on the screws. Don't drop the screws in the snow or you will have a fun time finding them. Also, note the orientation of the array as it must be reinstalled in the same orientation.
  - Carefully remove the AAB and lean it up against something making sure that the speakers and connectors don't fall into the snow.
  - Use a broom (at the site) to sweep all of the snow from the reflector board and the acoustic insulation to the bottom of the enclosure for removal. Be careful not to damage the insulation during the process as there may be ice formed in the foam.
- Reinstallation of the array
  - Place the array back into the enclosure in the exact orientation it was removed.
  - Start each of the four screws that hold the array into the appropriate nuts on the enclosure. It is very important and helpful to lift and support the array during the insertion and tightening of the screws, as this will prevent the threads from getting damaged.
  - Slowly tighten the four mounting screws evenly as you would lug nuts on a car so as not to deform the array mounting. The screws should only be snug, not tight, as over tightening will damage the threads. It is only necessary to make it snug so there is no air gap around the gasket.
  - Reconnect the two antenna cables making sure that both the cable and AAB connectors are dry and free of water or snow.
- Restarting the miniSodar
  - Turn the power amplifier on and wait 5 seconds.
  - Turn the ASP power switch to the on position. The boot process may take a minute or more. When booted the lights on the left of the display should cycle and the transmit pulse should be heard.
  - Replace the front cover of the enclosure to help keep heat inside and dust outside.