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# New Technology Research & Development Program
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# Tasks 3, 4 & 6 Deliverables Report

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Sonoma Technology, Inc.

1360 Redwood Way, Suite C
Petaluma, CA 94954-1169
707/665-9900
FAX 707/665-9800
www.sonomatech.com

# DEVELOPMENT AND IMPLEMENTATION OF OFFSHORE METEOROLOGICAL SYSTEMS TO SUPPORT TEXAQS-II

**FINAL REPORT**
**STI-905060-2993-FR**

**By:**
**Clinton P. MacDonald**
**Charley A. Knoderer**
**Donald L. Blumenthal**
**Sonoma Technology, Inc.**
**1360 Redwood Way, Suite C**
**Petaluma, CA 94954-1169**

**Prepared for:**
**Texas Commission on Environmental Quality**
**P.O. Box 13087, MC204**
**Austin, TX  78711-3087**

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# 1. INTRODUCTION AND PROJECT SUMMARY

## 1.1 INTRODUCTION

In an effort to mitigate air pollution in eastern Texas, the Texas Commission on Environmental Quality (TCEQ) and other study participants have undertaken an 18-month field program called the Texas Air Quality Study II (TexAQS-II). The study began in June 2005 and is expected to continue to October 2006. The purpose of the field program is to collect air quality and meteorological data that will be used as the scientific basis for the development of State Implementation Plans (SIPs) for ozone and regional haze. Ultimately, these data will be used to further a conceptual model of air pollution in eastern Texas and help determine whether prognostic models are properly representing the complex flow patterns that influence air pollution. The project data products will help scientists improve model results.

For this field program, TCEQ identified a need for aloft boundary layer wind, temperature, and mixing height data offshore over the Gulf of Mexico (GOM). These data are important because they provide upwind boundary information where aloft measurements do not currently exist and provide information regarding the transport of pollution from the southeastern United States and Mexico into Texas. For example, the data can be used to understand the transport of smoke from fires in the Yucatan Peninsula. In addition, these data may capture the complex land-sea breeze circulation that strongly influences the spatial and temporal characteristics of pollution in coastal areas.

To meet this offshore data need, TCEQ's Technology Research and Development program (NTRD) funded the preparation, installation, and operation of a radar wind profiler with a Radio Acoustic Sounding System (RWP/RASS), a mini-sodar (sonic detection and ranging), and surface meteorological instruments on an oil platform located in coastal waters over the GOM. These instruments were requested because their data products have been used successfully in many air quality studies including the 2000 Texas Air Quality Study and the 1993 Gulf of Mexico Air Quality Study (Lindsey and Dye, 1993).

In an ideal operating environment, the RWP/RASS system provides continuous (hourly) wind data with vertical resolution of about 100 m at heights from as low as 120 m up to as high as 4000 m above the platform and virtual temperature ($T_v$) measurements with a vertical resolution of 60 m at heights from about 100 m to as high as about 1600 m above the ground. However, operational constraints at the platform, including sea clutter and interference from a crane, increased the lowest height of wind data recovery to about 300 m. The RWP also provides reflectivity data from which mixing heights can be derived. The mini-sodar provides wind data at a vertical resolution of 5 m from about 15 m up to about 100 m above the platform; however, its height coverage was at times compromised by audible noise from platform operations and maintenance. The surface instruments measured wind, temperature, solar radiation, pressure, and dew point.

This document summarizes project activities (Section 1.2) and project delays (Section 1.3); gives an overview of site and data information (Section 2); describes issues surrounding the preparation, installation, and operation of an RWP/RASS and mini-Sodar in an offshore environment (Section 3); describes the instruments (Section 4); summarizes data processing and quality control (Section 5); and presents data file information (Section 6). The deliverables for project Tasks 1 through 5 are discussed in Appendix A. This report serves as the deliverable for Task 6.

## 1.2 PROJECT SUMMARY

Sonoma Technology, Inc. (STI) contracted to complete the setup, testing, optimization, and several months of operations of an RWP/RASS, mini-sodar, and surface meteorological instruments on an oil platform in the GOM from August 1, 2005, to January 31, 2006. In particular, grant funding was used to (1) modify the instruments to meet platform explosion-proofing requirements and to optimize the instruments for operation in an offshore environment; (2) procure space on an oil platform in the coastal waters of eastern Texas; (3) install infrastructure to support the measurement operations including power, shelter, and communications; (4) install and operate the instruments for several months during the first part of TexAQS-II; (5) identify and resolve instrument issues during operations; and (6) transition to a different TCEQ contract for continued operations during the TexAQS-II intensive study period in summer 2006.

## 1.3 PROJECT DELAYS

The 18-month TexAQS-II field study started on May 1, 2005. To provide data for the entire study period, STI originally planned to begin operating the instruments on the platform in April 2005 followed by five months of operations covered by this grant. However, the operation of most instruments did not begin until late September 2005. Therefore, the operational period funded under this grant was changed to cover the period from late September 2005 through January 2006. The reasons for this delay were communicated to TCEQ:

1. Finalizing the contract was delayed three months from its original date.
2. The instruments and infrastructure needed more extensive modifications than were anticipated in order to comply with Shell's Class 1 Division 2 explosion-proofing requirements. We had expected to have to adhere to federal requirements, which are similar to those required for other offshore measurement programs, but because TCEQ arranged for the platform at the beginning of the contract, we did not have advance knowledge of Shell's explosion-proofing requirements.
3. Locating and procuring the use of space on an oil platform and providing the infrastructure to support the operations (shelter, power, and communications) were originally contracted by TCEQ to another organization and then transferred to STI well after the start of the grant. The reason for the transfer of responsibility was that STI had the necessary contacts and information to find a suitable platform. Finding a platform operator willing to accommodate the equipment and negotiating an agreement took longer than anticipated.
4. Installation was suspended twice and personnel were evacuated from the platform because of Hurricane Katrina (August 26, 2005) and Hurricane Rita (September 19, 2005). In addition, STI's subcontractor (TEST Automation and Control) who performed much of the installation work was located in New Orleans. During Hurricane Katrina, we lost communications with TEST for about two weeks.

# 2. SITE AND DATA OVERVIEW

Preparations to install and operate the instruments on a platform in the GOM began in May 2005. By September 20, 2005, the RWP/RASS, mini-sodar, and surface meteorological instruments were operating on Shell's Brazos A-19 Platform D and were providing hourly meteorological data in real time to the TCEQ. However, the platform was evacuated for Hurricane Rita in September 2005, and all power shut down on the platform. The instruments remained inoperable until October 3, 2005. These instruments continue to operate on the issue date of this report and are planned to operate through September 2006 with TCEQ funding through a separate contract. Instrument downtimes that occurred during this period of operations are discussed in this section.

**Figure 2-1** shows Brazos A-19 and a map of its location. **Figures 2-2 through 2-4** show the instrumentation on the platform. This platform is located about 75 miles southwest of Galveston at 28.17 latitude north and 95.58 west longitude. The platform deck is at 24 m msl. Platform D was selected because (1) drilling activity was not expected to occur there during the TexAQS-II study; (2) the platform had space to accommodate the instruments, (3) the platform's location is suitable to meet the TexAQS-II measurement needs; and (4) Shell Oil was willing to make the platform available for the study.

**Figures 2-5 through 2-8** show samples of the data produced by the instruments. Figure 2-5 shows a time-height cross-section of hourly winds produced by the RWP on December 20, 2005. The flag on the back end of each wind barb indicates the speed of the wind, and the direction the barb is pointing indicates the wind direction. For example, Figure 2-5 shows westerly winds (winds coming from the west) at about 25 m/sec above about 1800 m above platform level (apl) in the morning and above about 1000 m in the afternoon. Below about 1000 m apl, winds are easterly and generally lighter then the westerly winds. Note that data are available in an altitude range of about 300 to 400 m apl to about 4000 m apl on this day. Because of strong reflections of the RWP's signal bouncing off the platform and ocean, the height of the lowest wind measurement (268 m) is about 120 m higher than can be expected in an ideal environment. Efforts were made to reduce the impact of these reflections during data recovery. The top height ranges from about 4000 m apl when the atmosphere is moist to about 1000 m apl or less when the atmosphere is dry.

To fill in gaps between the surface wind measurements and the lowest measurement of the RWP of about 300 m apl, a mini-sodar was installed. Figure 2-6 shows a sample plot of the mini-sodar data on December 28, 2005. The mini-sodar reported winds from 15 m apl to about 100 m apl on this day.

In addition to wind data collected by the RWP and mini-sodar, the RASS collects vertical profiles of $T_v$ from about 100 m apl to about 1000 m apl. $T_v$ can be as much as 5°C higher than ambient temperature depending on how much moisture is in the air. Figure 2-7 shows a sample plot of RASS $T_v$ data collected on December 20, 2005. The figure shows a temperature inversion at about 600 m apl.

Finally, the surface meteorological instruments measured hourly averaged wind speed, wind direction, air temperature, dew point temperature, relative humidity, direct solar radiation, and pressure. Figure 2-8 shows a plot of these data for December 20, 2005.

These data are available in a real time and historically beginning September 20, 2005, at <http://www.sonomatech.com/tceqdata>. Some data gaps exist due to instrument downtimes. **Table 2-1** shows the major instrument downtimes from the beginning of operations through January 31, 2006. **Figure 2-9** shows the data recovery over the same period. The most common reason for RWP/RASS downtimes was that Shell platform employees turned off the power to the RWP to operate a crane on the platform. This disruption was necessary because the 915-MHz operating frequency of the RWP was the same as a transmitter on the crane. In addition, a major RWP downtime occurred from November 12 to December 18, 2005. During this period, the RWP electronics were removed and sent to the manufacturer and to the National Oceanic and Atmospheric Administration (NOAA) to optimize the electronics to improve data recovery and reduce the effect of sea clutter. In addition to instrument downtimes, there were times when noise on the platform interfered with the mini-sodar, so that mini-sodar wind data could not be collected. The noise was mostly related to construction on the platform.

Table 2-1. Summary of major times when the instruments were not producing data.

| Major Downtimes (CST) | Instrument | Cause |
|---|---|---|
| 9/22/2005 0000 to 10/03/2005 0900 | RWP/RASS/sodar/surface meteorology | Power failure due to Hurricane Rita evacuation |
| 10/09/2005 0700 to 10/09/2005 2300 | RWP/RASS/sodar/surface meteorology | Power turned off for platform crane operations |
| 10/15/2005 1500 to 10/16/2005 0500 | RWP/RASS/sodar/surface meteorology | Power turned off for platform crane operations |
| 10/21/2005 0700 to 10/25/2005 1300 | RWP/RASS/sodar/surface meteorology | Power failure due to Hurricane Wilma evacuation |
| 10/26/2005 1100 to 10/27/2005 2300 | RWP/RASS/sodar/surface meteorology | Power turned off for platform crane operations |
| 11/12/2005 0100 to 12/18/2005 1900 | RWP/RASS/sodar/surface meteorology | Repair and modifications of final amplifier |

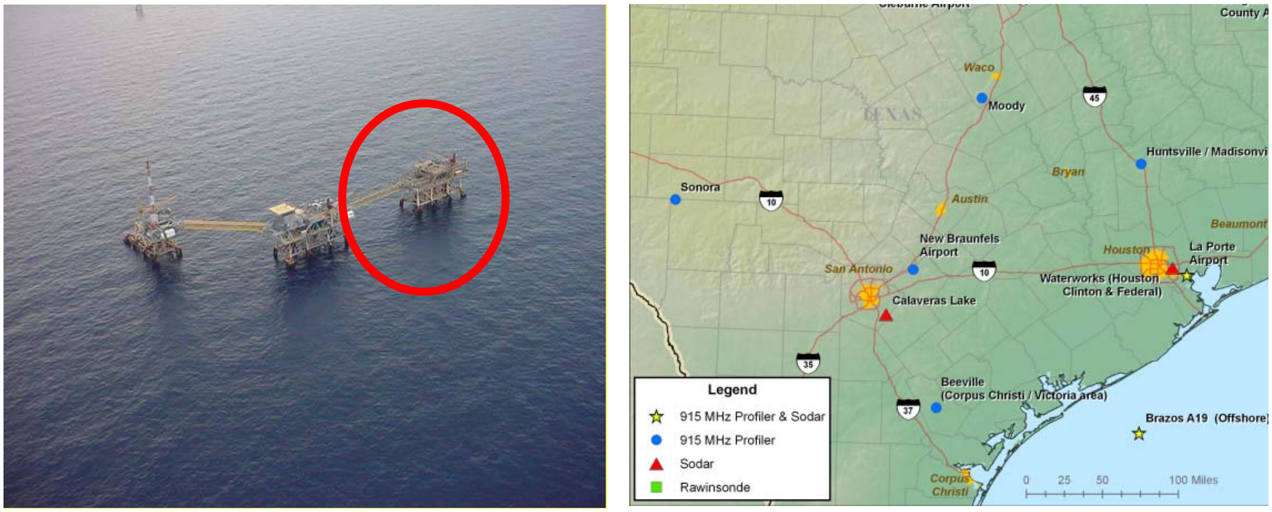


Figure 2-1. Image of Brazos A19 (left) and map showing its location (right).

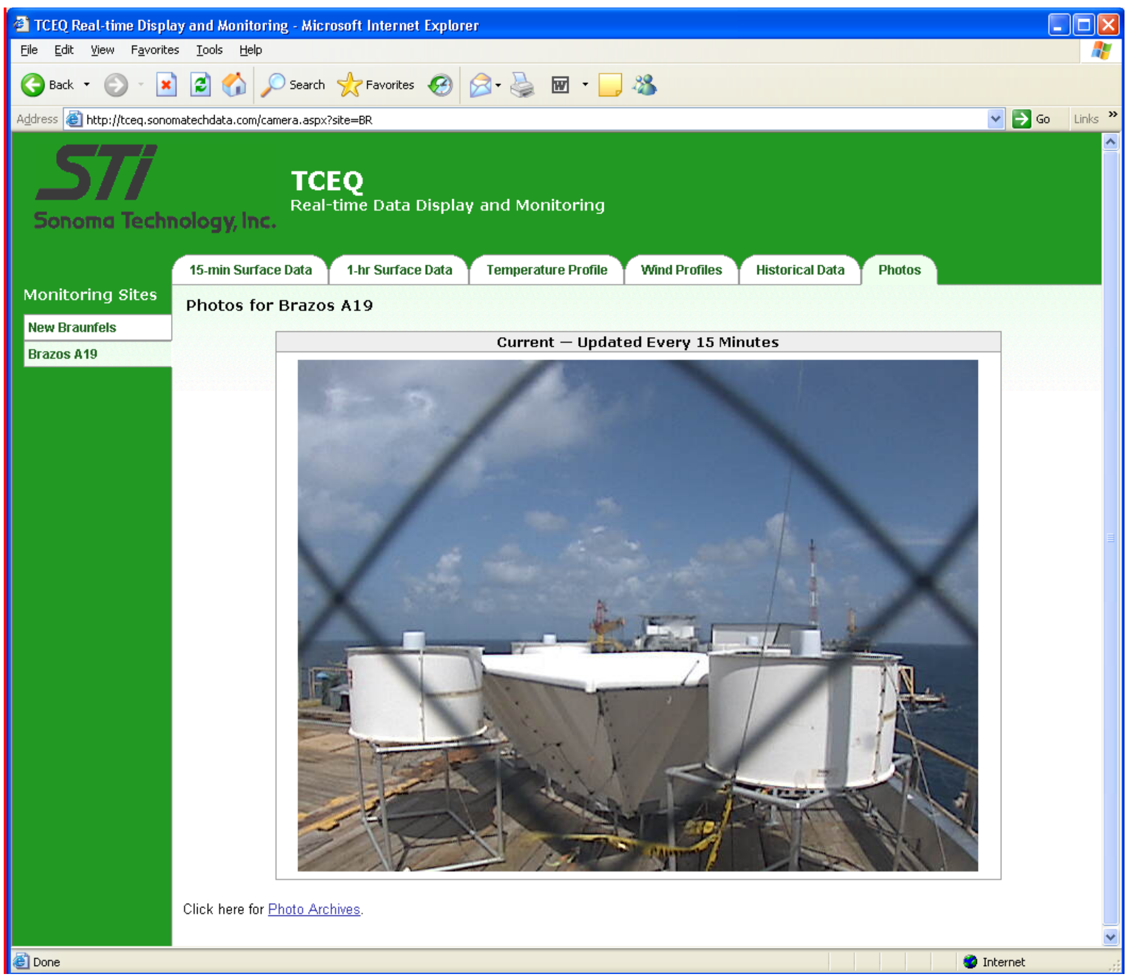


Figure 2-2. Instruments on the platform photographed by a platform camera that provides real-time images to the Internet.

Figure 2-3.  Atmospheric Systems mini-sodar (left) and Vaisala LAP-3000 Wind Profiler with RASS (right).

Figure 2-4.  Surface meteorological instruments (left) and DirecWay DW-6000 Satellite dish (right).

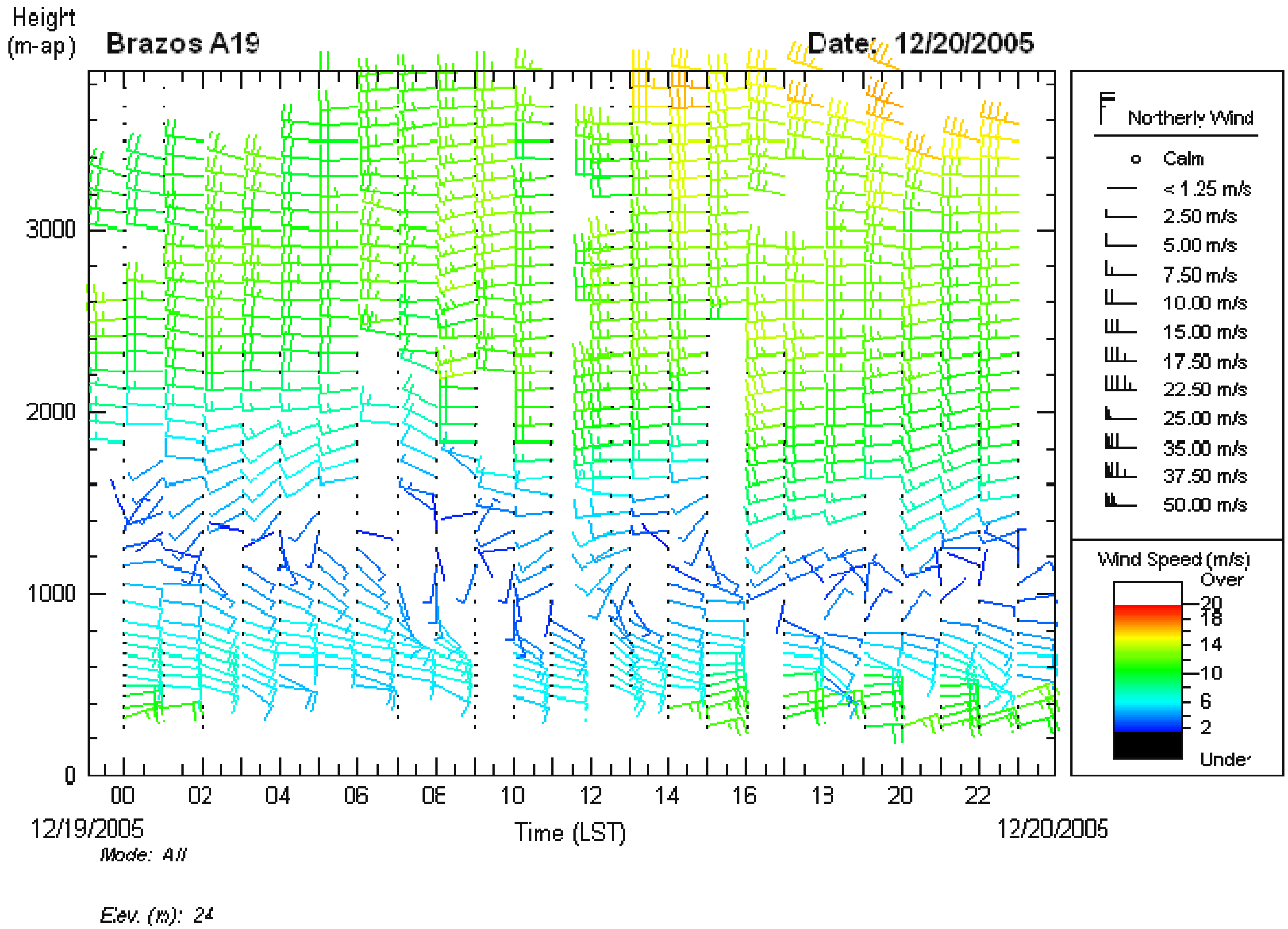


Figure 2-5. Example plot of winds measured by the RWP on December 20, 2005, at Brazos A19 in the GOM. Winds are plotted using the conventional wind barb plot format, where the orientation of the shaft indicates wind direction and the number and length of bars indicates wind speed. Note that the heights are in meters above platform level (m apl).

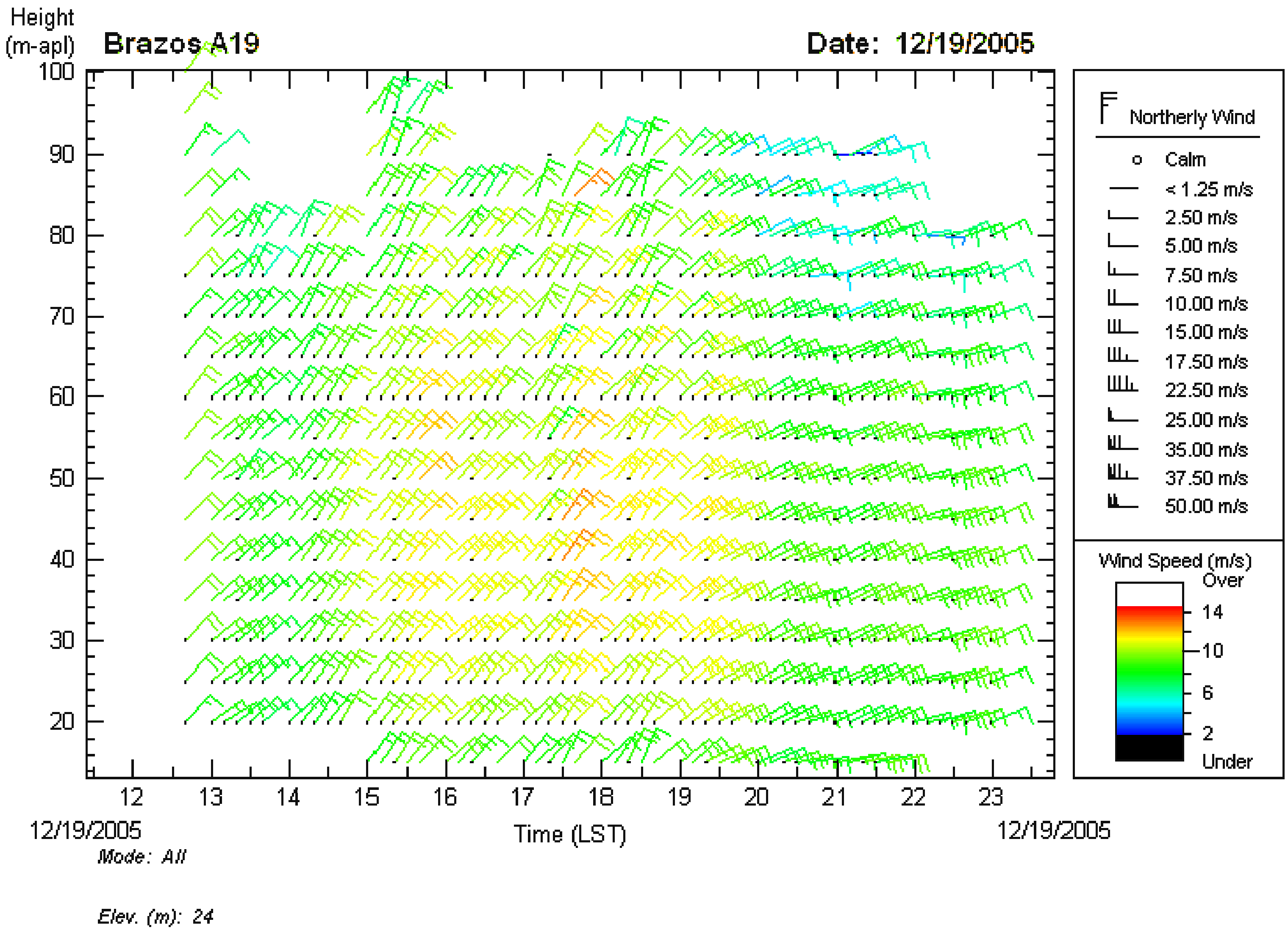


Figure 2-6. Example plot of wind profiles measured by the mini-sodar on December 19, 2005, at Brazos A19 in the GOM. Winds are plotted using the conventional wind barb plot format, where the orientation of the shaft indicates wind direction and the number and length of bars indicates wind speed

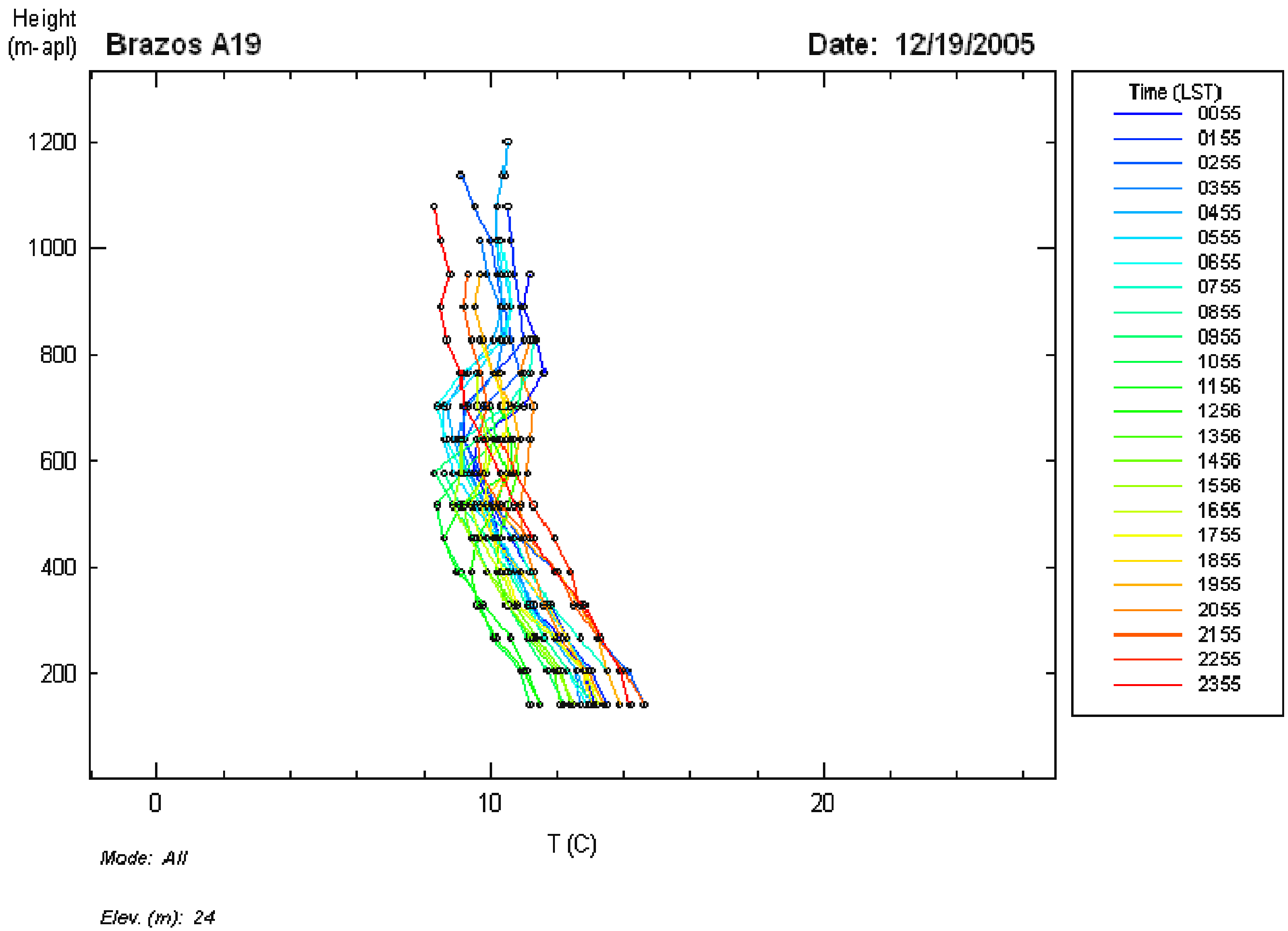


Figure 2-7. Example plot of $T_v$ profiles measured by the RASS on December 19, 2005, at Brazos A19 in the GOM. $T_v$ is plotted along the x axis and altitude along the y-axis. The line color of the profiles indicates the hours the data were collected.

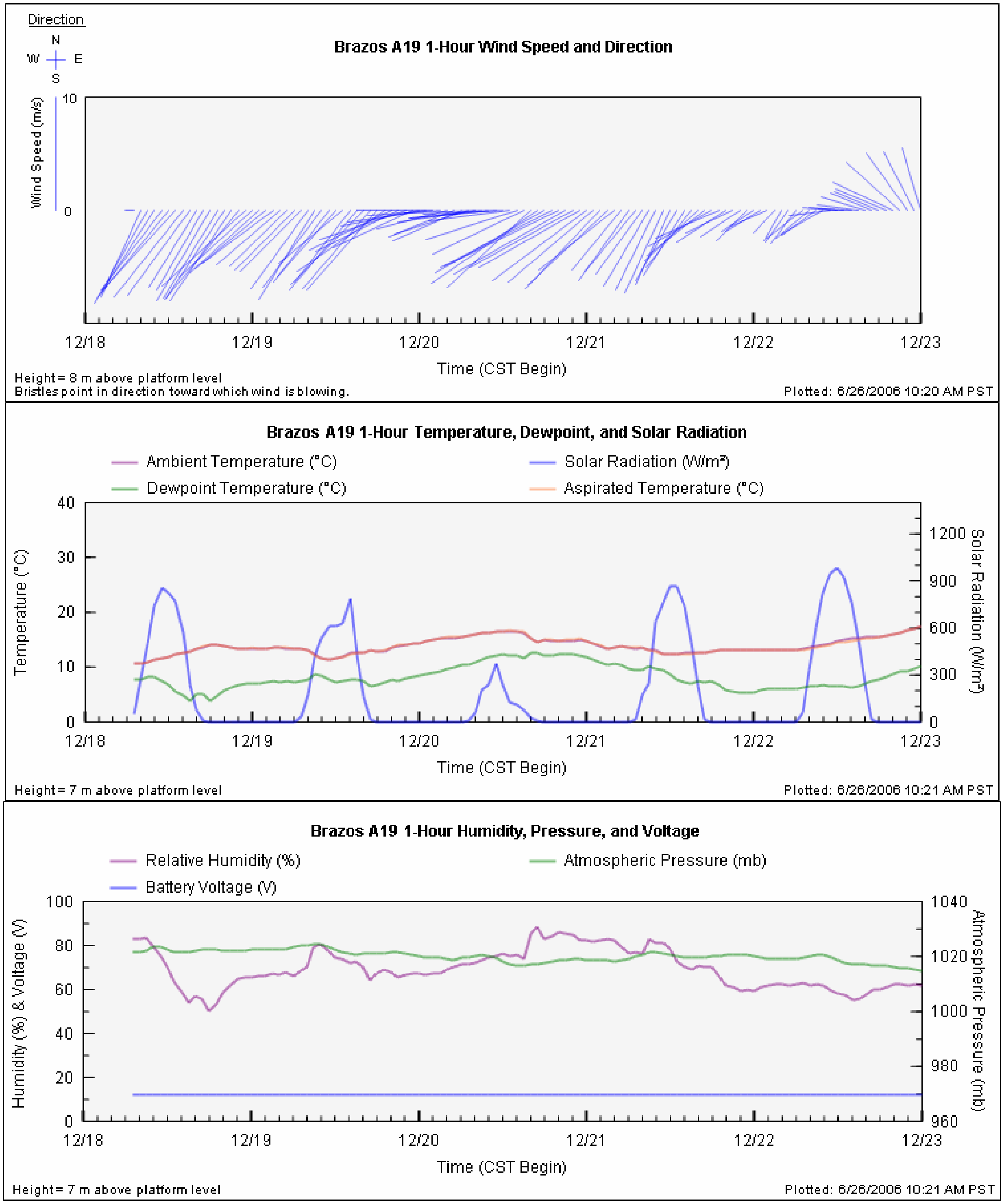


Figure 2-8. Surface meteorological data on December 20, 2005. Winds are plotted using bristles; the bristles point in the direction the wind is blowing, and the length of the bristle indicates the wind speed.

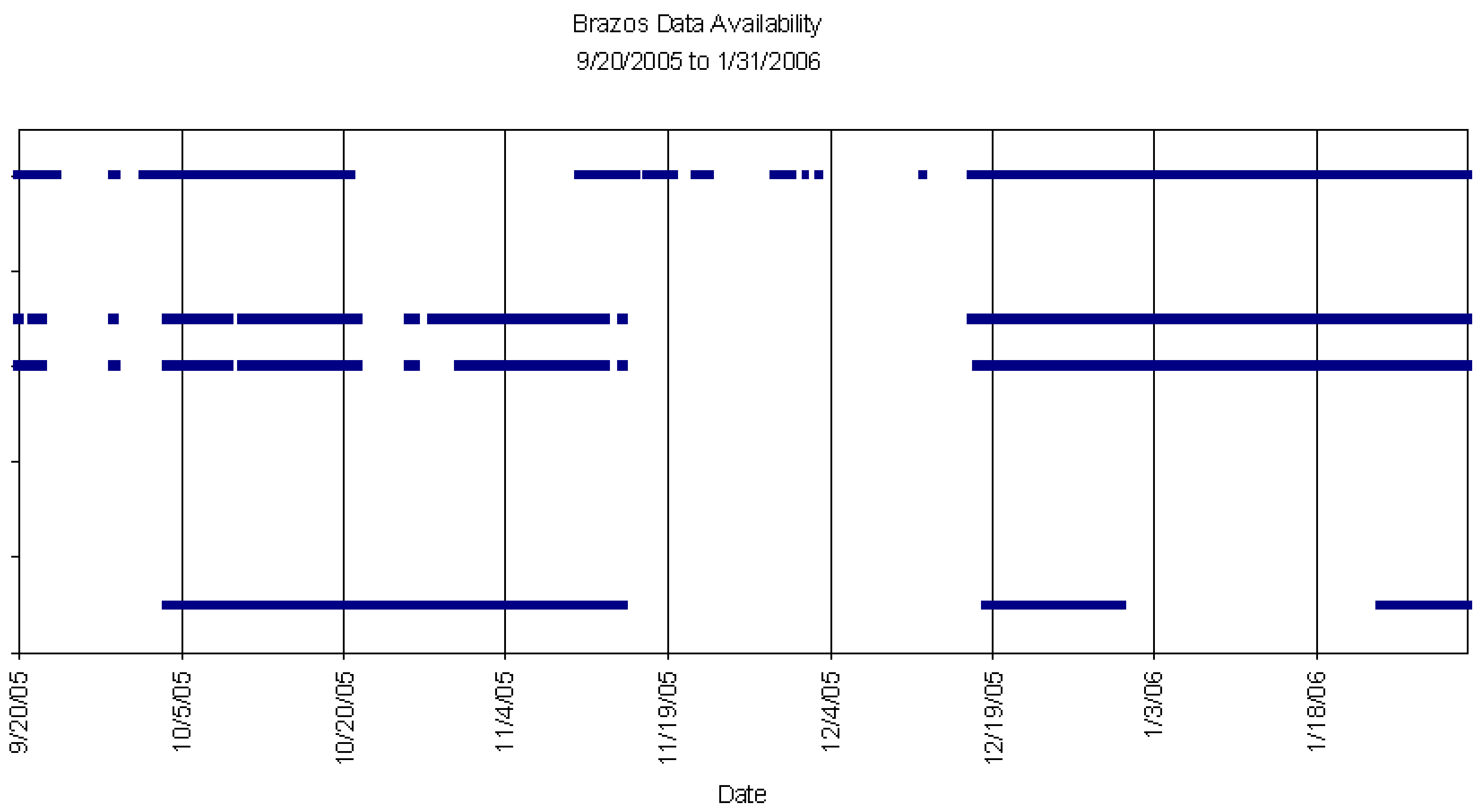


Figure 2-9. Hours when data were available (blue bars) by day from September 20, 2005, through January 31, 2006. Major downtimes and their causes are summarized in Table 2-1.

# 3. INSTALLATION AND OPERATIONAL CONSIDERATIONS AND ISSUES ASSOCIATED WITH OFFSHORE MEASUREMENTS

The process of installing and operating RWP/RASS, mini-sodar, and surface meteorological instruments on a Class I Oil Platform was complex. As guidance for similar future endeavors, we discuss the important installation and operational considerations and issues associated with this project. For installation they include (1) equipment shipping challenges to an offshore platform, (2) meeting Class I Division 2 explosion-proofing requirements, (3) installing reliable communications to transfer data from the platform, and (4) delays and risks associated with weather (e.g., hurricanes). For operations, they include (1) power interruptions, (2) elevated electronic and audible noise levels, (3) interference from nearby structures, such as large cranes, and (4) maintenance and turn-around time for correcting problems.

## 3.1 INSTALLATION CONSIDERATION AND ISSUES

### 3.1.1 Shipping

Shipping the equipment and infrastructure from the dock to the platform was performed by Shell Oil, Inc. via a small ship. Considerable planning and coordination were required to ensure that the equipment arrived on schedule and in good conditions. Prior to shipping, all equipment except the shelter was placed in two 10-ft x 20-ft Connex boxes. **Figure 3-1** shows a Connex box on Shell’s ship. Significant effort was made to ensure that the equipment would be safe during shipping. The most fragile equipment—the 5-ft x 5-ft radar antenna and the mini-sodar—were individually crated. The shelter was also shipped to the platform and required the installation of lifting brackets for hoisting onto the ship and platform. The shelter met Shell’s Class 1 Division 2 explosion-proofing requirements and was leased from Abbeville Offshore Quarters, Inc. in Louisiana. This shipping method was cost-effective and worked well. We recommend this shipping procedure for future offshore operations.

Figure 3-1. Picture of Connex box on Shell's ship.

### 3.1.2 Explosion-Proofing

Shell's Class I Division 2 explosion-proofing standards require that all electronic equipment carrying an electric current be at least 50 feet away from any gas well heads. Any equipment that is closer must be hermetically sealed or have positive pressure. Note that the federal requirements are less stringent than Shell's (10 ft instead of 50 ft). For this platform, the RWP and RASS were within 50 feet of a gas well head, so we used the positive pressure method to meet the requirements. The positive pressure method was selected because it would have been very expensive to alter the electronics in the antenna and final amplifier to be hermetically sealed. The positive pressure method involved modifications to the antenna frame and RWP final amplifier. The final amplifier is normally attached to the bottom of the antenna frame. For this installation, a bottom enclosure for the antenna (see **Figure 3-2**) was fabricated of aluminum and sealed with a neoprene gasket. Two bottom panels were bolted on to allow access to the bottom of the antenna. The final amplifier was modified and relocated to the side of the new enclosure so that the heat sink was still exposed to the ambient air. A purge system with pressure release valve was added to the base of the antenna to keep the pressure inside the antenna higher than the ambient pressure, eliminating any chance for gas to enter the antenna base. To provide air for the purge system, metal pipe was connected to an air compressor located on the bottom deck of the platform, requiring extensive bending and laying of the pipe. To feed the cables through the antenna frame, a 4-inch x 4-inch square was cut into the frame and a Roxtech wedge kit installed to provide an air-tight seal for the cables, as shown in

Figure 3-2. On the deck of the platform, as required by the regulations, all exposed cables were contained within cable trays to protect them. This method of meeting the Class 1 Division 2 requirements was difficult but worked well. In addition, because the air supplied to the antenna was dry and salt free, this system is expected to greatly increase the life of the RWP components in the harsh marine environment.

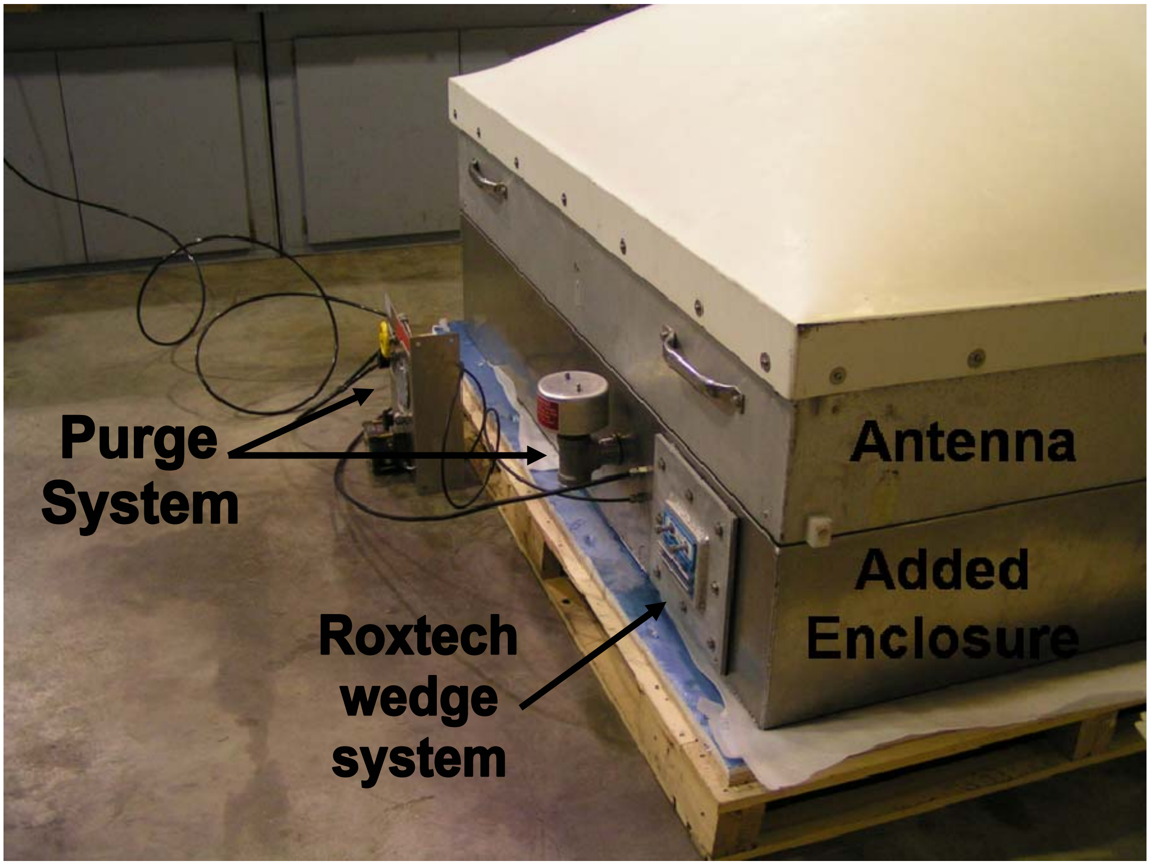


Figure 3-2. Roxtech wedge kit used to provide a seal for the cables. Also shown is the purge system used to keep positive air pressure inside the antenna enclosure.

### 3.1.3 Communications

This task was originally to be performed by the TCEQ but was transferred to STI because we were already managing other platform logistics. To obtain the data in real time from the platform and to monitor the systems, we investigated two solutions: two-way satellite Internet and microwave Internet. The microwave Internet, while easier to install, required laying several hundred feet of cable and was more costly. Because of the lower cost (about $1,000 in hardware and software, and $100 per month fee), the two-way satellite alternative was used. To set up the satellite Internet, a certified Direcway installer with the proper alignment tools was required. A Virtual Network Computing (VNC) connection was installed to the RWP computer, permitting two-way communication with the RWP/RASS, mini-sodar, and surface meteorological equipment, enabling direct data transfer to the office and remote control of the equipment. Because of the satellite system's low cost and reliability, it is recommended for other remote operations.

### 3.1.4 Hurricanes

The 2005 hurricane season was the most active on record. Three category five hurricanes crossed over GOM waters, two of which (Katrina and Rita) required the evacuation from Brazos A19. Unfortunately, these evacuations coincided with the installation of the equipment on the platform. During Hurricane Katrina, we were evacuated a few days prior to completing the installation and were unable to return to the platform for three weeks. The long delay occurred because our subcontractor, TEST Automation and Control, was located in New Orleans and because Shell Oil had to attend to hurricane-related issues before we could return to the platform. During Hurricane Rita, we were again evacuated; however, we were able to get most of the equipment operational before leaving the platform. We only needed to return to fine tune the mini-sodar to improve the data recovery. These events made clear that hurricanes are a real concern when conducting operations over the GOM. Several items of importance are related to hurricanes:

- The equipment to be installed must be able to withstand hurricane force winds. We tied down the equipment and shelter with steel guy wires for this project.
- Special equipment insurance is needed for offshore areas and for hurricanes. Our insurance company contended that our normal coverage did not extend outside the United States, and Brazos A19 was considered to be located in international waters.
- Back-up communication with the installation personnel is needed in the event that primary communications are disrupted.
- Delays due to hurricanes need to be considered when planning the installation.

## 3.2 OPERATIONAL CONSIDERATIONS

### 3.2.1 Power

Major power interruptions occurred twice during Hurricanes Katrina and Rita. Otherwise, occasional power spikes interrupted mini-sodar operations by blowing fuses on the battery charger. Shell's platform operators were very helpful and provided support for small maintenance items, including changing fuses. This support was available only after the platform operators' primary responsibilities were completed for the day, sometimes causing several hours or days of delay in data collection. However, having on-site maintenance was extremely helpful in increasing data recovery and conserving resources. We strongly recommend operations on offshore platforms be performed on manned or routinely visited platforms.

### 3.2.2 Interference

Interference is a known problem for RWPs on oil platforms, particularly due to sea clutter. Utilizing Vaisala's new digital IF hardware, along with multiple peak picking software, we were able to limit some of the interference caused by sea clutter. However, the presence of a large crane along the south end of the platform, and the platform structure itself, resulted in strong signal reflections that overwhelmed the return signal in the lowest range gates of the RWP. As a result, the lowest range gate that routinely measured winds was approximately 268 m apl. In an ideal environment, the lowest range gate that routinely measures winds would be approximately 120 m apl.

Audible noise interference posed a problem for the mini-sodar. In particular, the vertical and north beams of the mini-sodar measured noise levels 10 times greater than those recorded by the east beam. Identifying the noise sources responsible for interference was difficult due to unknown changes on the platform over the past six months. We are considering enclosing the mini-sodar in a second set of clutter fences in an attempt to minimize the amount of noise the mini-sodar receives.

RASS is also an interference source for the mini-sodar. Initially, the mini-sodar was tuned to a higher frequency to avoid the interference. However, the higher frequency resulted in much poorer data quality due to the unknown noise sources on the platform. As a result, wind profiles that were measured during the five minutes each hour when the RASS operated were eliminated from the data set.

### 3.2.3 Data Collection

The data collection process was set up to automatically push data from the oil platform to file transfer protocol (FTP) servers. When the data are uploaded, an automatic process takes the data in their raw form and stores them in an MS-SQL database, effectively combining all data into a single data set. Another automatic process generates images and uploads them to a Web site (http://tceq.sonomatechdata.com). These processes provided us with an efficient way to check data, catch any problems that may occur, and provide users real-time access to the data.

# 4. INSTRUMENT DESCRIPTIONS

## 4.1 RADAR WIND PROFILER AND RADIO ACOUSTIC SOUNDING SYSTEM

The 915-MHz Lower Atmospheric Profiler (LAP®-3000) with RASS measures vertical profiles of wind and $T_v$ in the boundary layer and lower troposphere. Specifications for the RWP and RASS are shown in **Table 4-1**.

Table 4-1. Specifications for the RWP, RASS, and mini-sodar equipment.

| Measured Parameter | Sensor | Sensor Manufacturer | Sensor Model | Sensor Specifications |
|---|---|---|---|---|
| Wind speed | RWP | Vaisala, Inc. | LAP®-3000 | Accuracy: ±1.0 m/s<br>Range: 0 to 24 m/s (per beam) |
| Wind direction | RWP | Vaisala, Inc. | LAP®-3000 | Accuracy: ±10°<br>Range: 0 to 360° |
| Virtual temperature | RASS | Vaisala, Inc. | LAP®-3000 | Accuracy: ±1.0°C<br>Range: 0°C to 40°C |
| Wind speed | Mini-sodar | Atmospheric Systems Corporation | Model-4000 | Accuracy: ±0.5 m/s<br>Range: 0 to 45 m/s (per beam) |
| Wind direction | Mini-sodar | Atmospheric Systems Corporation | Model-4000 | Accuracy: ±5°<br>Range: 0 to 360° |

The LAP®-3000 includes a single phased-array antenna. The radar beam is sequentially electronically aimed vertically and 23° from the vertical in up to four orthogonal directions. The LAP®-3000 includes electronic subsystems that control the radar's transmission, reception, signal processing, and RASS. The system also allows users to download data and remotely control the profiler operations.

The RWP transmits an electromagnetic pulse along the beam direction. The duration of the transmission determines the length of the pulse emitted by the antenna, which, in turn, corresponds to the volume of air illuminated (in electrical terms) by the radar beam. These radio signals are then scattered by small-scale turbulent fluctuations that induce irregularities in the radio refractive index of the atmosphere. A receiver measures the small amounts of the transmitted energy that are scattered back toward the RWP (referred to as "backscattering"). These backscattered signals are received at a slightly different frequency than the transmitted signal. This difference is called the Doppler frequency shift and is directly related to the velocity of the air moving towards or away from the RWP along the pointing direction of the beam. The radial velocity measured by the tilted beams is the vector sum of the horizontal motion of the air toward or away from the RWP and any vertical motion present in the beam. Using appropriate trigonometry, the three-dimensional meteorological velocity components (u,v,w) and wind speed and wind direction are calculated from the radial velocities with correction for vertical motions.

RASS consists of four vertically pointing acoustic sources (which are equivalent to high-quality, high powered loudspeakers) placed around the radar antenna and an electronics subsystem consisting of an acoustic power amplifier and signal-generating circuit boards. The acoustic sources are enclosed by noise-suppression shields to minimize nuisance effects that might bother people working near the instrument. Each acoustic source transmits approximately 75 watts of power and produces acoustic signals in approximately the 2020- to 2100-Hz range.

The principle of RASS operation is that when the wavelength of the acoustic signal matches the half wavelength of the radar (called the Bragg match), enhanced scattering of the radar signal occurs. During RASS operation, acoustic energy transmitted into the vertical beam of the radar produces the Bragg match and allows the RWP to measure the speed of the acoustic signals. By measuring the speed of sound as a function of altitude with the radar, $T_v$ profiles can be calculated.

The mini-sodar consists of a single phased-array antenna that uses acoustic pulses (i.e., chirps or beeps) to measure the profile of the three-dimensional wind vector in the lower atmospheric boundary layer (Crescenti, 1997). The phased-array mini-sodar antenna consists of a phased array of emitters (speakers), which acts to steer the acoustic pulses so that the individual components of the wind (two horizontal and one vertical; or u, v, and w) can be resolved. After each pulse, the mini-sodar listens for the backscattered sound and determines the wind speed from the Doppler shift in the acoustic frequency. The mini-sodar was tuned to a frequency of 4500 Hz. Specifications for the mini-sodar are shown in Table 4-1.

## 4.2 SAMPLING CONFIGURATIONS

The RWP was configured to measure hourly averaged profiles of wind speed, wind direction, vertical velocity, and returned signal strength (signal-to-noise ratio). The RASS system was configured to measure $T_v$. The sampling configurations for the RWP and RASS meteorological sensors are shown in **Tables 4-2 and 4-3**.

To measure the aloft winds, the RWP was configured to cycle in “low” and “high” operational modes. The “low” operational mode measured winds from about 268 m above platform level (apl) up to about 1800 m apl and had a vertical resolution of 57 m. The “high” mode had greater altitude coverage, from about 350 m apl up to about 3800m apl, and a coarser vertical resolution of 97 m. Winds from both modes were merged at 800 m apl to create a single profile with 57-m resolution below 800-m and 97-m resolution from 800 m to about 3800 m.

Table 4-2. Sampling configurations used for the RWP and RASS sensors.

| Specification | Winds | $T_v$ |
|---|---|---|
| Averaging period (min) | 55 | 5 |
| Reporting interval (min) | 60 | 60 |
| Time standard | CST | CST |
| Time convention | Begin | Begin |

Table 4-3. Sampling resolution for the RWP and RASS sensors.

| Specification | Winds | $T_v$ |
|---|---|---|
| Vertical resolution (m) | 57 (low mode)<br>97 (high mode) | 63 |
| Minimum altitude (m apl) | 268 (low mode)<br>373 (high mode) | 142 |
| Maximum altitude (m apl) | 1813 (low mode)<br>3875 (high mode) | 1578 |

The aloft $T_v$ measured by the RASS system was configured to sample for the last five minutes of each hour. The RASS sampling was performed with a 63-m vertical resolution, and the altitude coverage ranged from about 150 m apl up to about 1600 m apl.

The mini-sodars were configured to measure 10-minute averaged profiles of wind speed, wind direction, vertical velocity, and returned signal strength (signal-to-noise ratio). The sampling configurations for the mini-sodar meteorological sensor are shown in **Tables 4-4 and 4-5**.

The mini-sodar was configured to measure winds from 15 m apl up to about 150 m apl and had a vertical resolution of 5 m.

Table 4-4. Sampling configurations used for mini-sodar sensor.

| Specification | Winds |
|---|---|
| Averaging period (min) | 10 |
| Reporting interval (min) | 10 |
| Time standard | CST |
| Time convention | Begin |

Table 4-5. Sampling resolution for the mini-sodar sensor.

| Specification | Winds |
|---|---|
| Vertical resolution (m) | 5 |
| Minimum altitude (m apl) | 15 |
| Maximum altitude (m apl) | 150 |

The surface meteorological tower was configured to measure wind speed and wind direction using an aerovane-type wind speed sensor (RM Young AQ Wind Monitor) at 8 m apl. Air temperature, dew point temperature, relative humidity, direct solar radiation, and pressure were measured at 7 m apl. Sixty-minute averages were collected. The sampling configurations for the surface meteorological sensors are shown in **Table 4-6**.

Table 4-6. Sampling configurations used for the surface meteorological sensors.

| Specification | Surface Meteorology |
|---|---|
| Averaging Period (min) | 60 |
| Reporting Interval (min) | 60 |
| Time Standard | CST |
| Time Convention | Begin |

# 5. DATA PROCESSING AND QUALITY CONTROL

This section describes the steps that were followed to acquire, process, and perform quality control (QC) and editing of the upper-air and surface meteorological data collected during the sampling period.

The data validation process involved identifying inconsistent observations (outliers) and assigning QC codes to each data point to indicate its validity. Several stages, or “Levels”, in the data validation process were included:

<u>Level 0.0</u>. Raw, non QC’d data.

<u>Level 0.5</u>. Data that were subjected to automatic QC screening by software (e.g., Weber and Wuertz, 1991 for the radar).

<u>Level 1.0</u>. Data that were subjected to quantitative and qualitative reviews for accuracy, completeness, and internal consistency. Staff who understand the measurement systems and the meteorological processes expected to be reflected in the data performed the qualitative reviews.

<u>Level 2.0</u>. Data that were compared with prior hour data and model output to evaluate directional consistency with synoptic patterns. This level is often part of the data interpretation or analysis process. Data may also be compared with data from other instruments (nearby profilers, rawinsondes, or upper-air maps).

The following steps were used to bring data to Level 2.0 validation. **Figures 5-1 and 5-2** show examples of data plots after Level 2.0 validation.

1. The Level 0.0 data were obtained from Brazos A19 hourly via the Internet. Backup copies of the Level 0.0 data were automatically made and archived. In addition, backup data were obtained from the radar computer via a portable hard drive every three months and any missing data were added to the database.
2. Manual review of the data was performed by an experienced meteorologist. The reviewers carefully examined plots of the data, looking for outliers, and evaluated the reasonableness of the data. The reviewers flagged the resulting data as “valid”, “invalid”, or “missing”, using the appropriate QC codes.

   The following QC codes were used:

   0 = Valid
   1 = Valid, no vertical correction
   2 = Valid, calibration applied
   8 = Invalid with a data value of:
   -940 = failed auto QC
   -950 = unable to create consensus average
   -960 = radial velocities too high/low
   -980 = invalidated by reviewer
   9 = Missing with a data value of –999

   Note: We recommend using only data with a QC code 2.

3. Reviewers used internal and external sources of data to help them determine the validity of the observations. **Table 5-1** lists internal data sources that were commonly used and provides a brief explanation of their use. Internal data sources included other parameters that were measured by the same instrument, collocated data sources, and other internally generated data (e.g., instrument performance logs and site operator logs). For example, when checking for precipitation contamination in the profiler or RASS data, reviewers often relied on the profiler's vertical velocity measurements, which record the fall velocity of rain during precipitation events.

**Table 5-2** lists external data sources and gives a brief explanation of their use. Examples of external data include the NOAA buoy data, National Weather Service (NWS) upper-air and surface weather charts, and satellite images. NOAA buoy winds compared to platform winds to perform reasonableness checks are an example of external data use.

Table 5-1. Internal data sources used during data validation.

| Internal Data Sources | Usage |
|---|---|
| Profiler vertical velocity data | Check for vertical velocity biasing in the RASS data.<br>Check for precipitation contamination of upper-air winds. |
| Profiler signal-to-noise ratio (SNR) data | Check for precipitation contamination, bird contamination, ground clutter, and altitude coverage in upper-air winds. |
| Surface meteorological wind data | Check for consistency in the profiler's lower-level wind data. |

Table 5-2. External data sources used during data validation.

| External Data Sources | Explanation of Usage |
|---|---|
| NWS upper-air meteorological charts | Perform reasonableness checks to evaluate the spatial consistency of the upper-level winds based on geopotential height gradients depicted on 700-mb and 850-mb charts. |
| NWS surface meteorological charts | Track synoptic scale weather features (i.e., frontal positions, thunderstorms) that may affect instrument performance or data quality. |
| NOAA buoy data | Check for temporal and spatial consistency in the wind speed and wind direction data. |

# 6. DATA FILE INFORMATION

The CD accompanying this report contains upper-air data files and surface meteorological data files. The time standard for the data is Coordinated Universal Time (UTC). This section describes the file formats. To create data displays similar to those shown in this memorandum, the GraphXM software may be purchased from Vaisala, Inc. STI can provide with assistance to create the plots.

## 6.1 RWP, RASS, AND MINI-SODAR DATA FILES

The upper-air data files are provided in the FSL (Forecast Systems Laboratory) RAOB (RAdiosonde OBservation) format. The file-naming convention for the FSL RAOB wind data files is SS_YYYY_MM-MM.txt; the file-naming convention for the FSL RAOB RASS data files is SS_YYYY_MM-MM_RASS.txt; and the file-naming convention for the FSL RAOB mini-Sodar data files is SS_YYYY_MM-MM_MINI-SODAR.txt.

where:

| | | |
|---|---|---|
| *SS* | = | Two letter site ID |
| *YYYY* | = | Four digit year (2005) |
| *MM-MM* | = | Month (09-12) |

For example, the file BR_2005_09-12_MINI-SODAR.txt contains the mini-Sodar wind data from Brazos A19 for the period from September 1, 2005 to December 31, 2005.

The FSL RAOB data format (see **Figure 6-1** for an example file) is similar to the format used by the National Severe Storms Forecast Center (NSSFC). The first four lines of the sounding are identification and information lines. All additional lines are data lines. An entry of 32767 (original format) or 99999 (new format) indicates that the information is either missing, not reported, or not applicable. **Table 6-1** provides a description of the contents of the FSL RAOB file format.

```
                         ---COLUMN NUMBER---

     1       2       3       4      5     6       7       8       9
   LINTYP
                       header lines
    PROF      HOUR      DAY    MONTH     YEAR    (blank)    (blank)    MIN      RES
     1     WBAN#     WMO#     LAT      LON    ELEV     (blank)
     2     (blank)   (blank)  (blank)   (blank)  (blank)   (blank)
     3    (blank)     STAID   (blank)   (blank)  (blank)   WSUNITS

                       data lines
     9   PRESSURE    HEIGHT     VTEMP    DEWPT   WIND DIR    WIND SPD
     4
     4
     4
     4
     4
     .
     .
     .
```

Figure 6-1. Example of FSL RAOB file format.

Table 6-1. Legend describing the FSL RAOB file format.

| Parameter Name | Parameter Description |
|---|---|
| LINTYP | Type of identification line |
| PROF | Profiler sounding Date Information line |
| 1 | Station identification line |
| 3 | Station identifier and other indicators line |
| 4 | Mandatory level |
| 9 | Surface level |
| HOUR | Begin Hour of Day in UTC |
| DAY | Day of Month (1 - 31) |
| MONTH | Month of Year (1 - 12) |
| YEAR | Year (1900 - 2999) |
| MIN | Minute timestamp of data |
| RES | Resolution of the data |
| LAT | Latitude in degrees and hundredths |
| LON | Longitude in degrees and hundredths |
| ELEV | Elevation from station history in meters |
| WSUNITS | Wind speed units in tenths of a meter/second |
| STAID | Radar Station Name |
| PRESSURE | In tenths of millibars. These are all standard pressure heights except for line type 9, it could be a measurement. |
| HEIGHT | Height in meters (m) (MSL) |
| VTEMP | Virtual Temperature in tenths of degrees Celsius |
| DEWPT | Dew point temperature in tenths of a degree Celsius |
| WIND DIR | Wind direction in degrees |
| WIND SPD | Wind speed in knots or meters/second |

## 6.2 SURFACE METEOROLOGICAL DATA FILE

The file-naming convention for the surface meteorological data files is YYYY_MM-MM_sfc.txt,

where:

*YYYY* = Four digit year (2005)
*MM-MM* = Month (09-12)

For example, the file *2005_09-12_sfc.txt* contains the surface meteorological data from Brazos A19 for September 1 through December 31, 2005.

The surface meteorological data are stored in comma separated value (csv) format, and the first line contains header information defining each of the data fields found in lines 2 through the end of the file. The SiteCode is BR for Brazos A19 and the ClassName is Surface for all surface data. The DateTime field is in UTC, begin time. The height in the surface data file is the height of the sensor in meters apl, and the units for each parameter are found in the field to the right of the value. QC codes and levels are the last two fields in the file. **Table 6-2** summarizes the parameter codes found in the csv file, and **Figure 6-2** shows an example of the surface data file.

Table 6-2. Parameter codes and values for the surface meteorological data file.

| Parameter Code | Value |
|---|---|
| DP | Dew point temperature |
| WS | Wind speed |
| WD | Wind direction |
| SR | Solar radiation |
| RH | Relative humidity |
| P | Pressure |
| T | Temperature |
| TA | Ambient temperature |

```
SiteCode,ClassName,ParameterCode,DateTime(UTC),Height,Value,Units,QCCode,QCLevel
    BR,Surface,DP,10/3/2005 3:00:00 PM,7,-34.20000,°C,0,0
    BR,Surface,DP,10/3/2005 4:00:00 PM,7,-32.39000,°C,0,0
    BR,Surface,DP,10/3/2005 5:00:00 PM,7,-31.38000,°C,0,0
    BR,Surface,DP,10/3/2005 6:00:00 PM,7,-31.07000,°C,0,0
```

Figure 6-2. Example of surface data file.

# 7. REFERENCES

Crescenti G.G. (1997) A look back on two decades of Doppler sodar comparison studies. *Bull. Am. Meteorol. Soc.* **78**, 651-673.

Lindsey C.G. and Dye T.S. (1993) Upper air meteorological measurements for the Gulf of Mexico Air Quality Study. Paper presented at the *Air & Waste Management Association Regional Photochemical Measurement and Modeling Studies Conference, San Diego, CA, November 8-12*.

Weber B.L. and Wuertz D.B. (1991) Quality control algorithms for profiler measurements of wind and temperatures. Technical memorandum by NOAA Environmental Research Laboratories, Boulder, CO, ERL WPL-212.

# APPENDIX A

## SUMMARY OF TASK 1 THROUGH 6 DELIVERABLES

**Task 1**: Sonoma Technology Inc. shall prepare a Quality Integrated Work Plan (QIWP) that defines the quality control activities associated with the RWP, RASS, mini-sodar, and surface meteorological equipment. In addition, Sonoma Technology Inc. shall prepare a Health and Safety Plan (HASP) that identifies potential hazards at the monitoring site and specifies procedures that will reduce the risk of injury.

*The QIWP and HASP were e-mailed to the TCEQ on September 2, 2005.*

**Task 2**: Sonoma Technology Inc. shall submit a copy of the aviation insurance of the helicopter company to the TCEQ upon completion of this task. *The helicopter flights were not paid for by this grant so a copy of the aviation insurance was not provided for this grant.*

**Task 3**: Installation of Equipment: Sonoma Technology Inc. shall submit a written report to the TCEQ upon completion of this task to include, but not be limited to, photos of the installed equipment.

*This written report was provided as part of the September 2005 monthly progress report delivered on October 31, 2005. Photos and data were made available via the web at <http://tceq.sonomatechdata.com/camera.aspx?site=BR>.*

*The password for the photos is tceq*
*The user name is pic4U*

**Task 4**: Data Acquisition and Field Operations: Sonoma Technology Inc. shall acquire the surface and upper-air meteorological data and shall submit a written report to the TCEQ upon completion of this task to include, but not be limited to, a database containing the objectively and subjectively quality-controlled surface and upper-air meteorological data collected during the five-month field study.

*The data are available via the web at <http://tceq.sonomatechdata.com/camera.aspx?site=BR>. In addition, a CD containing the quality controlled data accompanies this final report. These data were sent to TCEQ's TexAQS-II field study representatives on March 24, 2006.*

**Task 5**: De-installation: Sonoma Technology Inc. shall de-install all equipment and return the site to its original condition. Deliverable: The PERFORMING PARTY shall submit a written report to the TCEQ upon completion of this task, to include but not limited to a summary on the de-installation of the equipment.

*As agreed to on conference calls with the NTRD project representative and Sonoma Technology Inc. and as documented in a letter sent December 29, 2005, to Ms. Kate Williams (the NTRD Grant Manager), the deinstallation task was not required during this grant period and will be covered by the TCEQ under another contract.*

**Task 6**: Sonoma Technology Inc. shall prepare and submit monthly detailed project reports and a comprehensive final report while ensuring compliance with all TCEQ program requirements.

*Monthly reports have been submitted to the TCEQ and NTRD each month beginning June 3, 2005. This final report meets the deliverable for Task 6 and was sent to the TCEQ on June 29, 2006.*