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SUMMARY OF THE NEW BRAUNFELS 2005 AND 2006 RADAR PROFILER OPERATIONS AND DATA AVAILABILITY

FINAL REPORT
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1. INTRODUCTION

The Texas Air Quality Study II (TexAQS-II) was designed to provide support for State Implementation Plan (SIP) revisions. The SIP revisions outline strategies for improving air quality to meet the new federal 8-hr ozone standard and regional haze requirements. For the TexAQS-II study, and to support local modeling efforts in San Antonio and Austin, Texas, Sonoma Technology, Inc. (STI) operated a 915-MHz radar wind profiler (RWP), Radio Acoustic Sounding System (RASS), and surface meteorological station at the New Braunfels Municipal Airport. Official (i.e., funded) instrument operations ran from July 3 through December 31, 2005, and June, August, September, and the first two weeks of October 2006. These operations were funded by the Capitol Area Council of Governments (CAPCOG), the Alamo Area Council of Governments (AACOG), and the Texas Commission on Environmental Quality (TCEQ). In addition, STI operated the instruments from January 1 through May 31, 2006, and July 2006, although these operations were not official and unfunded. The instruments were deinstalled in November 2006.

RWP and RASS instruments provide vertically, horizontally, and temporally resolved boundary layer wind, virtual temperature (T_v), and mixing height information. These data are being used by Texas Commission on Environmental Quality (TCEQ) and other study participants to explain the physical processes that influence air quality and to support modeling and air quality forecasting in eastern Texas.

This report summarizes the operations, subjective quality control of data collected by the RWP, RASS, and 10-m surface meteorological tower, and the estimation of mixing heights for the site at the New Braunfels Municipal Airport,. This report is accompanied by a compact disk (CD) containing the upper-air and surface meteorological data.. The data for June 29 through August 31, 2005, and June 1 through October 15, 2006, have been validated to Level 2 and are ready for use in modeling and data analysis. We have also included non-QC'd data, when available, from the unofficial (unfunded) operations period and data for periods for which data quality control was not funded. These non-QC'd data are available for September 1, 2005 through May 31, 2006.

2. MEASUREMENTS OVERVIEW AND DEINSTALLATION ACTIVITIES

The New Braunfels site is located at 29.7041 latitude north and 98.0288 longitude west at an elevation of 195 m above mean sea level. To optimize data recovery and resolution, the RWP was configured to cycle in low and high operational modes. In low operational mode, the RWP measured winds from 137 m above ground level (agl) up to 1,457 m agl with a vertical resolution of 55 m. In high mode, it had greater altitude coverage, from 323 m agl to 5,038 m agl, and a coarser vertical resolution of 96 m. Winds measured in both modes were merged to create a single profile with 55-m resolution data below 800 m agl and 97-m resolution data from 800 m agl to 5,038 m agl.

The RASS system measured T_v for the first five minutes of each hour. Virtual temperatures were measured from 120 m agl up to 1,620 m agl, with 60-m vertical resolution. The T_v is the temperature a dry parcel of air would have for its air pressure and density equal to that of the moist parcel of air that is actually being measured.

The surface meteorological tower was configured to measure wind speed and wind direction at 10 m agl, and air temperature, dew point temperature, relative humidity, direct solar radiation, and pressure at 2 m agl.

Figures 2-1 through 2-3 show examples of RWP/RASS data collected at New Braunfels. Figure 2-1 shows a time-height cross-section of wind data from the RWP on July 17, 2006. The winds are plotted as wind barbs—the color and barbs indicate the speed. Each short barb represents 2.5 m/s, and each long barb represents 5 m/s. The values of the barbs are combined to show speed. For example, a single long barb and a short barb denote 7.5 m/s (5 m/s + 2.5 m/s = 7.5 m/s). Pennants are 25 m/s. Barbs and pennants are drawn to the left of the direction of air movement.

In Figure 2-1, there is strong wind shear at about 1,000 m agl descending to about 400 m agl between July 17, 2006, at 2000 Central Standard Time (CST) and July 18, 2006, at 1000 CST. By July 18, 2006, at 1100 CST, the easterly aloft flow had descended to the surface, eliminating the wind shear.

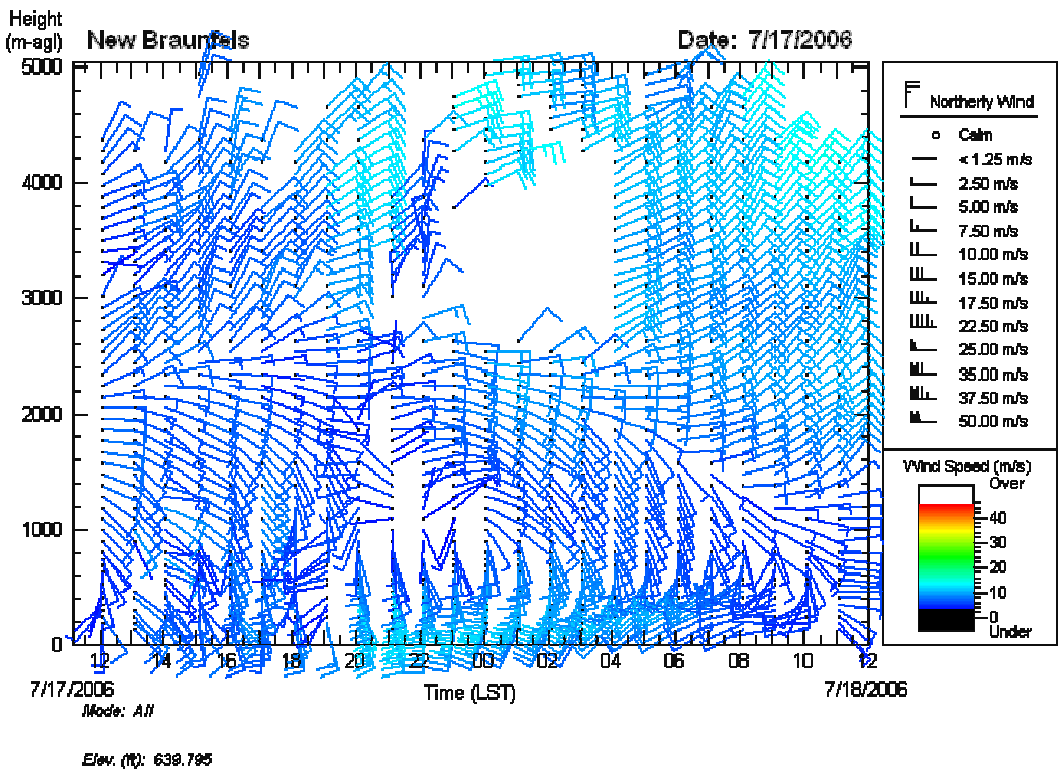

Figure 2-1. New Braunfels RWP wind data for July 17, 2006, at 1200 CST to July 18, 2006, at 1200 CST.

Figure 2-2 shows profiles of T_v measured by the RWP/RASS at New Braunfels for the hours starting at 1800 CST through 2300 CST on October 16, 2006. This example shows the transition from the convective boundary layer (CBL) to the nocturnal boundary layer (NBL) below about 300 m agl. Above 300 m agl, the T_v profile remains adiabatic through the transition.

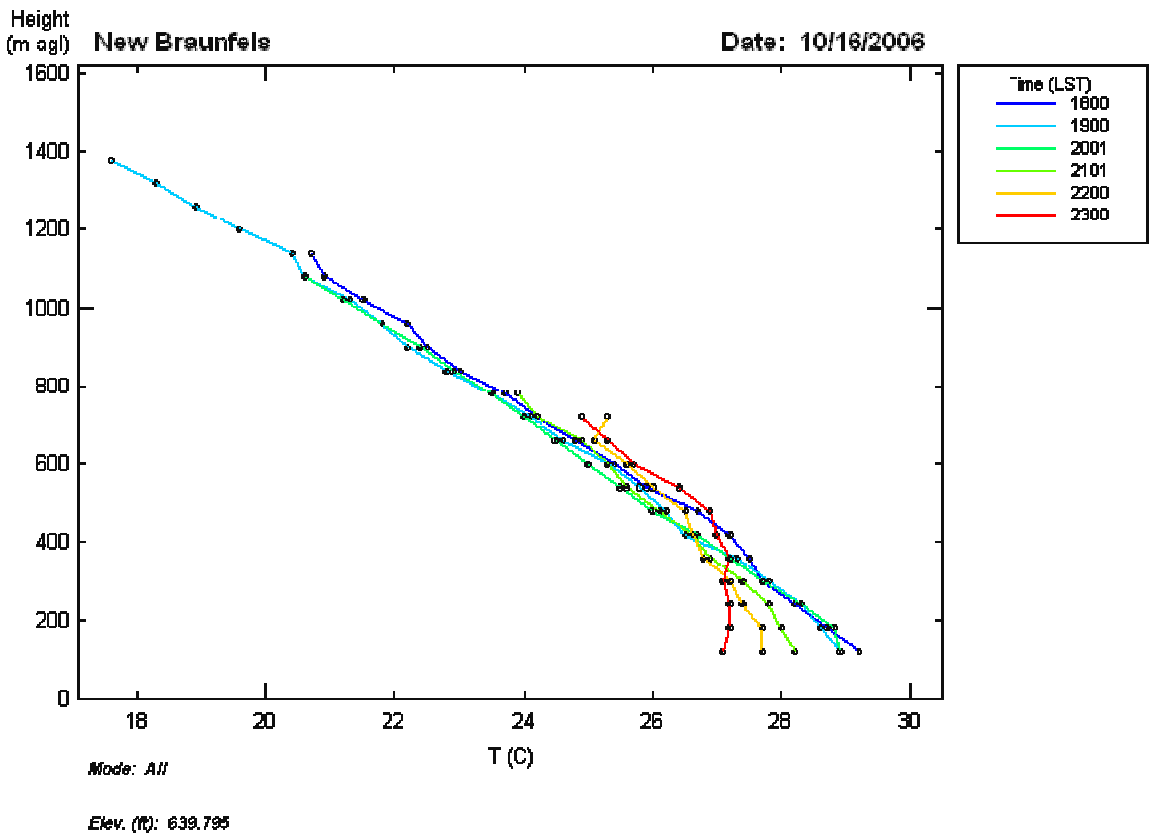

Figure 2-2. New Braunfels RASS T_v data for October 16, 2006, showing the transition from the CBL to the NBL.

Figure 2-3 shows profiles of T_v measured by the RWP/RASS at New Braunfels from October 14, 2006, for the hours starting at 0100 to 0600 CST. In this example, a descending temperature inversion is apparent at 500 m agl at 0100 CST descending to 300 m agl by 0600 CST. These descending inversions are important because they trap pollutants near the surface, which can lead to poor air quality.

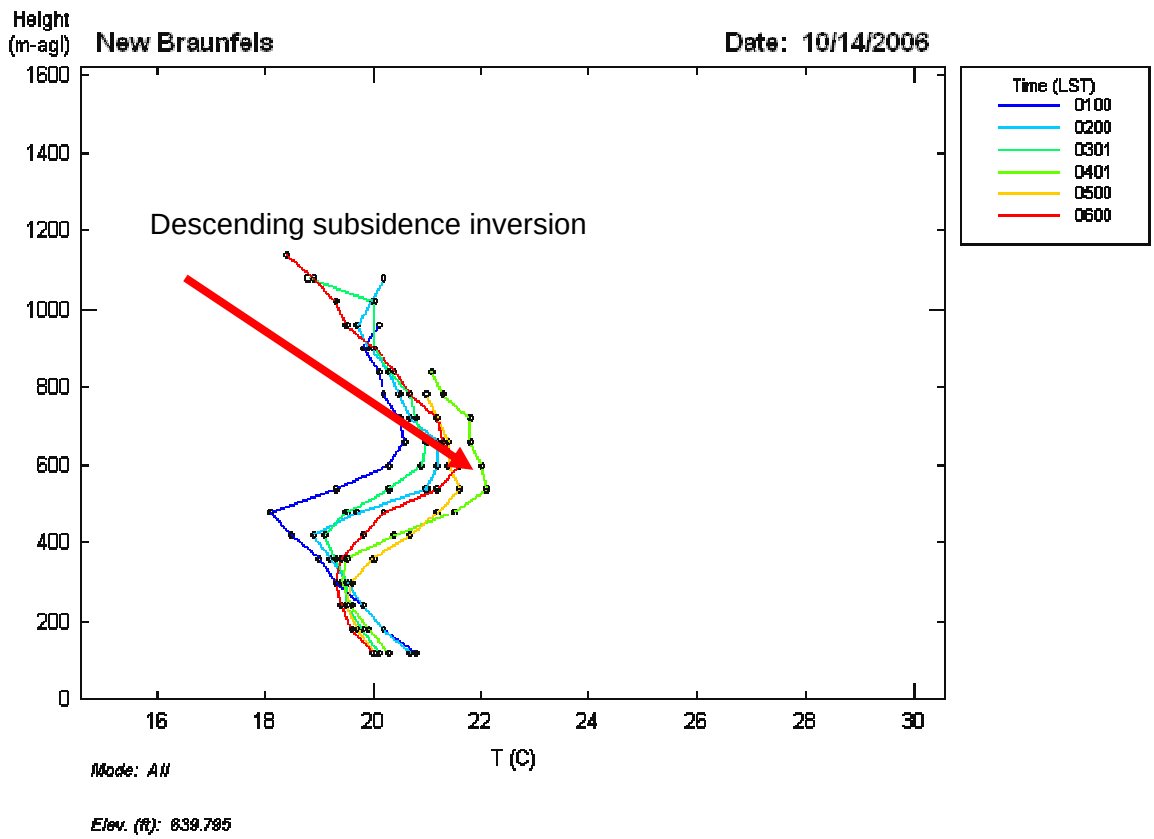

Figure 2-3. New Braunfels RASS T_v data for October 14, 2006, from 0100 to 0600 CST.

The instruments that collected the RWP wind, RASS T_v, and surface meteorological data (like the examples shown above) were deinstalled in November 2006. The deinstallation effort took several days to perform even though no major problems were encountered. Deinstallation consisted of the following major components:

- Creating a deinstallation plan.
- Acquiring local labor to assist in the deinstallation.
- Arranging shipping for the equipment to California.
- Removing the equipment from the site.
- Carefully packing and securing the equipment in a trailer for shipping.
- Checking that all equipment was returned to California in working order.
- Returning the equipment to a storage facility in Petaluma, California.

3. DATA AVAILABILITY

Table 3-1 summarizes times when RWP wind and RASS T_v data are not available for more than 5 hours in a day. **Table 3-2** summarizes times when surface data are not available for more than 5 hours in a day. The data are typically unavailable because of instrument problems or invalid data.

Table 3-1. Times when New Braunfels RWP/RASS wind and T_v data are not available for more than 5 hours.

Downtime (CST)
7/7/05 6:00 AM to 7/9/05 1:17 PM
7/9/05 4:00 PM to 7/12/05 12:00 AM
7/12/05 6:00 AM to 7/13/05 4:56 AM
7/16/05 4:06 AM to 7/18/05 2:32 PM
7/19/05 12:00 AM to 7/19/05 8:46 PM
7/20/05 6:07 AM to 7/21/05 1:50 AM
7/23/05 5:00 AM to 7/25/05 7:00 PM
8/6/05 5:00 AM to 8/7/05 5:00 AM
8/19/05 12:00 AM to 8/19/05 2:42 PM
8/25/05 8:00 PM to 8/26/05 5:00 AM
9/3/05 10:00 PM to 9/4/05 5:00 AM
9/11/05 4:00 PM to 9/12/05 3:09 PM
9/15/05 6:00 AM to 9/17/05 2:00 AM
9/17/05 4:00 AM to 9/18/05 2:00 AM
10/15/05 3:00 PM to 10/16/05 3:32 PM
11/9/05 1:00 AM to 11/9/05 10:00 PM
11/10/05 7:00 PM to 11/11/05 5:49 PM
11/16/05 7:00 AM to 11/17/05 12:23 AM
6/1/06 10:00 PM to 6/2/06 5:00 AM
6/3/06 6:00 PM to 6/4/06 7:24 PM
6/7/06 2:00 AM to 6/8/06 5:00 AM
6/17/06 1:07 PM to 6/18/06 4:26 PM
6/19/06 9:00 PM to 6/21/06 7:18 PM
6/23/06 7:00 PM to 6/24/06 5:00 AM
6/27/06 3:00 AM to 6/28/06 5:00 AM
8/23/06 11:00 PM to 8/24/06 5:00 AM
9/13/06 10:00 PM to 9/14/06 5:00 AM
9/15/06 4:00 PM to 9/16/06 4:28 PM

Table 3-2. Times when New Braunfels surface data are not available for more than 5 hours.

Downtime (CST)
8/18/05 6:00 PM to 8/31/05 10:00 PM
6/4/06 8:00 AM to 6/8/06 5:00 AM
6/19/06 11:00 PM to 6/20/06 5:00 AM
6/22/06 9:00 PM to 6/23/06 5:00 AM
6/23/06 8:00 PM to 6/24/06 5:00 AM
6/27/06 3:00 AM to 6/28/06 5:00 AM
8/3/06 2:00 PM to 8/12/06 9:00 AM

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

- RWP winds = 84%
- RASS T_v = 83%
- Surface meteorology = 83%

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 and RASS 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

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.

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 surface meteorological tower was configured to measure wind speed and wind direction at 10 m agl, air temperature, dew point temperature, relative humidity, direct solar radiation, and pressure at 2 m agl. The sampling configurations for the RWP, RASS, and surface meteorological sensors are shown in **Tables 4-2, 4-3, and 4-4.**.

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)	55 (low mode) 97 (high mode)	60
Minimum altitude (m agl)	137 (low mode) 137 (high mode)	120
Maximum altitude (m agl)	~1800 (low mode) ~4000 (high mode)	~1500

Table 4-4. 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. WIND AND TEMPERATURE DATA QUALITY CONTROL

The data on the accompanying CD were reviewed and validated by a meteorologist and are ready for immediate use by analysts and modelers. This section describes the steps that were followed to process and perform the data validation screening and quality control of the upper-air and surface meteorological data.

The data validation process involves identifying inconsistent observations (outliers) and assigning quality control (QC) codes to each data point to indicate its validity. Data are validated in several stages or "levels":

Level 0.0 validation. Raw data, not quality-controlled.

Level 0.5 validation. Data that have been subjected to automated QC screening.

Level 1.0 validation. Data that have been subjected to quantitative and qualitative reviews for accuracy, completeness, and internal consistency. Subjective reviews are performed by staff who understand the measurement systems and the meteorological processes expected to be shown by the data.

Level 2.0 validation. Data that have been subjected to quantitative and subjective reviews for external consistency. The New Braunfels data are validated to Level 2.0.

To bring the New Braunfels data to Level 2.0 validation, the reviewers carefully examined plots of the data, looked for outliers, and evaluated the reasonableness of the data. The reviewers verified the results of the automated QC screening, either accepting the results or redefining "suspect" data as "valid" or "invalid," as appropriate.

The following QC codes were used:

0 = Valid
1 = Estimated
2 = Calibration applied
5 = Failed auto QC (surface meteorological data only)
6 = Failed audit criteria (surface meteorological data only)
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 data with a QC code ≤ 2.

Reviewers used internal and external data sources to determine the validity of the observations. Internal data sources include parameters other than wind speed, wind direction, and T_v that were measured by the same instrument, and collocated data sources. When checking for precipitation contamination in the RWP or RASS data, for example, staff often relied on the RWP's vertical velocity measurements, which show the fall velocity of rain during precipitation

events. **Table 5-1** lists internal data sources that were commonly used and gives a brief explanation of their use.

External data sources are those not measured by the RWP/RASS instrument. Comparing National Weather Service (NWS) surface observations to surface winds is an example of using external data to check for reasonableness of the data collected. **Table 5-2** lists external data sources and gives a brief explanation of their 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.
RASS virtual temperature data	Check for consistency of the surface temperature 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.
NWS surface data	Check for temporal and spatial consistency in the wind speed, wind direction, temperature, pressure, moisture, and solar radiation data.

An example of wind data that were invalidated is shown in **Figure 5-1**. In this example, a persistent area of data indicating northerly winds can be seen at between 1900 and 0600 CST and between 1,000 m agl and 3,500 m agl. However, the reported northerly winds were actually caused by radar measurement of the motion of birds migrating to the south. Birds act as large radar "targets," so that signals from birds overwhelm the weaker atmospheric signals. These bird-contaminated data were identified through their high signal-to-noise ratio and invalidated

during quality control. Additional information about bird contamination of RWP data can be found in Wilczak et al., 1995.[1]

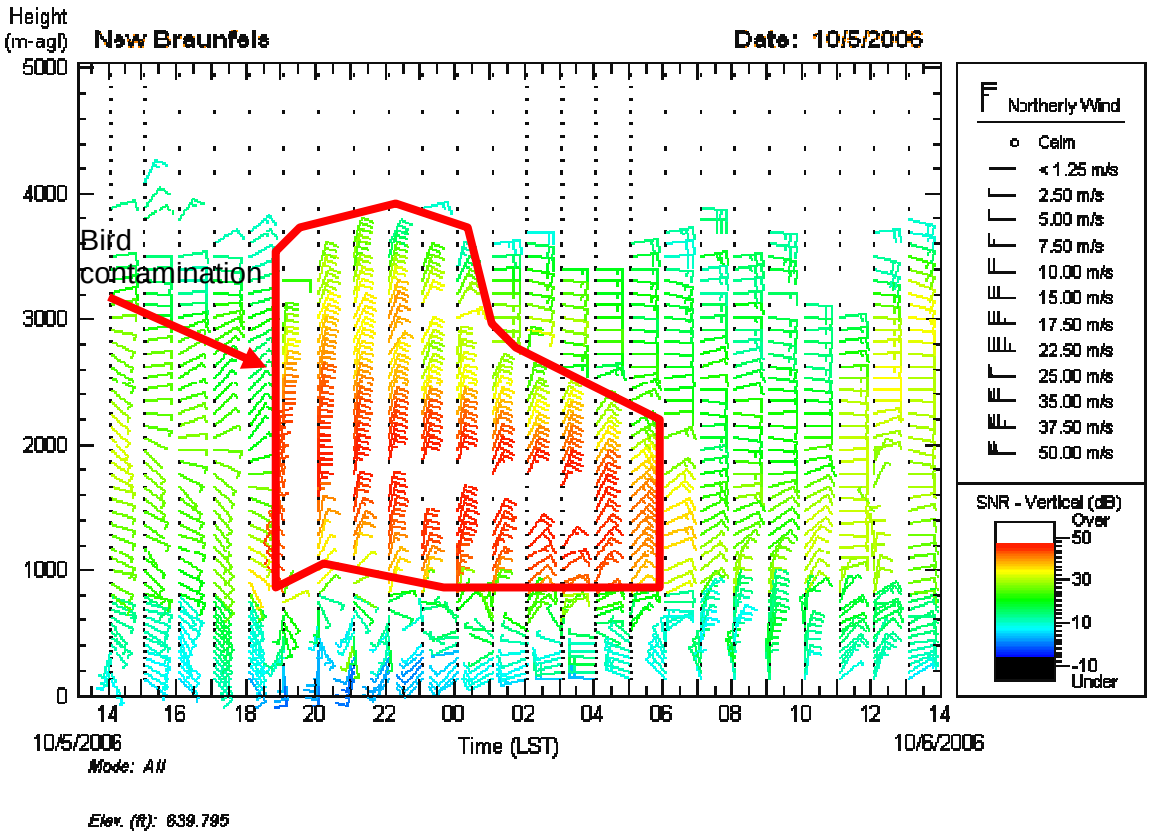

Figure 5-1. Invalidated RWP wind data collected at New Braunfels on October 5 and 6, 2006.

[1] Wilczak J.M., Strauch R.G., Weber B.L., Merritt D.A., Ralph F.M., Jordan J.R., Wolfe D.E., Lewis L.K., Wuertz D.B., Gaynor J.E., McLaughlin S., Rogers R., Riddle A., and Dye T. (1995) Contamination of wind profiler data by migrating birds: characteristics of corrupted data and potential solutions. *J. Atmos. Ocean. Technol.* **12** (3), 449-467.

6. MIXING HEIGHT DETECTION

The section describes the methods to estimate hourly mixing heights.

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 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 planetary boundary layer (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[2] showed that the radar refractive index peaked at the inversion located at the top of the CBL because of warm, dry, aloft air being entrained 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 New Braunfels. 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.

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 that often penetrates the Gulf Coast on most summer afternoons and evenings, undercutting the CBL. However, RASS T_v data can be used to distinguish the MBL. **Figure 6-2** shows afternoon RASS T_v profiles at New Braunfels on August 2, 2005, as an example of how such data can be used to detect the mixing height. The figure shows a temperature inversion at about 250 m agl.

[2] Wyngaard J.C. and LeMone M.A. (1980) Behavior of the refractive index structure parameter in the entraining convective boundary layer. *J. Atmos. Sci*. **37**, 1573-1585.

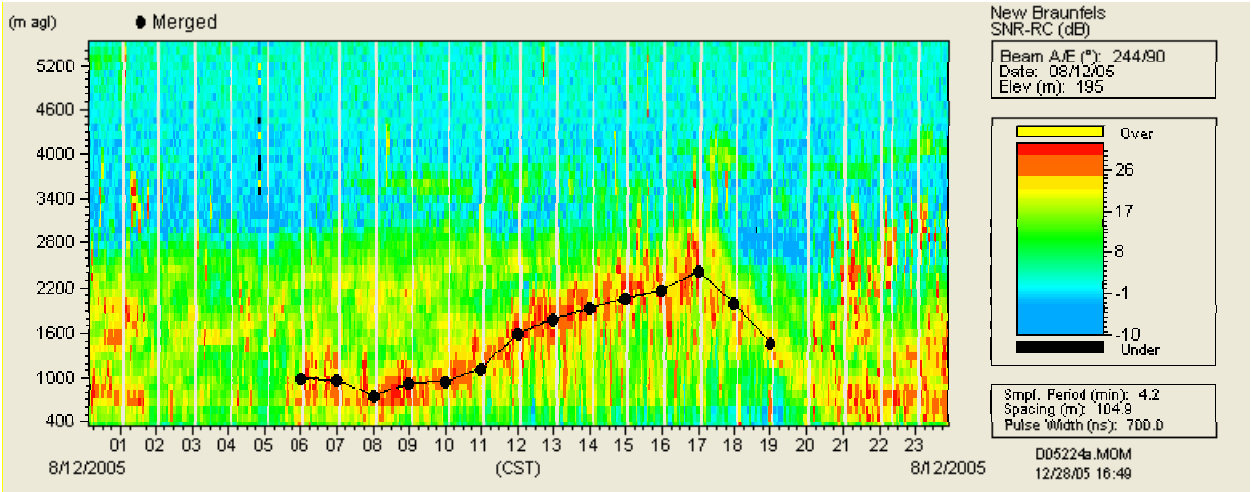

Figure 6-1. Time-height cross-section of RWP SNR data at New Braunfels on August 12, 2005. The top of the CBL is shown as the black solid line. Note that the CBL from 0500 to 0800 PST was estimated from RASS T_v data.

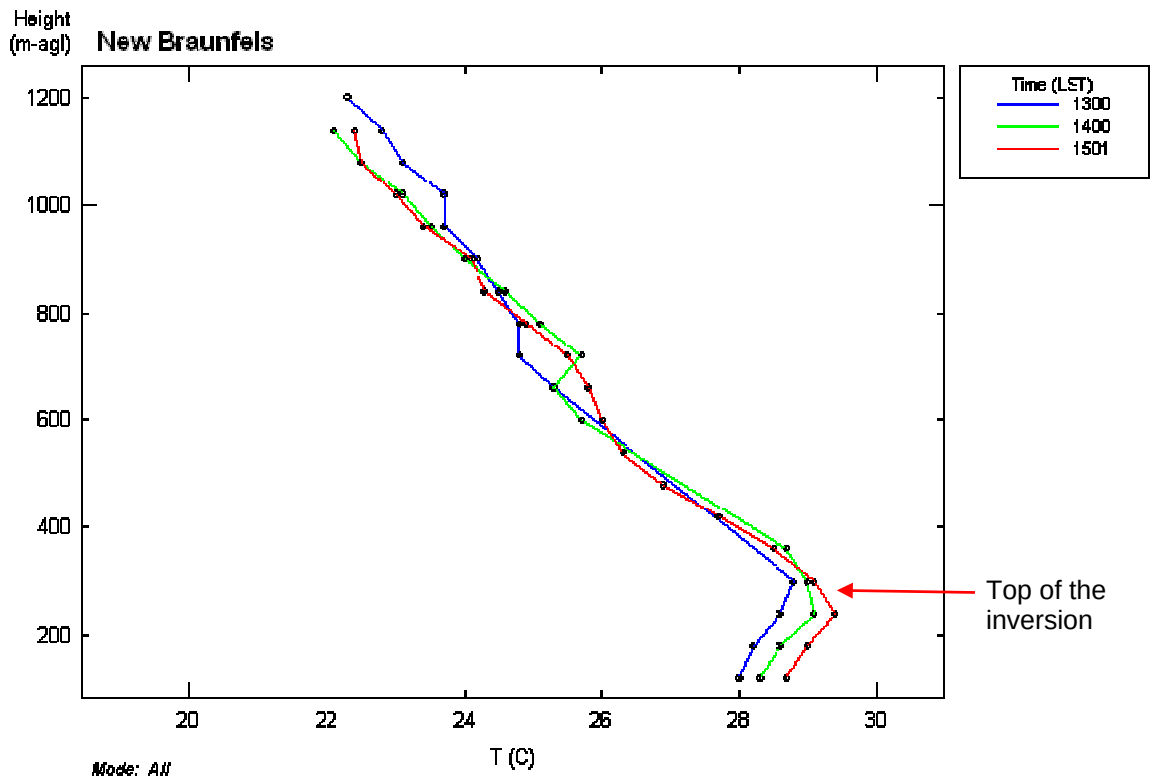

Figure 6-2. RASS T_v data at New Braunfels on August 2, 2005, showing an inversion at about 250 m.

7. DATA FILE INFORMATION

The upper-air and surface data are on the accompanying CD. The data on the CD for June 29 through August 31, 2005 and June 1, 2006 through October 15, 2006 have been validated to Level 2 and are ready for use in modeling and data analysis. We have also included non-QC'd data, when available, from the unofficial (unfunded) operations period and data for periods for which data quality control was not funded. These non-QC'd data are available for September 1, 2005 through May 31, 2006.. The time standard for the data is Coordinated Universal Time (UTC). This section describes the file formats.

Upper-Air Wind and Temperature Files

The upper-air data are provided in the FSL (Forecast Systems Laboratory) RAOB (RAdiosonde OBservation) format. The QC'd RWP wind file is named NB_RWP_WIND.txt. The additional wind data from the unofficial operations and data for periods for which subjective data quality control was not funded is called NB_RWP_WIND_RAW.txt. The QC'd RASS T_v file is named NB_RASS_TV.txt. The additional RASS data from the unofficial operations and data for periods for which subjective data quality control was not funded is called NB_RASS_TV_RAW.txt.

The FSL RAOB data format (**Figure 7-1**) 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** describes 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      TEMP    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)
TEMP:	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

Mixing Height Data Files

The mixing height data for June 30-August 31, 2005 (created under a previous contract) and June 1 – October 15, 2006 are on the CD accompanying this report. The mixing height data are stored in a Microsoft Excel spreadsheet. The first 31 lines contain header information defining each data field 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 meters agl. QC codes are in the last field in the file.

Surface Meteorological Data Files

The surface file is named NB_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 in lines 2 through the end of the file. The site code is NB for New Braunfels and the class name is Surface for all surface data. The date/time field is in UTC, begin time. The height

is the height of the sensor in meters agl 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** lists the parameter codes found in the csv file. Please note that the relative humidity data between July 17 and October 15, 2006, were taken from a site about 300 m from the RWP.

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

8. RECOMMENDATIONS

As a result of this project, we offer the following recommendations, beyond standard RWP/RASS installation, operations, and deinstallation procedures, that would help others in similar work:

- We used wireless Internet communications, which often did not work. We recommend using a two-way satellite Internet system instead, if land-line Internet is not available.
- We used a local electronics engineer and computer expert to assist with routine instrument and site maintenance. Although he was over-qualified for routine maintenance, his skills addressing other, more technical, issues saved time and money.
- We added a surge suppressor to the telephone line into the computer because a serial card had been destroyed by lighting. This suppressor complements the standard grounding of the meteorological tower and shelter.
- We raised all cables above the ground because fire ants eat through the cables.