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Title: Radar Wind Profiler and RASS HANDBOOK

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Radar Wind Profiler and RASS (RWP915) Handbook

R Coulter

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1.0 General Overview

The 915-MHz radar wind profiler/radio acoustic sounding system (RWP/RASS) measures wind profiles and backscattered signal strength between (nominally) 0.1 km and 6 km. Prior to 2010, an acoustic transmitter was incorporated with the system (RASS) to obtain virtual temperature profiles; after 2011 this no longer is included in the systems. It operates by transmitting electromagnetic energy into the atmosphere and measuring the strength and frequency of backscattered energy. Assuming the scattering elements in the atmosphere are moving with the mean wind, the horizontal wind field can be derived. The second ARM Mobile Facility (AMF2) has a 1290-MHz system developed by DeTect, Inc. that is capable of changing the beam-pointing angle on a pulse-by-pulse basis so that it can compensate for ship motions when deployed at sea.

2.0 Contacts

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3.0 Deployment Locations and History

Location	Description	Date Installed	Date Removed
Southern Great Plains (SGP)			
Central Facility	Winds/RASS	November 1992	March 2011
Central Facility	Vertical winds/precipitation	March 2011	Present
Intermediate Facility 1 Beaumont, KS	-	September 1996	March 2011
Intermediate Facility I8	Vertical/ precipitation	May 27, 2011	Present
Intermediate Facility 2 Medicine Lodge, KS	-	September 1996	September 2008
Intermediate Facility I9	Vertical/ precipitation	May 2, 2011	Present
Intermediate Facility 3 Meeker, OK	-	September 1996	February 2009
Intermediate Facility I10	Vertical/ precipitation	April 25, 2011	Present
North Slope of Alaska (NSA) Barrow			
-	-	April 2001	Present
ARM Mobile Facility 1 (AMF1)			
Niamey, Niger, Africa	915 MHz	April 2006	January 2007
Germany	1290 MHz	March 2008	August 2008
China	1290 MHz	September 2006	December 2006
Azores	1290 MHz	April 2009	December 2010
India	1290 MHz	November 2011	June 2012
ARM Mobile Facility 2 (AMF2)			
Steamboat Springs, CO	915 MHz	January 2011	April 2011
Gan, Maldives	290 MHz Beam-Steered	January 2012	March 2012
Mobile Aerosol Observing System (MAOS)			
BNL	915 MHz	July 2011	September 2011
Cape Cod	815 MHz	Future Deployment	

4.0 Near-Real-Time Data Plots

See the ARM Plot Browser.

5.0 Data Description and Examples

WIND PROFILE DATA

The data produced by this instrument come in three forms: raw spectra, moments, and time-averaged profiles.

- The spectra are the most basic form of data produced by the present version of this instrument. The method by which the spectra are obtained is discussed below in section 7.1.2. They display the energy content of the scattered signal over the range of Doppler shifts observed from each pointing direction and power level of the wind profiler. There is a single spectrum for each range gate, pointing direction, and power level. The spectrum represents an average of several (e.g., 60) individual spectra obtained over several seconds (e.g., 30).
- The moments data are calculated directly from the spectral data and represent, basically, the spectrum as a whole. They are calculated by integrating across the Doppler frequency domain. At each range gate, pointing direction, and power level, four quantities are calculated:

1. Mean Doppler Shift: The first moment of the spectrum, f_D calculated roughly as:

$$\overline{f_D} = \sum_{i=f_1}^{f_2} f_i S(f_i) \Big/ \sum_{i=f_1}^{f_2} S(f_i) \tag{1}$$

$$c = v_r + 20.05\sqrt{T_v}$$

where S(f) is the power at frequency f and f1 and f2 are the maximum and minimum frequencies, chosen about a mid-point frequency associated with the maximum signal power level.

2. Doppler width: The width of the spectrum, V_D, calculated as

$$V_D = 2\sqrt{\sum_{i=f_1}^{f_2}\left(\left(f_i - \overline{f_D}\right)^2 S(f_i)\right) \Big/ \sum_{i=f_1}^{f_2} S(f_i)} \tag{2}$$

3. Noise Level: This value is calculated using methods defined by Hildebrand and Sekhon (1974), based on the assumption of a Gaussian noise spectrum such that the variance of the spectral points should be equal to the square of their mean value divided by the number of spectral averages. Using this fact, the signal region is separated from the noise region and helps to define f_1 and f_2 above.
4. Signal-to-Noise Ratio (SNR): This value is calculated from the ratio of S(f) to the noise level determined above.

These data can be very useful in determining atmospheric structure on time scales as fine as a few minutes. Figure 1 shows the SNR and vertical velocity moments for a 24-hour period (note that the vertical velocity definition is such that positive is upward in this figure). Note that the vertical velocities and the SNR ratios are affected by rainfall (large downward motion associated with energy scattered from falling rainfall rather than atmospheric structure) at about 0300 and 0700 Local Standard Time (LST).

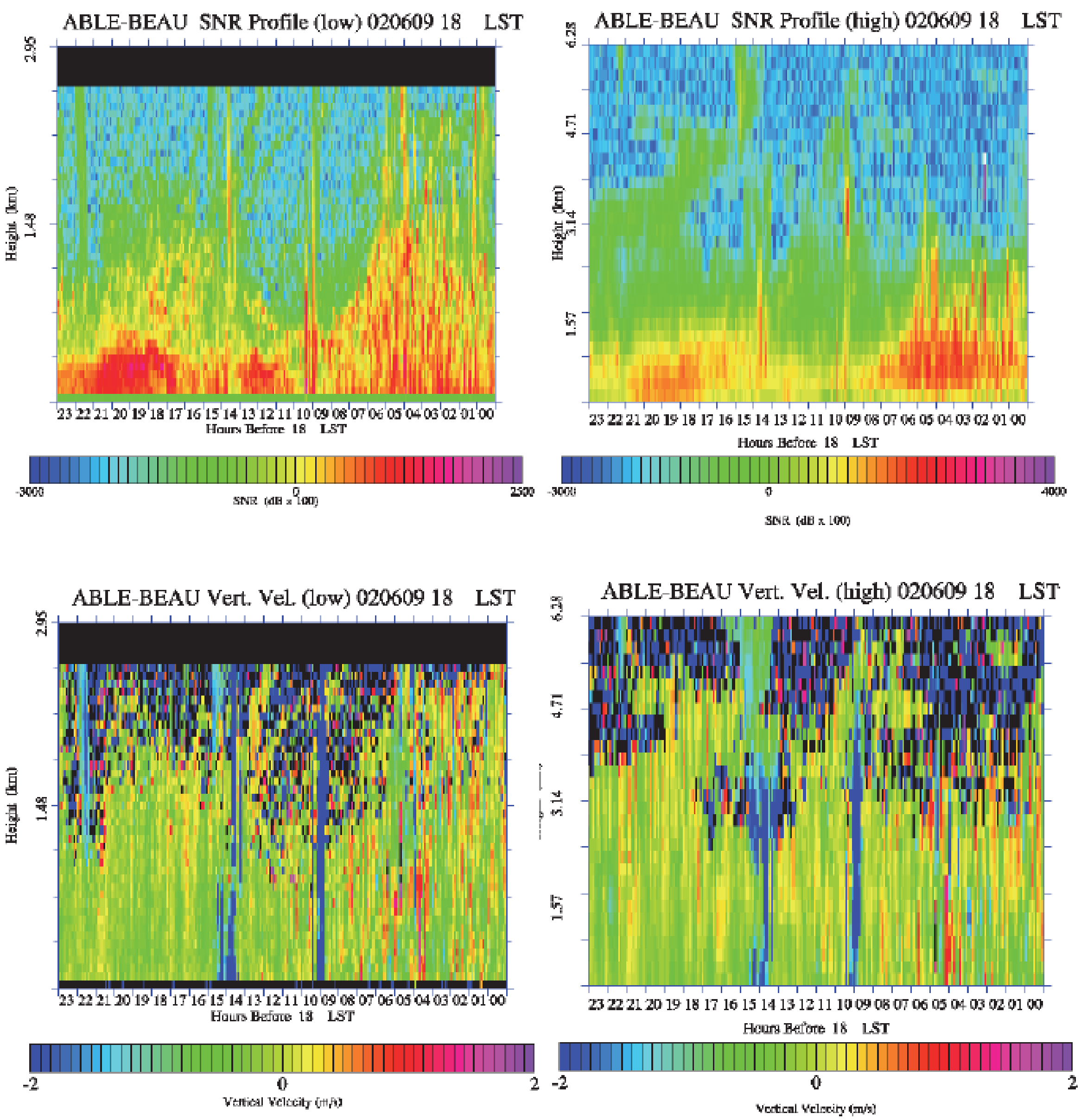

Figure 1. SNR and vertical velocity moments for a 24-hour period.

- The time-averaged profiles consist of values calculated over a user-defined time period (usually 1 hour for ARM data) normally calculated using consensus averaging (see section 7.1.2) to eliminate values at times and heights with unacceptable data. These quantities include, for each height, the wind speed and direction, the radial wind speed along each transmit direction, and the SNR ratio along each transmit direction. A 24-hour period of profiler winds at high and low powers is often portrayed using wind barbs, as shown in Figure 2:

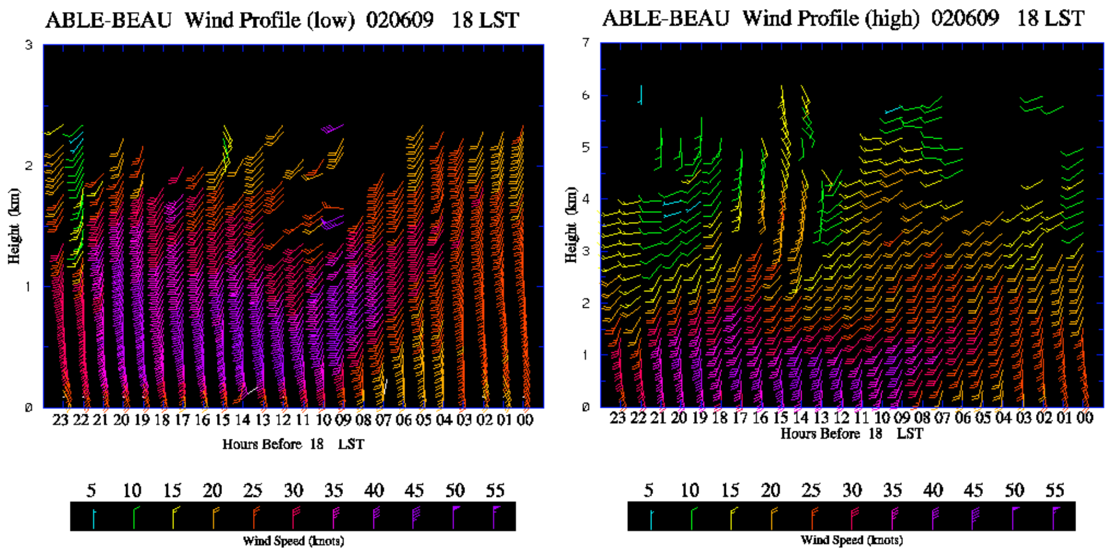

Figure 2. A 24-hour period of profiler winds at high and low powers shown using wind barbs.

VIRTUAL TEMPERATURE PROFILE DATA

RASS data is similar in format to the wind data, consisting of spectral, moments, and consensus-averaged data files. The RASS normally operates only during the first 10 minutes of the hour. There are a few differences in the data:

- The spectral data are determined in the same manner as is the wind profile spectral data. However, because the speed of sound is considerably larger than normal atmospheric wind velocities, the size of the fast Fourier transform necessary to cover both large and small Doppler shifts is relatively large (2048 points nominally). To save space, only selected points around zero (atmospheric motion) and around 340 m/s (the speed of sound) are saved. There is a single spectrum for each range gate. Because there is only a single power level and pointing direction (vertical), there is normally only one spectrum per range gate. The spectrum represents an average of several individual spectra obtained over several seconds (e.g., 30) similar to the wind analysis; however, because of the large number of points, only about 10–15 spectra per time interval are averaged.
- The moments data are processed much the same as the wind speed data; however, there are two signal sources to consider. Because the true velocity of the propagating sound wave, c, depends on the motion of the atmosphere, i.e.,

$$c = v_r + 20.05\sqrt{T_v} \tag{3}$$

where v_r is the air speed along the direction of the sound and T_v is the virtual temperature, it is sometimes necessary to compensate for this motion when calculating T_v. Even though the vertical motion (the direction of the propagating sound wave) is usually small, there are situations where it is important, such as convective conditions (vertical velocities on the order of 5 m/s at times) and orographic forcing. Unfortunately there are also occasions where the use of the corrected value is not propitious, such as during precipitation, when detected descending motion is not due to air motion. Thus, moments similar to those calculated for the wind profiles are determined for both the vertical air motion and the vertically moving sound pulse.

- The time-averaged wind profiles are, once again, calculated in a manner similar to the time-averaged wind profile estimates. However, the calculated virtual temperature (in degrees Celsius) is produced with and without a correction for the sensed vertical atmospheric motion. A 24-hour display of virtual temperatures is often displayed, as shown below in Figure 3. Note that each "hour" value, while depicted as "filling" an entire hour, is in fact representative only of the first 10 minutes of that hour unless the profiler is configured to operate RASS for longer, or different, time periods.

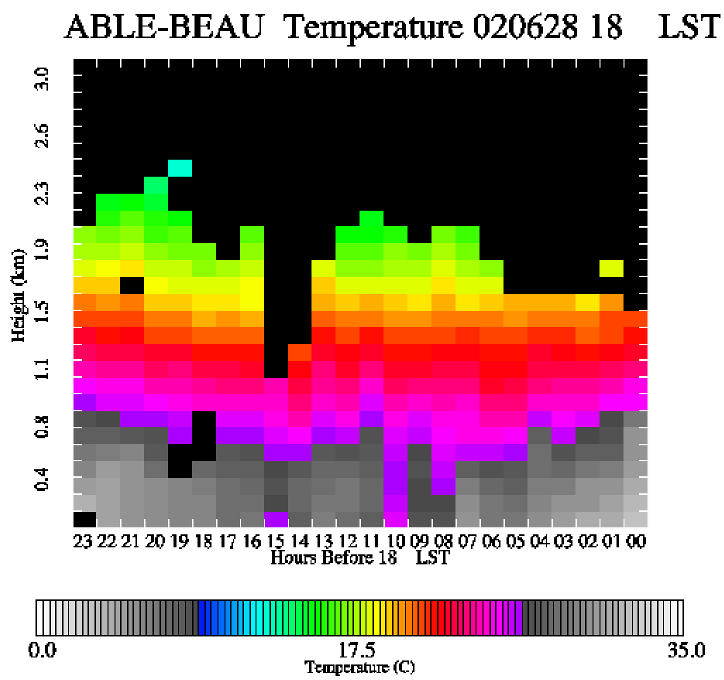

Figure 3. A 24-hour display of virtual temperatures.

PRECIPITATION OPERATION

The four RWPs at the Central Facility of the SGP site are mostly operated in a precipitation mode in conjunction with cloud scanning radars. In this mode, the RWPs transmit only in the vertical direction with shorter averaging times and larger spectral domains. In this mode they are not able to obtain winds very efficiently. However they can sample precipitation quite well to as high as 15 km. In this case, they measure the fall velocity of rain or snow, relative to the air motion. In conjunction with some assumptions regarding the relationship between terminal velocity of water/snow and the spectrum of the fall velocities, updraft/downdraft locations and magnitudes can be determined. Particularly in parallel with scanning Doppler radar measurements, these measurements can contribute to a better understanding of in-cloud processes. The file structures described below are similar for this operation; there is only the vertical component in this case.

5.1 Data File Contents

WIND PROFILE DATA

- Spectral Data

- At each height, beam pointing direction, and power level:
  - Spectral amplitude (at each bin of fast Fourier transform).
- Moments Data
  - At each beam pointing direction and power level:
  - At each range gate:
    - Mean Doppler shift (in % of Niquist frequency)
    - Spectral width (in % of Niquist frequency)
    - SNR level (in Db)
    - Noise Level (in Db).
- Average Data
  - At each power level:
  - At each height:
    - Wind Speed (m/s)
    - Wind Direction (deg relative to true north)
    - For each beam pointing direction:
      - Radial wind speed (positive = toward the antenna)
      - Number of moments that passed consensus criteria
      - Average SNR ratio.

VIRTUAL TEMPERATURE PROFILE DATA (PRIOR TO 2011)

- Spectral Data
  - At each height:
    - Spectral amplitude (at selected bins of fast Fourier transform).
- Moments Data
  - At each range gate:
    - Mean Doppler shift of vertical atmospheric motion (in % of Niquist frequency)
    - Spectral width of vertical atmospheric motion (in % of Niquist frequency)
    - Noise level of atmospheric portion of spectrum (in Db)
    - SNR level of atmospheric portion of spectrum (in Db)
    - Mean Doppler shift of acoustic signal (in % of Niquist frequency)
    - Spectral width of acoustic signal (in % of Niquist frequency)
    - Noise level of acoustic signal portion of spectrum (in Db)
    - SNR level of acoustic signal portion of spectrum (in Db).

- Average Data
  - At each height:
    - Virtual temperature (deg C)
    - Corrected (for vertical motion) virtual temperature (deg C)
    - Vertical wind speed (m/s, positive upward)
    - Number of moments that passed consensus criteria for:
      - Uncorrected virtual temperature
      - Corrected virtual temperature
      - Vertical motion
    - SNR Ratio (dB) for:
      - Uncorrected virtual temperature
      - Corrected virtual temperature
      - Vertical motion

Additional information may be found in the netCDF file header descriptions for RWP data ordered from the ARM Data Archive

5.1.1 Primary Variables and Expected Uncertainty

The primary quantities measured with the system are the intensity and Doppler frequency of backscattered radiation. The wind speed is determined from the Doppler frequency of energy scattered from refractive index fluctuations (caused primarily by moisture fluctuations but also, to a lesser extent, by temperature fluctuations) embedded within the atmosphere; the virtual temperature is determined from the Doppler frequency of microwave energy scattered from acoustic energy propagating through the atmosphere.

5.1.1.1 Definition of Uncertainty

- The primary observed quantities are Doppler frequency and signal amplitude. Note that the observed quantities above are not the principal quantities of interest to most scientists. The derived quantities of most interest to scientists are the wind speed, wind direction, vertical wind speed, and virtual temperature as a function of height. The accuracies of these quantities, while dependent upon the accuracy of the frequency measurement, are also affected by atmospheric effects and vary considerably according to conditions. The wind speed is derived from measurements from, normally, five beams. Because the individual components are not collocated in space, horizontal homogeneity is assumed to derive the wind vector at a single height. Furthermore, the data are sampled at equal time intervals along each transmit direction. Thus, the vertical beam is sampled at larger height intervals than are the tilted beams (by 1/(sin(elevation angle)). This difference is approximately 3%, which can be significant at large ranges. For example, at a nominal height of 1000 meters (tilted beams), the vertical beam information is derived from 1035 meters, which can be significant in some situations

- Nominal accuracy for wind speed: 1 m/s
- Nominal accuracy for radial wind components along the pointing direction of the transmitter (e.g., vertical velocity): 0.5 m/s
- Nominal accuracy for wind dir: 3 deg
- Nominal accuracy for virtual temp: 0.5 K.

The above figures are the result of more than one year of daily and multi-daily comparisons with winds derived from the balloon-borne sounding system at the Central Facility of the Southern Great Plains site.

5.1.2 Secondary / Underlying Variables

This section is not applicable to this instrument

5.1.3 Diagnostic Variables

This section is not applicable to this instrument

5.1.4 Data Quality Flags

No flags are applied during data ingest of the consensus-averaged winds and virtual temperatures. However, the data are examined regularly by the instrument mentor and maintained; files are created and maintained by the Data Quality Office (DQO) on a monthly basis for each of the instruments that determine locations (temporally and spatially) where data should be eliminated based on a brute force, multi-pass comparison with data from neighboring points (above, below, before, and after). This routine eliminates most of the questionable data; however, there are several situations that defy straightforward objective analysis routines. However, most of these situations can be delineated by subjective analysis. This is done monthly by the instrument mentor. The primary situations that can create seemingly good, but actually erroneous data include:

- Precipitation: Both rain and snow are excellent sources of scatter of electromagnetic radiation; thus, they have the potential to provide considerable increases in the effective range for useful data. However, precipitation is generally possessed of a heterogeneous spatial distribution on the scale of the separation of the transmitted beams. This can lead to significant errors in estimates of the true wind speed. Rainfall is more amenable to objective analysis detection because it usually has a large downward velocity in comparison to atmospheric motion. Snow, on the other hand, has quite small terminal velocities. Figure 4 shows these effects.

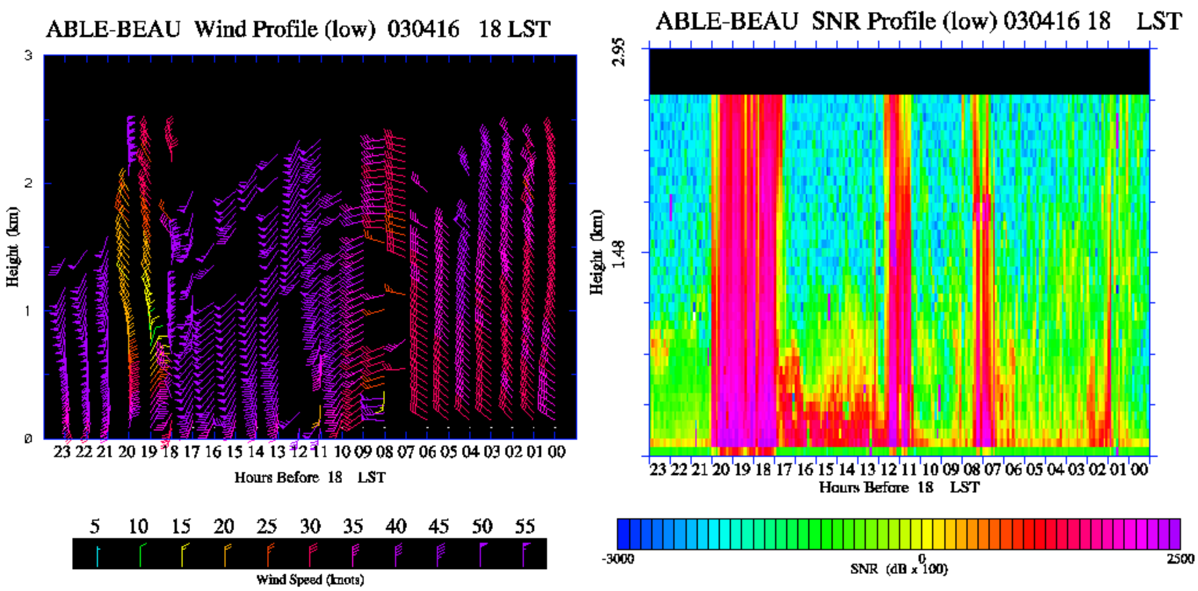

Figure 4. The effects of precipitation (rain and snow) on estimates of wind speed and SNR.

Note that the data around 2200 hours LST is obviously strongly affected by the precipitation (region of dark red extending to all heights between 20 and 18 hours before 18 LST) observed in the SNR profile. However, the precipitation around 0600 and 1000 hours is largely “thrown out” by the consensus-averaging requirements and the precipitation around 1600 hours has no obvious detrimental effect on the calculated wind profile.

- Birds: The effects of birds, particularly migrating birds, is both difficult to detect and significant. The profiler is sensitive not only to the motion of the bird itself, but to the motion of its wings. During migrating seasons (fall and spring), nighttime winds from the north (fall) and south (spring) are often affected by these effects. The birds generally fly along the direction of the wind and increase the detected wind speed by 5 m/s or more (Coulter and Holdridge 1996, Pekour and Coulter 1998). Figure 5 shows the low (bottom) and high (top) power winds (left) and SNR (right) that are affected by migrating birds. Note the obvious wind direction shift near 2000 hours LST for roughly a 5-hour period. In this case, the winds were light enough that the birds flew north anyway. In cases when the winds are directly along the direction of the birds’ desired direction of flight, the evidence is quite difficult to determine using the wind barb plot alone. Note the “random-type” strong reflections around 0.7 km on the low power SNR. These are characteristic of migrating bird signals. Note also that the signature for the high power returns is considerably different from the low power returns because of the considerably longer transmit pulse duration used. Finally, note that in this case, the high-power winds are more affected at lower altitudes than are the low-power winds. Obviously, purely objective analysis is difficult in these cases.

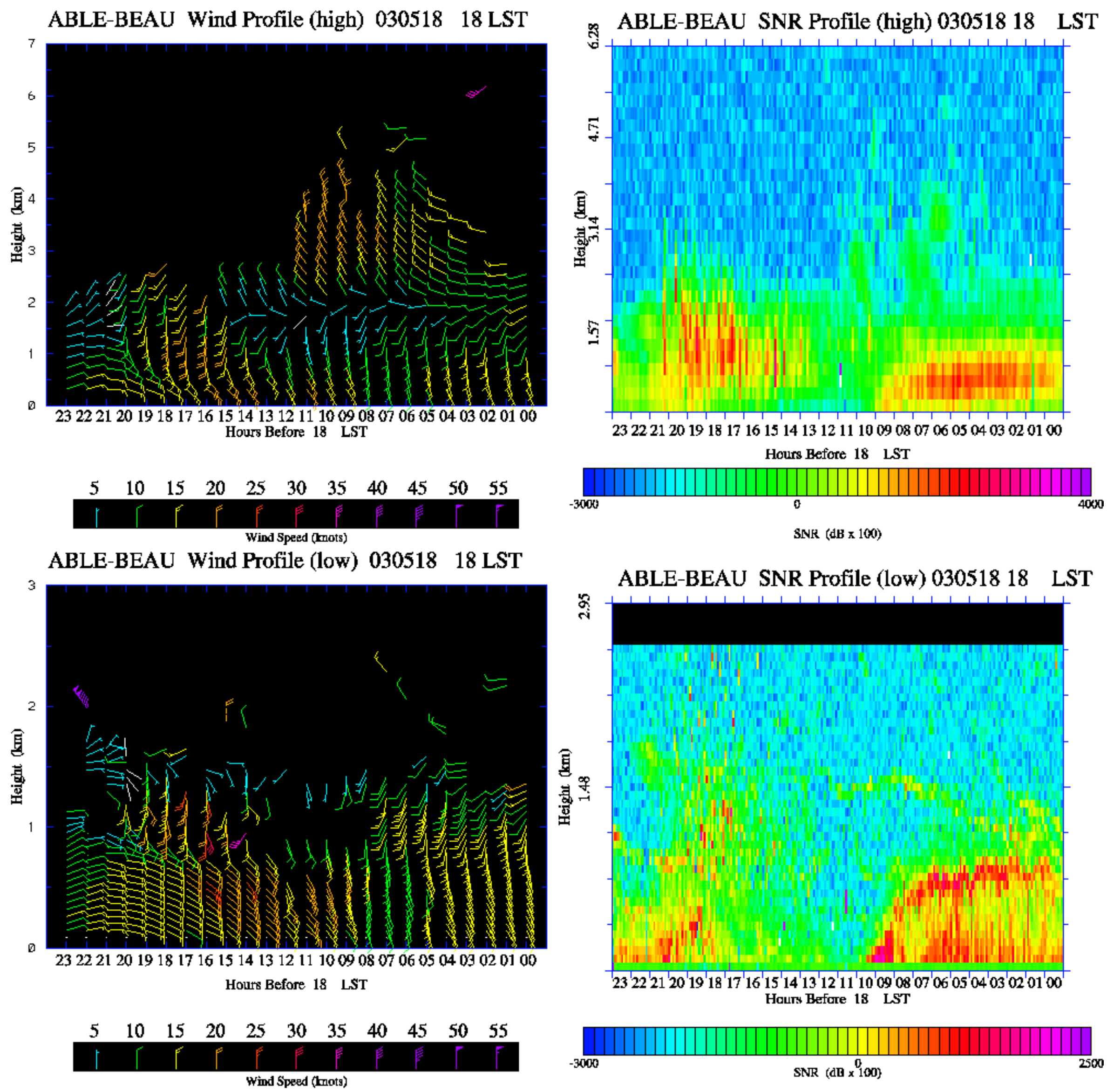

Figure 5. Low (bottom) and high (top) power winds (left) and SNR (right) that are affected by migrating birds.

- 60-Hz noise: When 60-Hz noise gets directly into the analyzed Doppler signal it is detected approximately as a Doppler shift associated with a radial wind speed of 10 m/s. Because the niquist frequency for winds is often near 10 m/s, the noise signal is sometimes aliased back into the spectrum as well. Depending on which antenna beam is affected, very large deviations in wind speed can occur. Some of these are easily removed, but some provide consistent values not totally removed by some objective analysis routines. In addition, it reduces the range of accessible data (see above).

5.1.5 Dimension Variables

This section is not applicable to this instrument.

5.2 Annotated Examples

This section is not applicable to this instrument.

5.3 User Notes and Known Problems

Update: Problem with the 915 RWPs at the Intermediate Facilities (6/22/00)

A noise peak in the spectra of the intermediate facility profilers located at +- 60 Hz from 0 was reported beginning on April 9, 1997. This was a relatively serious problem because it effectively raised the minimum detectable signal level from -22 dB to -16 dB, a factor of 4. We still do not know the true cause of the problem, except that it appeared to be a 60-Hz noise problem. However, actions taken at Beaumont, including adjusting, but not changing, the configuration of the ground wires has considerably reduced the occurrences of "bad" accepted data due to 60-Hz noise (75% approximately) and reduced the minimum detectable SNR level to about -20 to -21 dB. At Medicine Lodge, maintenance on the phase shifter assembly in December 1999 apparently changed the configuration in some minor way so that it also is reporting much less "bad" data and has a minimum SNR level near -20 dB. In both cases, however, the minimum SNR level is due to the 60-Hz noise. At Meeker, the problem has never been quite so severe and has a minimum SNR value near -19 to -20 dB.

5.4 Frequently Asked Questions

Why don't the profiler values of winds and/or temperature agree with values from the radiosonde balloon-borne sounding system (BBSS)?

- The RWP provides values averaged over (nominally) 1 hour while the BBSS obtains only a grab sample at one instant in time at each height.
- The balloon from the BBSS travels with the mean wind; hence, it is not collocated with measurements from the RWP.
- The RWP values are volume averages over (nominally) 60–240 meters in height by 9 degrees horizontally.
- The BBSS measures temperature; the RWP measures virtual temperature.
- The RWP may be detecting birds rather than the true wind.

6.0 Data Quality

6.1 Data Quality Health and Status

The Data Quality Office (DQO) website has links to several tools for inspecting and assessing RWP data quality:

- DQ Explorer
- DQ Plot Browser

- NCVweb: Interactive web-based tool for viewing ARM data

The tables and graphs shown contain the techniques used by ARM's data quality analysts, instrument mentors, and site scientists to monitor and diagnose data quality.

6.2 Data Reviews by Instrument Mentor

- Quality Control (QC) frequency: Daily
- QC delay: Instantaneous; daily
- QC type: Min/max flags, graphical plots, comparisons
- Inputs: Raw data
- Outputs: Summary reports

Data QC procedures for this system are mature.

1. Data Flags:

   A procedure used to be in place for several years that produces a parallel datastream to the ".a2" data, which consists of consensus-averaged wind and temperature profiles produced by the wind profiler. These data are unchanged from the original data but have an additional data field consisting of flags referring to data that are questionable. The flags were determined based on differences between successive wind or temperature variables. Comparisons are made both in time and space and both forward and backward (i.e., comparisons with previous and successive values at a given height as well as comparisons with values above and below at a given time.) If the values exceed defined limits they are flagged.

2. Comparison with radiosonde data:

   Every routine launch of radiosondes by the BBSS used to be compared in wind speed, wind direction, and virtual temperature between BBSS and the 50-MHz and 915- MHz profilers at the Central Facility. The approach taken is to compare all values of "good" profiler values with BBSS values averaged over nearly the same height interval. The differences are used to produce the mean, standard deviation, maximum, minimum, and number of values. These data are appended to a file that dates back to June 20, 1995. Summary plots of these data are inspected to determine degraded system performance (see Coulter and Lesht, "Results of an Automated Comparison Between Winds and Virtual Temperatures from Radiosonde and Profilers" (PDF Document) in *Proceedings of the Sixth Atmospheric Radiation Measurement (ARM) Science Team Meeting*, CONF-9603149, San Antonio March 4–7, 1996, U.S. Department of Energy, pp. 59–60). The statistics of the differences were inspected daily.

3. Estimated maximum height of return:

   The daily data from both 915-MHz wind profilers are used to determine the maximum height attained in at least 25%, 50%, and 75% of the profiles during each 24-hour period. These data are appended to a file (for each site) beginning January 25, 1993 (915 - CF), March 24, 1994 (50 - CF), and January 1, 1997 (915 - Intermediate facilities). These data are plotted occasionally to determine trends that might indicate hardware problems.

4. Daily inspection:

   Vertical time sections of hourly averaged wind and temperature over a 24-hour period are inspected daily for system consistency and operation via data placed at a Web site.

6.3 Data Assessments by Site Scientist / Data Quality Office

All DQO and most Site Scientist techniques for checking have been incorporated within DQ Explorer.

6.4 Value-Added Procedures and Quality Measurement Experiments

Many of the scientific needs of the ARM Climate Research Facility are met through the analysis and processing of existing data products into value-added products (VAPs). Despite extensive instrumentation deployed at the ARM sites, there will always be quantities of interest that are either impractical or impossible to measure directly or routinely. Physical models using ARM instrument data as inputs are implemented as VAPs and can help fill some of the unmet measurement needs of the program. Conversely, ARM produces some VAPs, not to fill unmet measurement needs, but to improve the quality of existing measurements. In addition, when more than one measurement is available, ARM also produces “best-estimate” VAPs. For more information see http://www.arm.gov/data/vaps.

7.0 Instrument Details

7.1 Detailed Description

7.1.1 List of Components

The 915-MHz and 1290-MHz radar wind profiler is manufactured by Vaisala Corp. It consists of a single-phased microstrip antenna array consisting of nine “panels” (most systems have only four panels). The antenna is approximately 4-m square and is oriented in a horizontal plane so the “in-phase” beam travels vertically. The 1290-MHz beam steered profile is manufactured by DeTect, Inc. It has phase control over each of the 64 discrete elements to enable beam pointing on a pulse-by-pulse basis.

7.1.2 System Configuration and Measurement Methods

The radar wind profilers operate by transmitting in two different vertical planes and receiving backscattered energy from refractive index fluctuations that are moving with the mean wind. By sampling in the vertical direction and in two tilted planes, the three components of motion can be determined. The system consists of a single-phased array antenna that transmits alternately along five pointing directions: one vertical, two in the north-south vertical plane (one south of vertical, one north of vertical), and two in the east-west vertical plane (one east of vertical, one west of vertical). The non-vertical beams are tilted at about 14 degrees from vertical.

Radial components of motion along each pointing direction are determined sequentially. It takes, nominally, 30-45 seconds (dwell time) to determine the radial components from a single pointing direction. Thus, at the SGP site the system cycles through five beams (south,nNorth, east, west, and vertical) at low power, and then cycles the five beams again at a high power (longer pulse length) setting. Then the whole process is repeated. About five minutes elapse before the system returns to the beginning of its sequence. Within an averaging interval, the estimates from each beam-power combination are saved (11–12 in a 1-hour period); these values are examined and compared at the end of the period to determine the consensus-averaged radial components of motion.

Briefly, consensus averaging consists of determining if a certain percentage (e.g., 50%) of the values fall within a certain range of each other (e.g., 2 m/s). If they do, those values are averaged to produce the radial wind estimate. The radial values are then combined to produce the wind profile. The results of this averaging process are what are reported in the ".a2" data files produced by the ARM data system. Included in these files are height, speed, direction, radial components, # values in consensus, and SNR.

During a single time period during which the system operates in a single pointing direction (dwell time), the data that is produced in the ".a1" and ".a0" files is created. The system transmits pulses at about 1–10 kHz rate into the atmosphere. The backscatter from each transmit pulse is sampled at, for example, a 1-MHz rate. This results in 1 sample every 150 minutes in range. The samples at each range gate are averaged together (time domain integration) over some number (e.g., 100) of pulses to produce a phase value for input into a FFT. After (e.g., 64) values are produced, the FFT is performed (one for each range gate). This process takes on the order of 1 second. A number (about 30) of these spectra are then averaged together during the dwell time. At the end of the dwell time we have produced a single averaged spectrum from each range gate along the designated pointing direction. The spectra themselves are placed in the ".a0" data files.

The spectra are analyzed by the system before moving to the next pointing direction. This analysis produces estimates of the SNR, the noise, the mean velocity (proportional to frequency), and the first moment (spectral width) at each range gate. This is the information that is stored in the ".a1" data files. Both the ".a1" and ".a0" data files thus have information at about (dwell time) intervals; however, the data sequences among pointing directions and output powers.

A note of warning about the mean values in the ".a1" files. The values are in % of full scale times 100, where full scale is the nyquist velocity of the spectrum. Thus, velocity estimates are determined by multiplying the "mdf" column times the "oband" or "vband" values (described in the metadata) and dividing by 10,000.

RASS operation is essentially the same, except that the averaging time is about 10 minutes and only a single pointing direction (vertical) is used. Also, the atmosphere is "seeded" with a sound wave; the index of refraction changes created by the sound wave are the signal source. To sample both the sound wave (speed about 340 m/s) and the atmosphere (to remove air velocity from temperature estimates), a larger FFT is required (2048 points). This requires a smaller number of points for each time domain integration and increases the processor time required to calculate the FFT. The ".a0" files again are spectra; however, only a portion of the spectra are reported, namely a region near 0 Doppler shift to account for atmospheric motions and a region around the expected speed of sound. The ".a1" files now consist of moments and widths from both the atmospheric portion of the spectrum and from the acoustic portion (the main contributor to the temperature calculation). The ".a2" files consist of profiles of temperature and number of consensus values.

In normal operation, temperature profiles are determined during the first 10 minutes of every hour, and the wind profile is averaged over the remaining 50 minutes.

7.1.3 Specifications

- **Frequency**: 915 or 1290 MHz
- **Maximum Range**: 3–6 km (15 km for precipitation detection)
- **Range Gate**: .06–1 km
- **Pulse Length**: 60, 100, 200, 400 m
- **# Spectra/Ave Spectrum**: 1–100
- **# Pulse/Time Domain Integration**: 1–1000.

7.2 Theory of Operation

This section is not applicable to this instrument.

7.3 Calibration

7.3.1 Theory

This section is not applicable to this instrument.

7.3.2 Procedures

This section is not applicable to this instrument.

7.3.3 History

This section is not applicable to this instrument.

7.4 Operation and Maintenance

7.4.1 User Manual

This section is not applicable to this instrument.

7.4.2 Routine and Corrective Maintenance Documentation

This section is not applicable to this instrument.

7.4.3 Software Documentation

ARM netCDF file header descriptions may be found in the netCDF file header descriptions for RWP data ordered from the ARM Data Archive.

7.4.4 Additional Documentation

A. Calibrations and Related Performance Checks

1. What are factory-recommended calibration procedures? (Identify NIST traceability.)

The only true calibration procedures are carried out during the Acceptance Test Plan (ATP) that is performed immediately before the instruments are put into service. These are/were carried out by Radian personnel and the instrument mentor. They include the following:

- Output Power: Measured at the output of the final amplifier/preamplifier, including both forward and reflected power measurements (3990 W and >500 W for 50 MHz and 915 MHz, respectively).
- Center Frequency: Transmit frequency (49.8 MHz and 915 MHz for 50rwp and 915rwp, respectively) is measured using a signal generator input to the receiver.
- Doppler Direction: Using a special control parameter file, small signal frequency differences are analyzed to determine the appropriate sign of the analyzed frequency difference.
- Dynamic Range: A signal generator with variable attenuator is used as input to the system to establish a dynamic range of at least 55 dB.
- System Sensitivity: Signal generator is used to establish a minimum detectable level of at least -127 dBm.
- Range Verification: A delay line is used to establish range accuracy of +/- 30 m. All the above procedures are detailed in the ATP, Chapter 3, pages 3-9 through 3-26.

2. What are the factory-recommended performance checks?

As detailed in the ATP (Chapter 4), these include visual inspection, system power, timing, data transfer, antenna integrity, and RASS operation verification. Additional performance checks are detailed on page 100 of the system manual supplied by Radian and include:

- Control lights
- Date and time accuracy
- Data display operating
- Final amplifier current stationary
- Appropriate antenna rotation
- Data appearance
- SNR levels unchanged.

3. What are the mentor calibration procedures?

There are no “mentor calibration procedures” other than comparison of data with other available sources of data. This, however, is more of a QC check.

4. What are the mentor performance checks?

These include:

- Regular noise level checks (done by Site Ops)
- Regular final amplifier current checks (done by Site Ops)
- Daily data existence (done by mentor)
- Vertical time sections of winds and temperatures (done by mentor)
- Continuous (daily) maximum height attained monitoring (done by mentor).

5. How are calibration and related performance checks documented?

   a. Where are procedures documented?
   ATP, system operator’s manual supplied by Vaisala and DeTect, and an Operators manual specific to the SGP supplied by the instrument mentor.

   b. Have major changes to calibration procedures occurred? NO
   If so, for which components and when?

   c. Are major changes to calibration procedures expected to occur? NO
   If so, for which components and when?

6. Who implements (mentor) calibration and performance checks?

   – _ Mentor: Site Ops for system hardware Mentor for data integrity
   – _ Factory: Factory, Site Ops, mentor
   – _ Site Ops: Site Ops
   – _ Other _________:

7. What is the standard schedule of calibrations and checks?

Factory calibrations are done at time of installation and are recommended by the mentor for every year.

Other checks are recommended for Site Ops to perform in the Operator’s Manual (p. 7):

- Every 3 months operating level comparison
- Every 2 years antenna analysis (factory procedure)
- Monthly: Frame support levels and pointing direction, RASS sources level, acoustic sources operating
- Daily: Operation, data existence
- Weekly: Data integrity.

8. How are the calibration and check procedures initiated (queued)?
   - x Scheduled Calendar Event: Monthly change of temperature range appropriate and expected to maximize accuracy and reliability of virtual temperature profiles.
   - _ Work Order: When data existence fails, or other problem is identified by the mentor.
   - _ Data Inspection: Daily (data existence, maximum height, and comparison with BBSS) and weekly (vertical time sections of wind vectors and virtual temperature contours).
   - _ Instrument Failure: Site Ops checks daily for operation, monthly for physical level and pointing direction, output levels.
   - _ Other____:
9. How long does it take to perform calibration and performance check procedures? (List separately).
   - Basic factory calibration: 1–2 days
   - System operating: 30 minutes/day
   - Data existence and daily checks: 30 minutes/day
   - Data quality: 2 hours/5 days.
10. Are any data affected or lost during calibration or performance check procedures?
    - Basic factory calibration: All data lost
    - System operating: None
    - Data existence and daily checks: None
    - Data quality: None.
11. What are corrective procedures when calibrations and or performance checks fall behind schedule?

    None.

B. Calibration Data

1. Where are calibration data documented? (List for each procedure.)
   - _ Site Data System:
   - _ Site Ops Database - Hard Copy: ATP
   - _ Site Ops Database - Electronic Copy: Site Ops log
   - _ Instrument Mentor - Hard Copy: ATP
   - _ Instrument Mentor - Electronic Copy:
   - _ Data Logger:
   - _ netCDF file:
   - _ Special Archive Database:
   - _ Special databases accessible via the WWW:
   - _ Other: Mentor log book; profiler log book (at profiler).

2. Where are calibration coefficients and algorithms applied to convert data to geophysical units?

   In system operating program (POP3), applied to a1 and a2 data.

C. Maintenance Procedures

1. What are the factory-recommended maintenance procedures: (preventive and corrective)?
   - In System Manual (p. 97):
     - Clean air filters
     - Remove dust
     - Check cables
     - Inspect antenna, fences, exterior cables, clutter screens, guys, anchors.
2. What are the mentor preventative and corrective maintenance procedures?
   - In Operators Manual (p. 7). These include the following:
     - Regular noise level checks (done by Site Ops)
     - Regular final amplifier current checks (done by Site Ops)
     - Daily data existence (done by mentor)
     - Vertical time sections of winds and temperatures (done by mentor)
     - Continuous (daily) maximum height attained monitoring (done by mentor).
3. How are maintenance procedures documented?
   - Where are procedures documented?
     - In System Operators Manual (p. 97–100)
     - In Operators Manual (p. 7)
     - Site Ops log at site data system (SDS).
   - Have major changes to maintenance procedures occurred? NO
     If so, for which components and when?
   - Are major changes to maintenance procedures expected to occur? NO
     If so, for which components and when?
4. What is the procedure schedule?
   - Daily: Check operation, verify data existence
   - Weekly: Check data quality
   - Monthly: Check system alignment, cables, output levels, antenna switching
   - Yearly: Repeat ATP.
5. How are the procedures initiated (queued)?
   - _ Scheduled Calendar Event: Automatic change of parameter files for temps

- _ Work Order: Data nonexistence or apparent malfunction determined by mentor
- x Data Inspection: Regular and automatic procedure of mentor
- _ Instrument Failure:
- x Other: Site Ops standing operation: daily check of operation, monthly checks of hardware.

6. How long does it take to perform maintenance procedure?
   - System operating: 30 minutes/day
   - Data existence and daily checks: 30 minutes/day
   - Data quality: 2 hours/5 days.
7. Are any data affected or lost during maintenance procedure?
   No.
8. How are potential effects to data documented?
   - Data Quality Reports.
9. What are corrective procedures when maintenance falls behind schedule?
   - None.
10. Where is actual maintenance work documented?
    - Site Ops log
    - Instrument mentor's personal log.

D. Data Integrity and Quality Inspections

1. What nodes or activities along the data pipeline effect (or can potentially affect) the data stream?
   - _ Controller Boxes
   - _ Microprocessors
   - _ Data Logger
   - x Communication lines/links
   - _ Calibration Data files
   - x Ingest Modules
   - _ Others? (List).
2. What are current difficulties?
   - Data ingest for 1290 Beam Steered system.
3. List and describe any standard or non-standard data inspections (active or planned) under each of the following categories:
   - x Data Existence check: Daily ingest of "raw" consensus files (active)
   - _ Mentor QC checks (during ingest): QC delta checks (planned)
   - _ Mentor QC checks (outside of ingest):

- Vertical time section of vector and contour plots.(active)
- Maximum height of wind and temperature profiles/day (active)
- Comparison with BBSS (active).

– _ Within Platform Check:

– _ Multiple Platform Check: Comparison with BBSS

– _ VAPs:

- Combine 915, 50 virtual temperature profiles (planned)
- Establish flags for questionable data (planned)
- Compare temps and winds with BBSS (planned)

– _ Other automated netCDF file checks

– _ Other analytic tools or algorithms.

4. Does storage media exist on the instrument system to back up data and store it for delayed data ingest? Please identify media and the maximum period of time that the data can be backed up on the media.

   The hard disk can hold spectra and consensus files for approximately 12 days. It can hold consensus-only files for 1 year. An optical disk can hold spectral data for 12 months.

7.5 Glossary

See the ARM Glossary.

7.6 Acronyms

See the ARM Acronyms and Abbreviations.

7.7 Citable References

There are numerous references to radar wind profiling, too many to list. A good collection can be found in the proceedings from:

- Lower Tropospheric Profiling: Needs and Technologies. American Meteorological Society and German Meteorological Society. Boulder, Colorado, September 10–13, 1991.
- Third International Symposium on Tropospheric Profiling: Needs and Technologies, Max-Planck-Gesellschaft zur Forderung der Wissenschaften, NCAR, NOAA. Hamburg, Germany, August 30–September 2, 1994.

A few recent papers:

- Angevine, WM, and JI MacPherson. 1995. "Comparison of Wind Profiler and Aircraft Wind Measurements at Chebogue Point, Nova Scotia." *Journal of Atmospheric and Oceanic Technology* 12: 421–426.
- Merritt, DA. 1995. "Statistical Averaging Method for Wind Profiler Doppler Spectra." *Journal of Atmospheric and Oceanic Technology* 12: 985–995.
- Nastrom GD and FD Eaton. 1995. "Variations of Winds and Turbulence seen by the 50-MHz Radar at White Sands Missile Range, New Mexico." *Journal of Applied Meteorology* 10: 2135–2148.
- Wilczak, JM, et al. 1995. "Contamination of Wind Profiler Data by Migrating Birds: Characteristics of Corrupted Data and Potential Solutions." *Journal of Atmospheric and Oceanic Technology* 12: 449–467.
- Williams CR, WL Ecklund, and KL Gage. 1995. "Classification of Precipitating Clouds in the Tropics Using 915-MHz Wind Profilers." *Journal of Atmospheric and Oceanic Technology* 12: 1996–1012.

A few early classic papers:

- Ecklund WL, DA Carter, and BB Balsley. 1988. "A UHF Wind Profiler for the Boundary Layer: Brief Description and Initial Results." *Journal of Atmospheric and Oceanic Technology* 5: 432–441.
- Ecklund WL, DA Carter, BB Balsley, PE Currier, JL Green, BL Weber, and KS Gage. 1990. "Field Tests of a Lower Tropospheric Wind Profiler." *Radio Science* 25: 899–906.

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