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SUMMARY OF THE BRAZOS A-19 2005 AND 2006 RADAR PROFILER OPERATIONS AND DATA AVAILABILITY

FINAL REPORT
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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 undertook an 18-month field program called the Texas Air Quality Study II (TexAQS-II). The study began in June 2005 and ended October 2006. The purpose of the field program was to collect air quality and meteorological data that are now being used as the scientific basis for the development of State Implementation Plans (SIPs) for ozone and regional haze. Ultimately, the 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.

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 about 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 from September 2005 through January 2006. The TCEQ and Mineral Management Services (MMS) then funded operations from April through October 2006 and the subsequent deinstallation of the equipment. 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).

This document summarizes project activities (Section 1.2); 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); discusses methods to create mixing heights (Section 6); and defines the data files on the compact disk (CD) that accompanies this report (Section 7). The CD contains quality-controlled upper-air and surface meteorological data collected during the official (i.e., funded) operations period that are validated to Level 2 and ready for use in modeling and data analysis. We have also included data, when available, from the unfunded operations; however, these data have not been quality-controlled. References cited in this report are compiled in Section 8.

1.2 PROJECT SUMMARY

Sonoma Technology, Inc. (STI) was contracted to complete the setup, testing, optimization, and operations of an RWP/RASS, mini-sodar, and surface meteorological instruments on an oil platform in the GOM from September 1, 2005, to January 31, 2006, and from April 1, 2006, through September 30, 2006. In particular, STI (1) modified the instruments to meet platform explosion-proofing requirements and to optimize the instruments for operation in an offshore environment; (2) procured space on an oil platform in the coastal waters of eastern Texas; (3) installed infrastructure to support the measurement operations including power, shelter, and communications; (4) installed and operated the instruments during TexAQS-II; (5) identified and resolved instrument issues during operations; (6) deinstalled the equipment from the platform; and (7) provided objectively quality-controlled (QC'd) data, part of which were QC'd by STI (for a separate grant activity) and part by TAMU (for this grant activity).

2. SITE AND DATA OVERVIEW

In an ideal operating environment, the RWP/RASS 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 4,000 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 offshore platform, including sea clutter and interference from a crane, increased the lowest height of wind data recovery to about 270 m above the platform. 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 routinely compromised by audible noise from platform operations and maintenance. The surface instruments measured wind, temperature, solar radiation, pressure, and dew point.

Preparations to install and operate these 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 Oil Corporation's (Shell) 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 resumed operation from October 3, 2005 through October 15, 2006 (although the operational project officially ended September 30, 2006). Instrument downtimes that occurred during this latter period of operations are discussed in this section.

Table 2-1 summarizes the measurements made on Brazos A-19 Platform D**.** Mixing heights were not derived for the period September 28, 2005, through March 31, 2006, because the grant activity to complete this work was terminated on December 31, 2005, by TCEQ. **Figure 2-1** shows the Brazos A-19 complex, including platform D 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 of the Brazos A-19 complex was selected because (1) drilling activity was not expected to occur there during the TexAQS-II; (2) the platform had space to accommodate the instruments; (3) the platform's location was suitable to meet the TexAQS-II measurement needs; and (4) Shell was willing to make the platform available for the study.

Table 2-1. Summary of measurements.

Instrument	Parameter	Time Resolution	Vertical Resolution (m above platform level (apl))	Typical Height Coverage (m apl)
RWP	Winds	Hourly	57 in lowest 800 and 97 above 800	~270 up to 3,500
RWP	Mixing Heights	Hourly	60 in lowest 800 and 120 above 800	~268 up to 3,500
RASS	Virtual Temperature	Hourly	63	~140 up to 1,000
Sodar	Winds	Hourly	5	~15 up to 100
Surface	Winds, Temperature, Pressure, Relative Humidity, Solar Radiation	15-minute and hourly	NA	8 for winds, otherwise 7

(a)

(b)

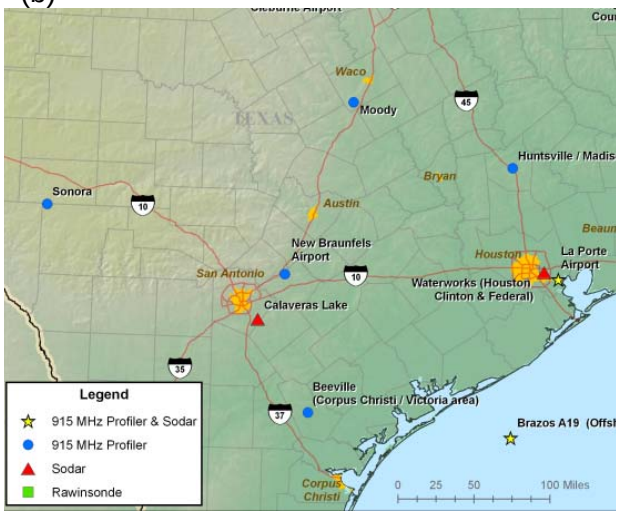


Figure 2-1. Image of Brazos A19 (a) and map showing its location (b).

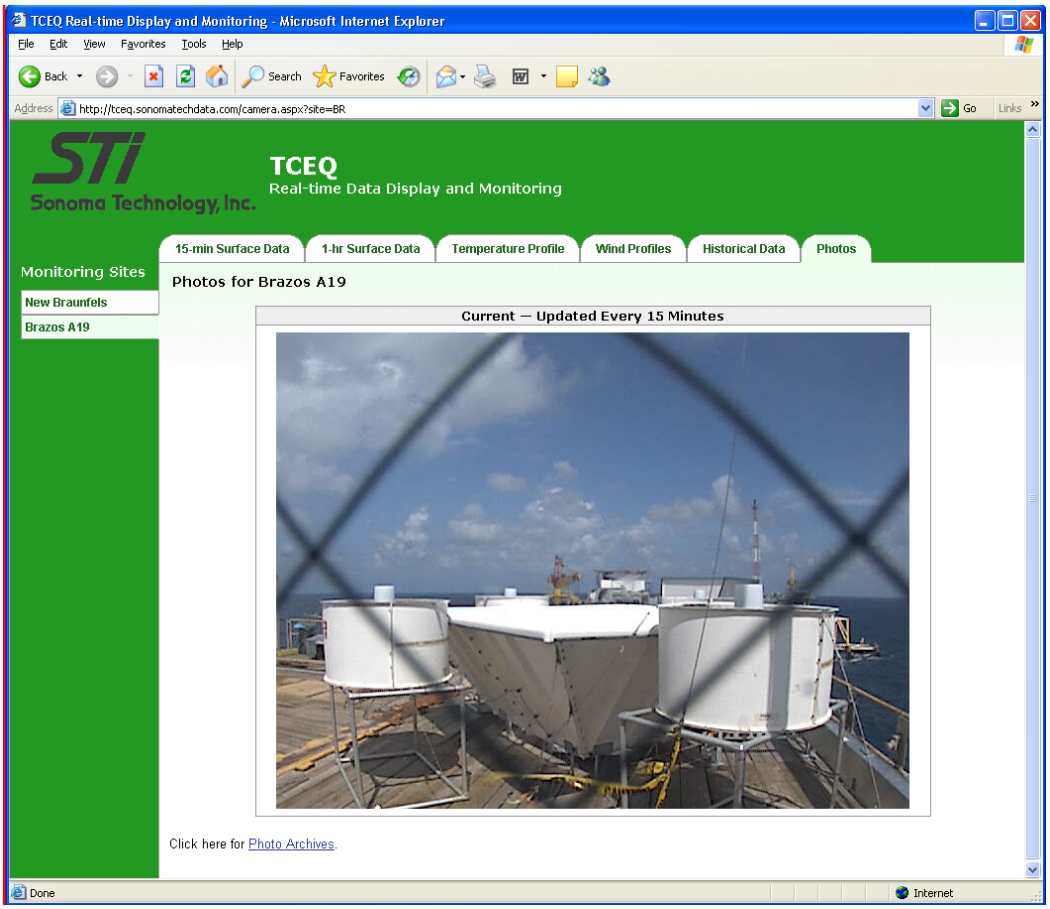


Figure 2-2. Instruments on the platform photographed by a platform camera that provides real-time images to the Internet.

(a) (b)

Figure 2-3. Atmospheric Systems' mini-sodar (a) and Vaisala's LAP-3000 Wind Profiler with RASS (b).

(a) (b)

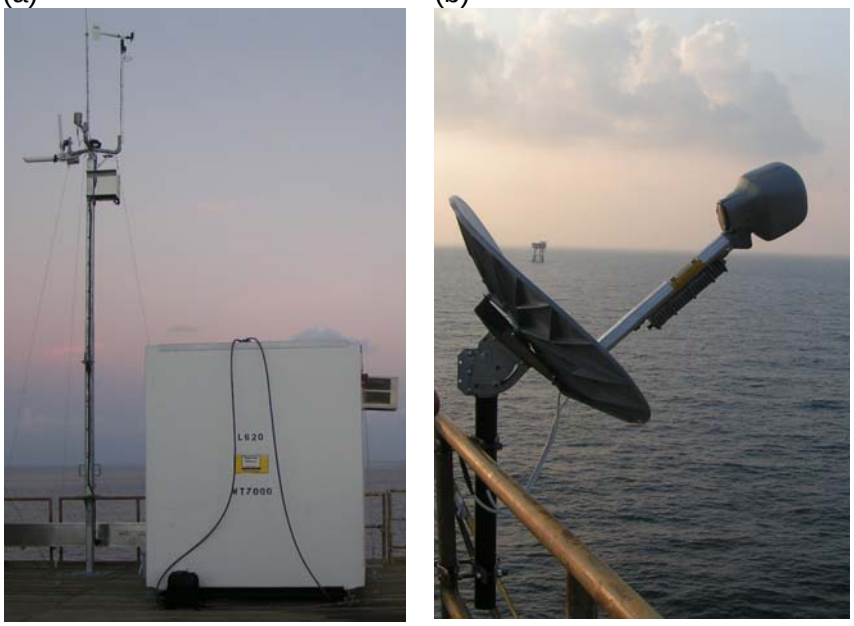


Figure 2-4. Surface meteorological instruments (a) and DirecWay DW-6000 Satellite dish (b).

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 October 2, 2006. 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 southeasterly winds (winds coming from the southeasterly) at about 5 m/sec at about 2,500 m above platform level (apl) in the evening. Note that data are available in an altitude range of about 268 m apl to about 2,000 to 4,000 m apl. 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 4,000 m apl when the atmosphere is moist to about 1,000 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 for December 28, 2005. The mini-sodar reported winds from 15 m apl to about 100 m apl on this day. However, data recovery was poor on many days because of noise on the platform.

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 1,000 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 September 7, 2006. The figure shows adiabatic temperature profiles up to about 1,400 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.

Both real-time and historical data were made available beginning September 20, 2005 (http://www.sonomatech.com/tceqdata). The historical data will be available on this site through January 31, 2007. Some data gaps exist due to instrument downtimes. **Table 2-2** shows instrument downtimes of more than 24 hours from the beginning of operations through October 15, 2006. Please note that official (funded) operations ceased in February and March 2006 and October 1 through October 15, 2006; however, we have included downtime information for these periods as well. In addition to instrument downtimes, noise on the platform often interfered with the mini-sodar, so that accurate mini-sodar wind data could not be collected at all times. Major downtimes and causes are discussed below:

- The most common cause for RWP/RASS downtime 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. Instrument downtimes generally lasted a few hours to a day.
- A significant RWP/RASS and surface meteorology downtime occurred from September 1 to October 3, 2005, due to Hurricanes Rita and Katrina.
- A significant RWP/RASS and surface meteorology 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 be repaired and optimized to improve data recovery and reduce the effect of sea clutter.
- A significant mini-sodar downtime occurred July 6 through August 10, 2006. This downtime resulted from the failure of the Shell-approved battery charging system. To obtain and install a replacement charger took about four weeks.
- A significant RASS downtime occurred from June 10 through September 6, 2006. This downtime was caused by problem with the RASS sound card and speakers. Several events took place that led to this extended interruption:
  - We asked Shell personnel to check the speakers on the RASS, and they confirmed that all four speakers were not working, which is very rare. About 2.5 weeks elapsed before this information came to us because the Shell people were extremely busy with special platform work.
  - We had two spare speaker diaphragms on the platform, but needed four. We ordered the special diaphragms from Brown Sound. The diaphragms usually take about 7-10 days to be delivered. However, when they had not been delivered after 10 days, we followed up with Brown Sound. We were told they would arrive any day. However, because of problems with the manufacturer, the diaphragms finally arrived after about three weeks.
  - We checked the diaphragms to make sure they were correct and sent them to the platform. We confirmed with Shell that the diaphragms had arrived at the platform and asked Shell to place them in the shelter. We traveled to the platform to replace

the diaphragms; and when we arrived, despite extensive searching by Shell staff, the new diaphragms could not be located. With the spares we had on the platform, we replaced two of the diaphragms, which failed after a few hours. After extensive testing, we determined that the failure was due to a faulty sound card.

- We ordered a new sound card and went to New Braunfels to get spare diaphragms from that site.
- We traveled back to the platform and replaced the sound card and the diaphragms, and the problem was solved.

These downtimes, coupled with data that have been invalidated due to interference, has resulted in the following data completeness statistics for the official operations period:

- RWP winds = 59%
- RASS T_v = 56%
- Sodar winds = 60%
- Surface meteorology = 60%

Table 2-2. Summary of major times when the instruments did not produce valid data.

Downtimes (CST)	Instrument	Cause
Most of the time from 9/1/2005 to 10/03/2005	RWP/RASS/sodar/surface meteorology	Installation difficulties associated with Hurricanes Rita and Katrina
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
02/18/2006 1100 to 04/05/2006 20:18	Sodar	Battery charger fuse failure
03/16/2006 1900 to 03/17/2006 1255	RWP/RASS	Platform operator shutdown
05/26/2006 1955 to 05/28/2006 1955	RWP/RASS	Platform operator shutdown
05/31/2006 0700 to 06/01/2006 0540	Sodar	Hard drive full
06/09/2006 1755 to 06/10/2006 1455	RWP/RASS	Platform operator shutdown
6/10/2006 1155 to 9/6/2006 0800	RASS	Computer and speaker failure
06/14/2006 1053 to 06/16/2006 1813	RWP	Platform operator shutdown
06/17/2006 2059 to 06/19/2006 2309	RWP	Platform operator shutdown
07/06/2006 1200 to 07/24/2006 0600	Surface meteorology	Battery charger failure
07/06/2006 1320 to 08/10/2006 1410	Sodar	Battery charger failure
08/06/2006 1355 to 08/09/2006 0024	RWP	Platform operator shutdown
08/11/2006 0002 to 08/12/2006 0055	RWP	Platform operator shutdown
08/13/2006 1402 to 08/14/2006 1722	RWP	Platform operator shutdown
09/26/2006 1855 to 09/27/2006 1655	RWP/RASS	Platform operator shutdown
10/05/2006 1400 to 10/09/2006 0000	RASS	Speaker failure
10/05/2006 1400 to 10/09/2006 0000	Sodar	Battery charger failure

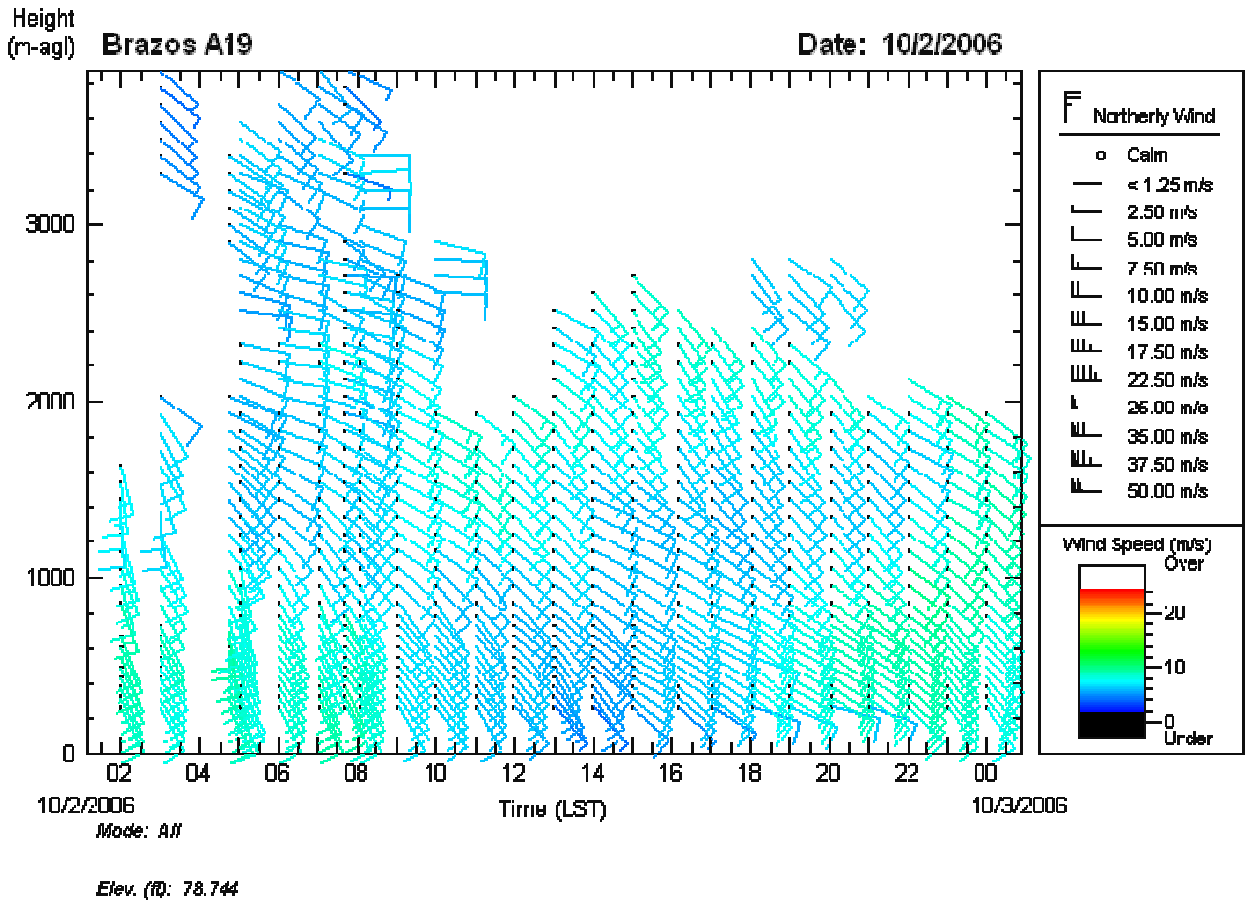


Figure 2-5. Example plot of winds measured by the RWP on October 2, 2006, at Brazos A19 in the GOM. Winds are plotted using the conventional wind barb plot format, where the orientation of the shaft indicates wind direction and the number and length of bars indicates wind speed. Note that the heights are in meters above platform level (m apl).

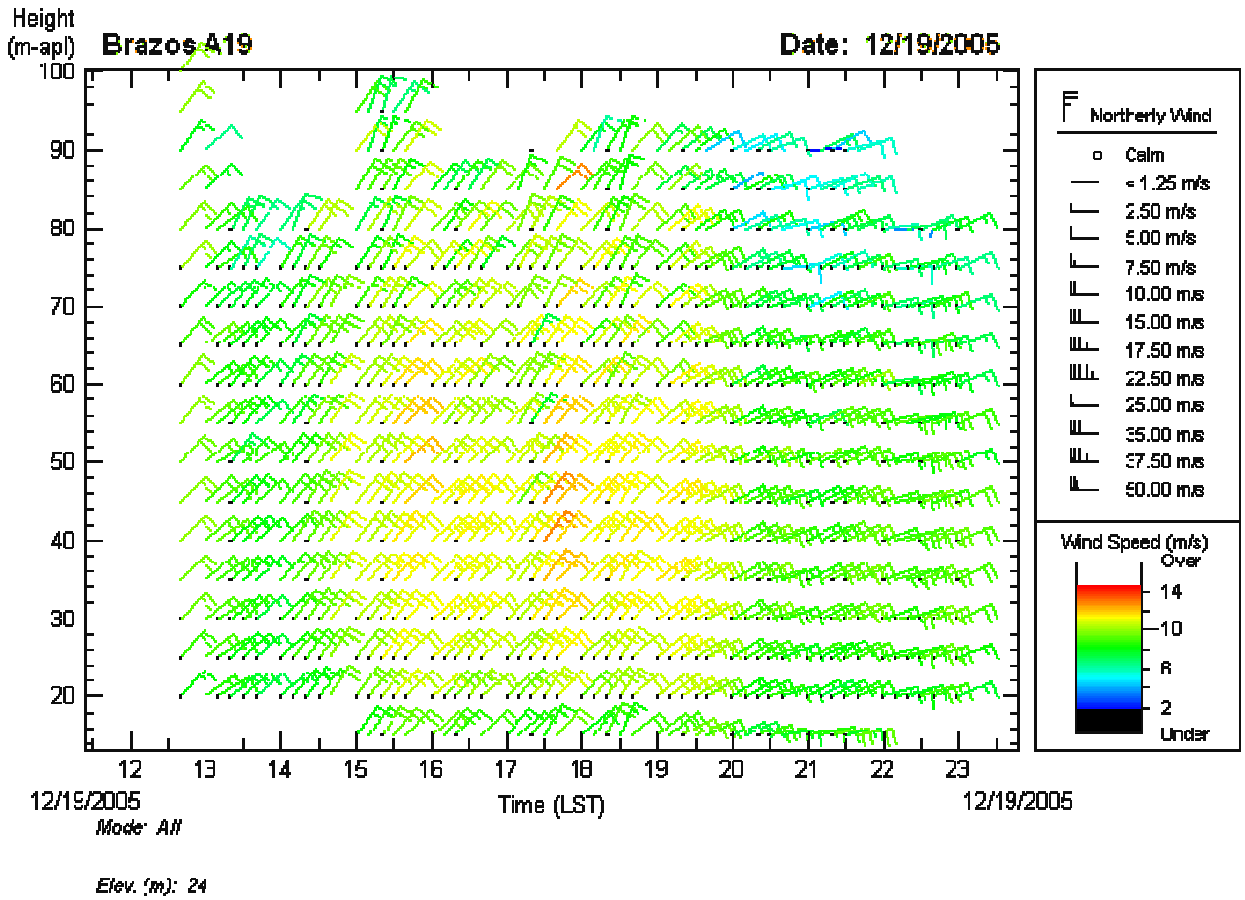


Figure 2-6. Example plot of wind profiles measured by the mini-sodar on December 19, 2005, at Brazos A19 in the GOM. Winds are plotted using the conventional wind barb plot format, where the orientation of the shaft indicates wind direction and the number and length of bars indicates wind speed.

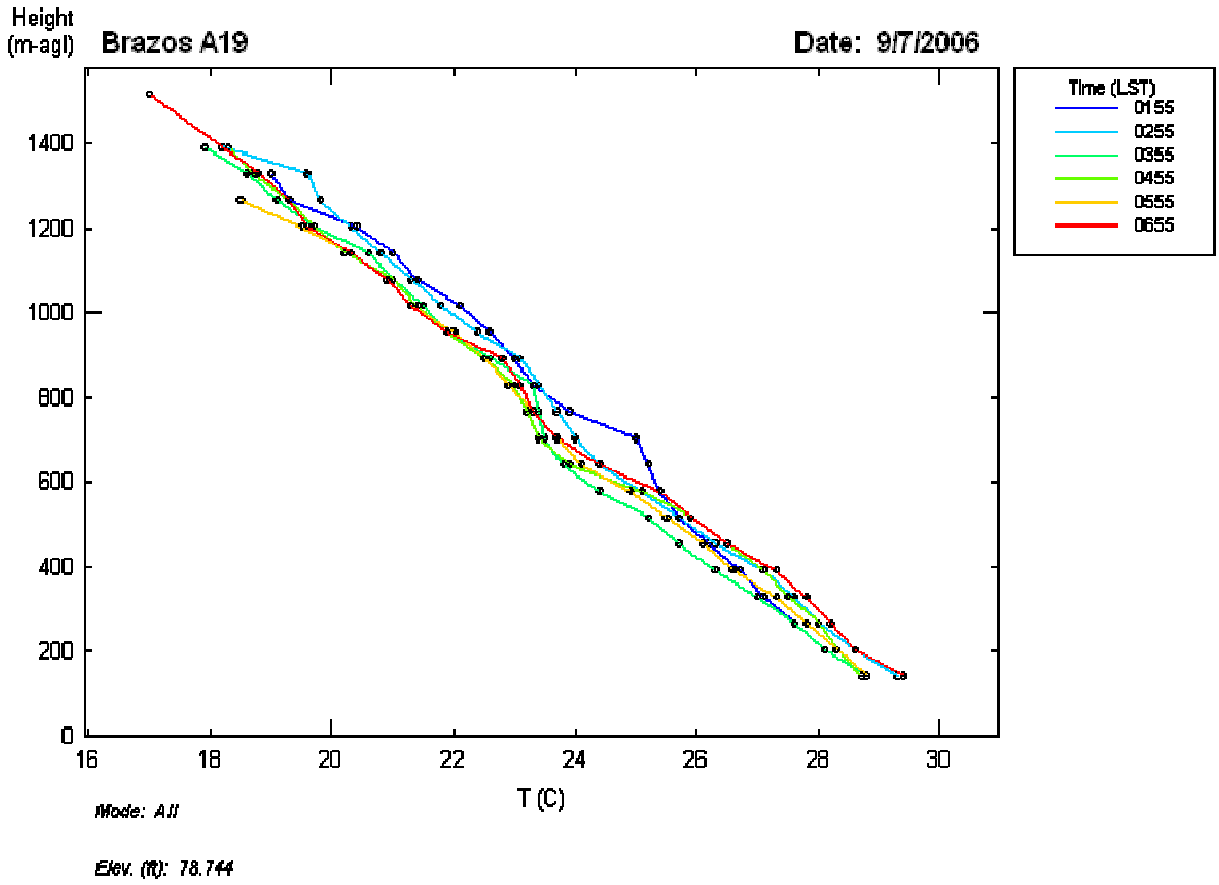
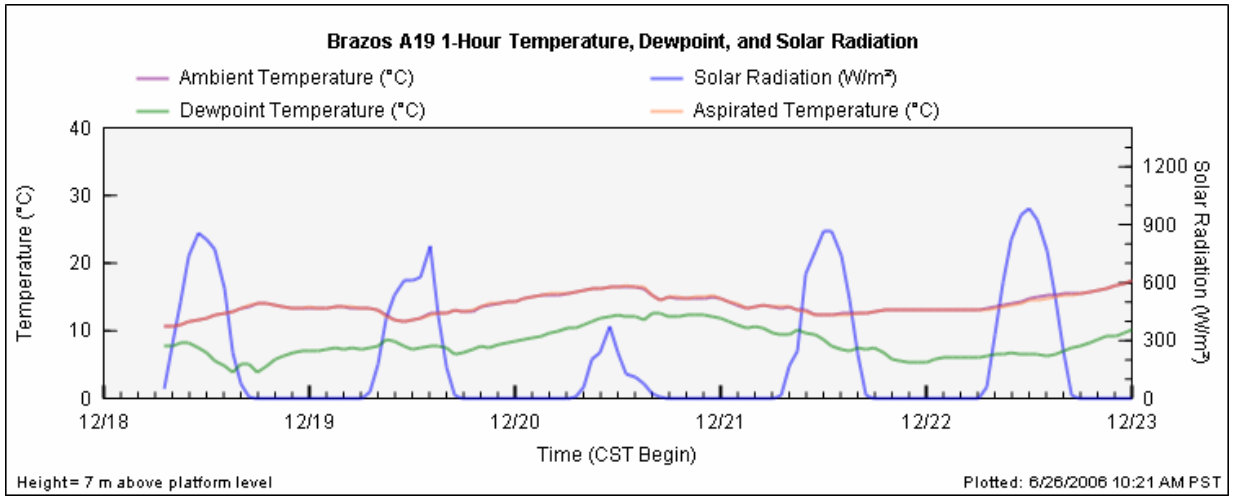


Figure 2-7. Example plot of T_v profiles measured by the RASS on September 7, 2006, at Brazos A19 in the GOM. T_v is plotted along the x-axis and altitude along the y-axis. The line color of the profiles indicates the hours the data were collected.



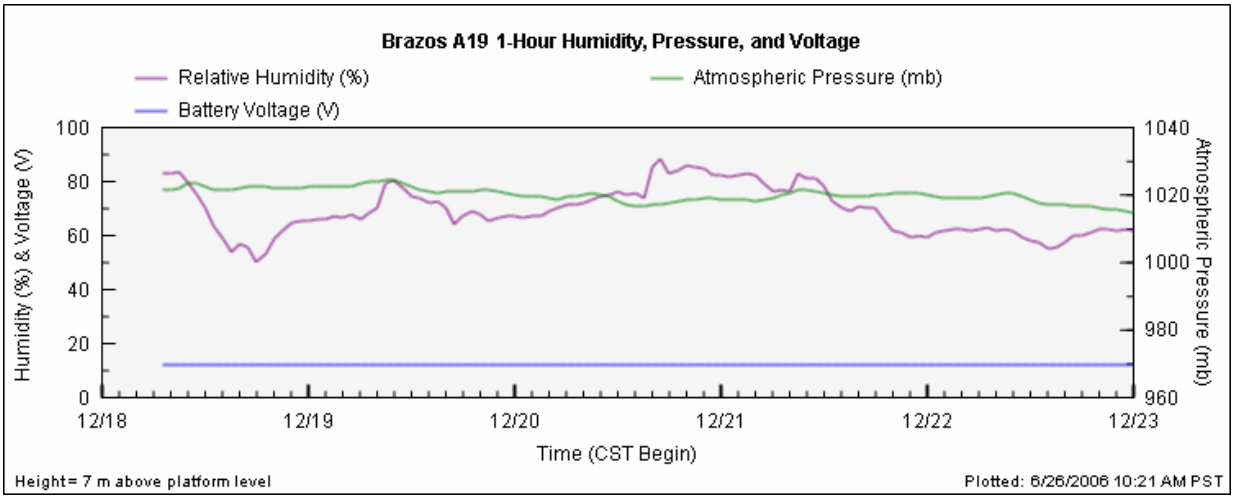


Figure 2-8. Surface meteorological data on December 20, 2005. Winds are plotted using bristles; the bristles point in the direction the wind is blowing, and the length of the bristles indicates the wind speed.

3. INSTALLATION, DEINSTALLATION, AND OPERATIONAL CONSIDERATIONS AND ISSUES ASSOCIATED WITH OFFSHORE MEASUREMENTS

The process of installing, operating, and deinstalling 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) the challenges of shipping equipment 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, (4) maintenance and turnaround time for correcting problems, and (5) interruptions from platform activities.

3.1 INSTALLATION CONSIDERATION AND ISSUES

3.1.1 Shipping

Shipping the equipment and infrastructure from the dock to the platform and back to the dock at the end of operations 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 condition and were returned in good condition. 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. Substantial 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 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 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. Because the expense of hermetically sealing the electronics required alterations to the antenna and final amplifier, the positive pressure method was selected. 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, which required extensive bending and laying, was connected to an air compressor located on the bottom deck of the platform. 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 explosion-proofing requirements was difficult but worked well and did not fail during the entire period of operation. In addition, because the air supplied to the antenna was dry and salt free, this system is expected to have greatly increased the life of the RWP components in the harsh marine environment.

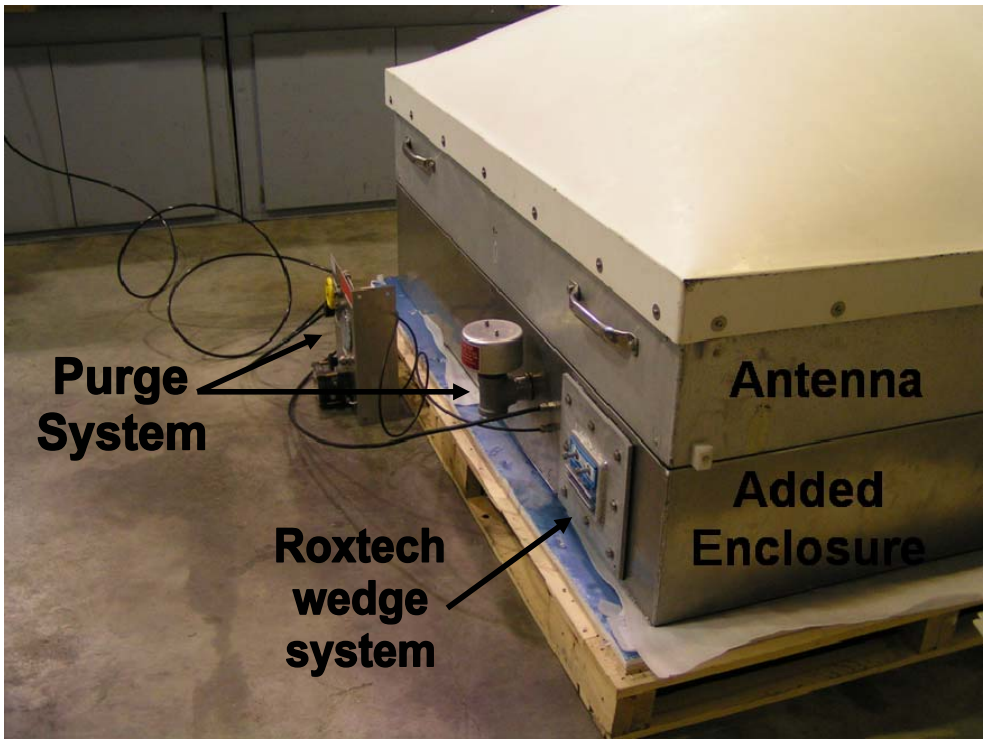


Figure 3-2. Roxtech wedge kit used to provide a seal for the cables. Also shown is the purge system used to keep positive air pressure inside the antenna enclosure.

3.1.3 Communications

To obtain the data in real time from the platform and to monitor the systems, we investigated two solutions: two-way satellite Internet connection and microwave Internet connection. The microwave Internet connection, while easier to install, required laying several hundred feet of cable and was more costly. Because of the lower cost, the two-way satellite alternative was used. To set up the satellite Internet connection, 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 STI's in-house computer and remote control of the equipment. This system worked well until July 2006, when the transmitter failed due to water penetration and subsequent corrosion; the water leakage was caused by a faulty seal. The repair of the satellite system was time-consuming because the original satellite system had been discontinued and DirecWay had been acquired by HughesNet.

Both factors negatively impacted the receipt of timely and accurate information. However, no data were lost because they were backed up at the site. The system was eventually upgraded to an improved model which worked well for the remainder of the project. Despite these issues with the original system and because of its low cost and reliability, the satellite Internet connection system is recommended for other remote operations.

3.1.4 Hurricanes

The 2005 hurricane season was the most active on record. Three Category 5 hurricanes crossed over GOM waters, two of which (Katrina and Rita) required the evacuation of Brazos A19. Unfortunately, these evacuations coincided with the installation of the equipment on the platform. During Hurricane Katrina, personnel were evacuated a few days before installation could be completed and were unable to return to the platform for three weeks. The long delay occurred because the subcontractor, TEST Automation and Control, was located in New Orleans (which was devastated) and because Shell had to attend to hurricane-related issues before other personnel 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 data recovery. These events clearly illustrate 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 withstand hurricane force winds. We secured 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 and other weather events need to be considered in installation and deinstallation planning.

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 data collection delays of several hours or days. Despite these delays, we recommend operations on offshore platforms be performed on manned or routinely visited platforms, provided that they do not need to turn off the equipment (see Section 3.2.3).

3.2.2 Interference

Interference is a known problem with RWPs on oil platforms, particularly due to sea clutter. Utilizing Vaisala's new digital intermediate frequency (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 routinely measured winds was approximately 268 m apl. In an ideal environment, the lowest range gate routinely measuring winds would be approximately 120 m apl.

Audible noise interference posed a major 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 several unknown changes and continual operations on the platform during the project.

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 measured during the five minutes each hour when the RASS operated were eliminated from the data set.

3.2.3 Interruptions From Platform Activities

Brazos A-19 is a manned complex that had extensive platform activities. These activities required Shell to turn off the RWP on a routine basis. This was because a radio control device on the crane that Shell used to offload ships and move equipment on deck operated at the same frequency as the RWP. When the RWP was on, the crane would not work. The routine shutting down of the RWP resulted in loss of data and was hard on the equipment because protocols to turn off the equipment were not always followed.

3.2.4 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 were uploaded, an automatic process took the data in their raw form and stored them in an MS-SQL database, effectively combining all data into a single data set. Another automatic process generated images and uploaded them to a Web site (http://tceq.sonomatechdata.com). These processes provided us with an efficient way to check data and detect problems and gave users real-time access to the data.

3.3 DEINSTALLATION CONSIDERATIONS AND ISSUES

The instruments were deinstalled in late November 2006. The deinstallation effort took several days even though no major problems were encountered. Deinstallation consisted of the following major components:

- Creating a detailed deinstallation plan.
- Acquiring a qualified subcontractor to assist in the deinstallation of the equipment, including removal of power (that ran from Platform D to Platform B) and the purge system. We subcontracted with TEST Automation and Control and recommend them for future similar endeavors.
- Arranging to get the Connex boxes from the rental agency to the platform, from the platform to Galveston, from Galveston to California, and back to the rental agency.
- Breaking down the equipment on the platform and carefully packing the equipment in the Connex boxes for shipping.
- Arranging for the shelter to be shipped to Abbeville, Louisiana.
- Passing the Shell platform inspection after the deinstallation was complete.
- Checking that all equipment was returned to California in working order.
- Returning the equipment to a storage facility in Petaluma, California.

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 Range: 0 to 24 m/s (per beam)
Wind direction	RWP	Vaisala, Inc.	LAP®-3000	Accuracy: ±10° Range: 0 to 360°
Virtual temperature	RASS	Vaisala, Inc.	LAP®-3000	Accuracy: ±1.0°C Range: 0°C to 40°C
Wind speed	Mini-sodar	Atmospheric Systems Corporation	Model-4000	Accuracy: ±0.5 m/s Range: 0 to 45 m/s (per beam)
Wind direction	Mini-sodar	Atmospheric Systems Corporation	Model-4000	Accuracy: ±5° 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 frequency slightly different from the transmitted signal. This difference is called the Doppler frequency shift and is directly related to the velocity of the air moving toward 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 about 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.

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 1,800 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 3,800m 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 3,800 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) 97 (high mode)	63
Minimum altitude (m apl)	268 (low mode) 373 (high mode)	142
Maximum altitude (m apl)	1813 (low mode) 3875 (high mode)	1578

The aloft T_v, measured by the RASS system, sampled during 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 1,600 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 at 8 m apl, and air temperature, dew point temperature, relative humidity, direct solar radiation, and pressure 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, quality control (QC), and edit the upper-air and surface meteorological data collected during the sampling period. The data from October 3, 2005, through January 31, 2006, were quality-controlled by STI, and the data from April 1, 2006, though October 15, 2006, were quality-controlled by TAMU.

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:

Level 0.0. Raw data, not quality-controlled.

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

Level 1.0. 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.

Level 2.0. 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 validate data to 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, identified 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 (note: we recommend using only data with a QC code ≤ 2):

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

3. Reviewers used internal and external sources of data to 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 RWP or RASS data, reviewers often relied on the RWP's vertical velocity measurements, which record the fall velocity of rain during precipitation events.

Table 5-2 lists external data sources and brief explanations 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
RWP vertical velocity data	Check for vertical velocity biasing in the RASS data. Check for precipitation contamination of upper-air winds.
RWP 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 RWP'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. MIXING HEIGHT DETECTION

This section describes the steps that were followed to create hourly mixing height data. The mixing height data for April 1, 2006, though October 15, 2006, were produced by TAMU as part of the grant activity. Mixing heights have not been derived for September 28, 2005, through March 31, 2006, because the grant activity to complete this work was terminated by TCEQ due to lack of funds on December 31, 2005.

6.1 RADAR WIND PROFILER-DERIVED MIXING HEIGHTS

RWP reflectivity data (or signal-to-noise ratio [SNR] data) can be used to estimate the height of the surface-based mixed layer, the marine boundary layer (MBL), the convective boundary layer (CBL), the residual layer, and the subsidence inversion. RWP reflectivity data are strongly influenced by the refractive index of the atmosphere. Turbulence produces variations in atmospheric temperature, humidity, and pressure, which in turn cause variations in the radar refractive index. In the PBL, humidity fluctuations contribute most to the variations in the radar refractive index. The greatest humidity variations tend to occur at the top of the aforementioned boundary layers. For example, Wyngaard and Lemone (1980) showed that the radar refractive index peaked at the inversion located at the top of the CBL because of warm, dry, aloft air entraining into cooler, moister air below the inversion.

Viewing time-height cross-sectional plots of the SNR data can be an effective method of estimating mixing height in real time or for post-analysis. **Figure 6-1** shows time-height SNR data at Brazos A-19. Blue and green in the cross-section show weak signal returns, and orange and red show strong returns. The black line during daylight hours indicates the mixing height analyzed from the SNR. At times, the peak SNR may not always define the surface-based mixed layer and may depict some other aloft layer such as a subsidence inversion. It is, therefore, important to view SNR plots in conjunction with vertical velocity, spectral width, and RASS T_v to ensure that peak SNR properly characterizes the surface-based mixing height.

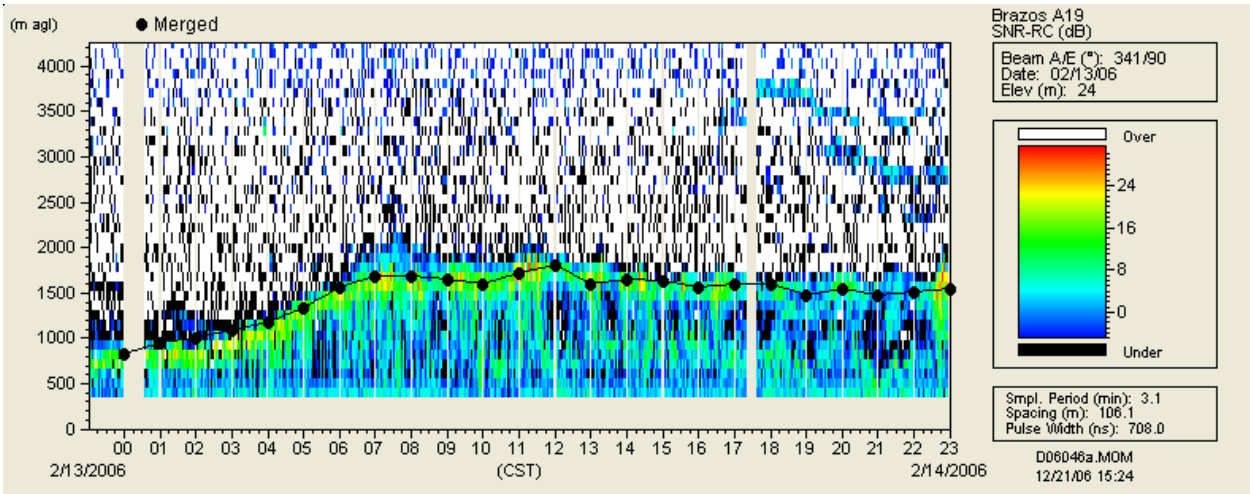


Figure 6-1. Time-height cross-section of RWP SNR data at Brazos A-19 on February 13, 2006. The top of the MBL is shown as the black solid line.

6.2 RASS T_V-DERIVED MIXING HEIGHTS

Generally SNR measured by boundary layer RWPs will not resolve low-level inversions when such inversions are less than about 200 to 300 m agl. Consequently, T_v data collected by RASS, coupled with surface T_v measurements, are used to provide estimates of the depth of shallow boundary layers. Further, when several different layers exist within the PBL, the peak SNR data do not always depict the layer of interest or the lowest layer. For example, SNR data may not resolve an MBL. However, RASS T_v data can be used to help distinguish the MBL. **Figure 6-2** shows a morning RASS T_v profile at Brazos A-19 on October 29, 2006, as an example of how such data can be used to detect the mixing height. The figure shows a temperature inversion at about 1,100 m apl.

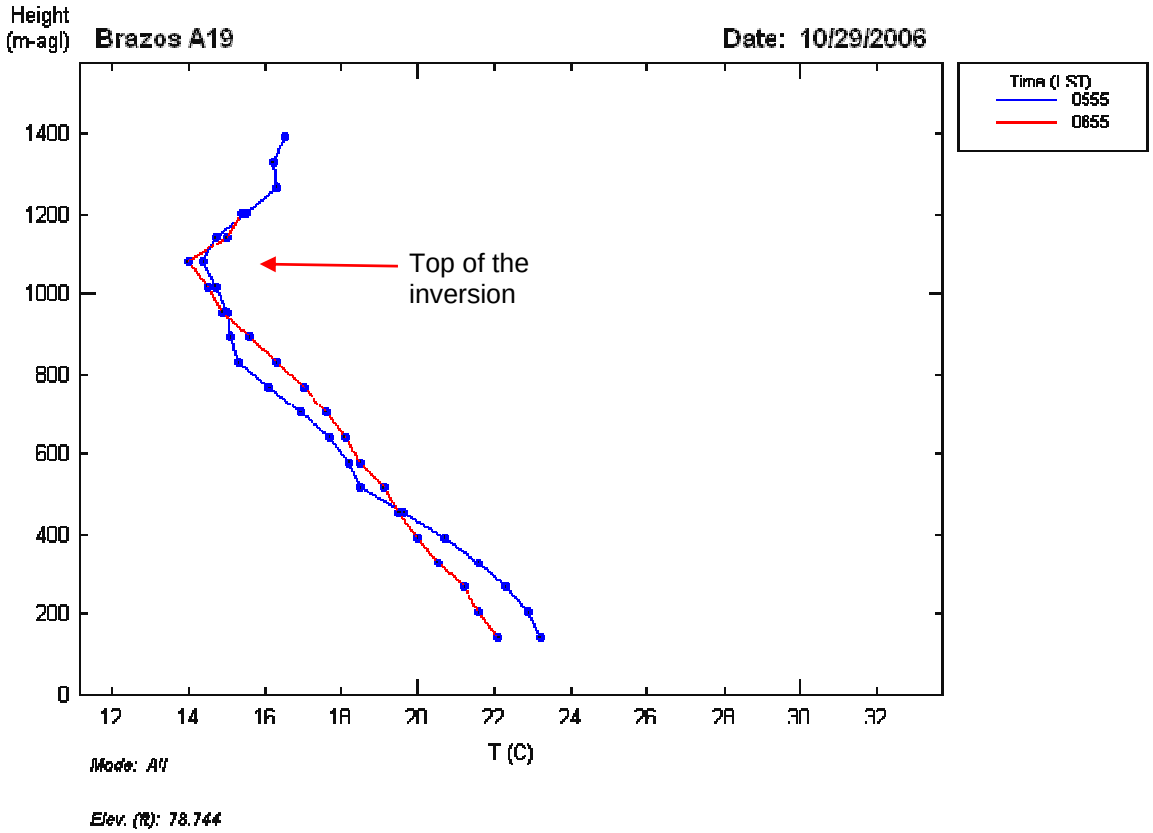


Figure 6-2. RASS T_v data at Brazos A-19 on October 29, 2006, showing an inversion at about 1,100 m apl.

7. 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.

7.1 RWP, RASS, AND MINI-SODAR DATA FILES

The upper-air data are provided in the FSL (Forecast Systems Laboratory) RAOB (RAdiosonde OBservation) format. The quality-controlled RWP wind file is named BZ_RWP_WIND.txt. The file of additional wind data from the unofficial operations that have not been quality-controlled is called BZ_RWP_WIND_RAW.txt. The quality-controlled RASS T_v data file is named BZ_RASS_Tv.txt. The file of additional RASS data from the unofficial operations that have not been quality-controlled is called BZ_RASS_TV_RAW.txt. The quality-controlled Sodar wind file is named BZ_Sodar_WIND.txt. The file of additional wind data from the unofficial operations that have not been quality-controlled is called BZ_Sodar_WIND_RAW.txt.

The FSL RAOB data format (see **Figure 7-1** for an example file) is similar to the format used by the Storm Prediction Center. 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 missing, not reported, or not applicable. **Table 7-1** 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 7-1. Example of FSL RAOB file format.

Table 7-1. 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

7.2 MIXING HEIGHT DATA FILES

The mixing height file is named BZ_Mixing.txt. The mixing height data are stored in worksheets, by month, in a Microsoft Excel spreadsheet. The first 31 lines contain header information defining the data in lines 32 through the end of the file. The Date/Time fields are in both CST and UTC, begin time. The mixing heights are in m apl. QC codes are in the last field in the file. Data with QC codes less than 2 are valid.

7.3 SURFACE METEOROLOGICAL DATA FILE

The surface data file is named BZ_Surface.txt. The surface meteorological data are stored in comma separated value (csv) format, and the first line contains header information defining each data field listed in lines 2 through the end of the file. The SiteCode is BZ 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 7-2** summarizes the parameter codes found in the csv file, and **Figure 7-2** shows an example of the surface data file.

Table 7-2. Parameter codes and parameter for the surface meteorological data file.

Parameter Code	Parameter
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
        BZ,Surface,DP,10/3/2005 3:00:00 PM,7,-34.20000,°C,0,0
        BZ,Surface,DP,10/3/2005 4:00:00 PM,7,-32.39000,°C,0,0
        BZ,Surface,DP,10/3/2005 5:00:00 PM,7,-31.38000,°C,0,0
        BZ,Surface,DP,10/3/2005 6:00:00 PM,7,-31.07000,°C,0,0
```

Figure 7-2. Example of surface data file.

8. REFERENCES

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