N94-24210

INTERCOMPARISON OF REMOTE AND BALLOON-BORNE SENSORS OPERATED AT JAPE-91

S3-71
201675
p-9

Richard J. Okrasinski and Greg J. Cook
Physical Science Laboratory
New Mexico State University
Las Cruces, NM

Robert O. Olsen
U.S. Army Research Laboratory
Battlefield Environment Directorate
White Sands Missile Range, NM

SUMMARY

In recent years, there has been an increased availability of different types of remote sensors for measuring atmospheric parameters. With the introduction of remote sensors into field operation, questions arise as to their accuracy and precision. An attempt was made to address this issue by analyzing and intercomparing sets of wind and temperature data obtained during the Joint Acoustic Propagation Experiment (JAPE-91) conducted at White Sands Missile Range, New Mexico, in July and August, 1991. The remote sensing systems that were deployed included a 924 MHz wind profiler, two Doppler acoustic sodars, and a Radio Acoustic Sounding System (RASS). In situ measurements of wind, temperature, and humidity were also obtained from radiosondes. Individual system characteristics and the results of intercomparing the derived wind and temperature data from each of the systems are presented.

INTRODUCTION

The Joint Acoustic Propagation Experiment (JAPE-91) was conducted at White Sands Missile Range in south central New Mexico during July 11 - 28 and August 19 - 29, 1991. Two Doppler sodars, a 924 MHz wind profiler, and a Radio Acoustic Sounding System (RASS) were deployed by the U.S. Army Research Laboratory to collect boundary-layer wind and temperature data in support of the experiment. Upper-air wind, temperature, and humidity data were also collected by periodically released rawinsondes.

This information was later analyzed to evaluate the capabilities of the four remote sensors. Wind data from the UHF profiler and temperature data collected by the RASS were statistically compared with concurrent rawinsonde measurements. Similarly, simultaneous measurements from the two sodars were compared with each other and with concurrent wind profiler data. The percent of time that data were successfully measured at each sampling height was also calculated to determine the functional vertical range of each sensor.

INSTRUMENT DESCRIPTION

Both sodars, manufactured by REMTECH, Inc., transmit one vertical and two tilted acoustic beams. Changes in the acoustic refractive index caused by temperature fluctuations scatter some of the transmitted energy back to the antennas. Doppler shifts in these backscattered signals are used to derive the wind velocities along the three beam paths from which horizontal wind speeds and directions are then computed. The sodars are used to measure winds between 50 and 750 m above the surface.

The older A0 model uses a trailer-mounted array of three acoustic antennas, two of which are tilted 18° from the vertical, and the newer PA2 uses a single phased array antenna with three electronically steered beams, two of which are directed 30° from the vertical and 90° from each other. Frequency coded transmissions are propagated at frequencies centered at 1600 Hz with an acoustic power of 60 W by the A0 and at 2100 Hz with an acoustic power of 140 W by the PA2.

The wind profiler transmits three 924 MHz beams, one vertical and two tilted 15° from vertical, from three antennas. Doppler shifts in the backscattered signals are used to derive the wind velocities along the beam paths. One-hour-averaged horizontal wind data are computed from the radial velocities using a random sample consensus technique. The maximum measurement height is a function of the intensity of the backscattering and the vertical resolution of the wind data, but is usually between 2 and 4 km. Peak pulse power is 500 W.

The vertical radar antenna is also used to track 2000 Hz acoustic beams transmitted by the conjunctive RASS. Doppler shifts in the backscattered energy determine the speed of the acoustic signal, which is proportional to the virtual temperature of the medium. Maximum measurement height is about 1 km. Both the wind profiler and the RASS were developed by the NOAA Wave Propagation Laboratory.

Different radiosonde systems were deployed for the July and August phases of JAPE. In July, a system manufactured by Atmospheric Instrument Research, Inc. (AIR) was used, which consists of a 1680 MHz sonde tracked by an automatic radio theodolite using a phase array antenna. Height, temperature, humidity, and balloon-to-ground azimuth and elevation angles were recorded for every 4 - 5 seconds of flight. In August, an Omega Navaid system, using equipment manufactured by Vaisala Oy, was substituted to collect data at greater heights. Vaisala RS-80 radiosondes tracked by a Vaisala Digicora ground station provided measurements for every 10 seconds of flight.

DATA COLLECTION

JAPE-91 was conducted in the extreme southeast corner of White Sands Missile Range in south central New Mexico. This is an arid region situated in a broad basin between two mountain ranges. The nearest significant feature is the 300-m high Jarilla Mountains approximately 4 km to the east. The test area slopes from an elevation of 1275 to 1254 m above sea level from south to north.

The A0 sodar, the wind profiler and RASS, and the radiosonde station were located at the same site. The PA2 sodar was situated approximately 4.5 km south, next to a 40-m hill. Other than the hill, there were no significant terrain features in the vicinity of the two locations.

Fifteen-minute-averaged wind data were collected by the PA2 sodar during July 21 - 29 every 50 m from 50 to 750 m. Concurrent A0 winds were measured every 50 m from 50 to 750 m from 2045 on July 20 to 1515 on July 27 MDT, and from 50 to 600 m the rest of the time. Both sodars were operated more than 90% of the time between midnight July 21 and 0930 on July 29 MDT. Only the A0 was operated in August.

Two sets of one-hour-averaged UHF wind profiler data were collected. Winds with a vertical resolution of 101 m were measured at 25 levels between 167 and 2601 m, and 203-m resolution winds were measured at 24 levels between 246 and 4911 m. The profiler was turned off during several testing periods to avoid interfering with other instrumentation. A total of 84 hours of data were collected in July.

Five-minute-averaged virtual temperatures were collected hourly by the RASS between 127 and 1283 m above the ground at 12 equally spaced heights. Forty-five hours of data were collected in July and 144 hours were collected in August.

Thirty-three AIR radiosondes were flown during July and tracked to 5 km above the surface. Seven Vaisala sondes, tracked to 15 - 20 km, were released during August.

DATA COMPARISONS

UHF Wind Profiler

In most cases, the wind profiler does not successfully collect data at all of its programmed altitudes. The strength of the returned signal is a function of the intensity of the turbulent scattering in the region being probed and is often too weak to be interpreted. Lower resolution winds are measured with greater success, because longer pulse lengths and more energy are transmitted. The profiler height range, therefore, is dependent on both the state of the atmosphere and the resolution of the measurement. The percent of time that one-hour wind profiler measurements were successfully collected in July was computed for each interrogation height and plotted in

Figure 1. Considerably more low-resolution data were obtained. At 2 km, for example, 101-m and 203-m resolution winds were collected about 55% and 90% of the time, respectively.

To investigate the accuracy of these measurements, low-resolution (203-m) wind profiler data collected in July were statistically compared with data from 20 rawinsonde soundings that were launched within 30 minutes of one of the profiler interrogation times. The rawinsonde winds were calculated for 200-m layers and interpolated to the profiler heights, so that both data sets had approximately the same vertical scale. There is still a rather large temporal difference, however, because the profiler winds were averaged over one hour and the rawinsonde winds were computed for approximately 40 seconds of flight. In addition, the balloon drifts away from the site as it rises. Nevertheless, the agreement between the rawinsondes and profiler was fairly good, as shown in Figure 2, where the rms wind speed and vector wind differences are plotted versus height. The latter were calculated by taking the square root of the sum of the mean square differences in the east-west and north-south component winds and are, therefore, a function of the differences in both wind speed and direction. Most of the rms vector differences were close to 2.5 m s^{-1}. This is not much larger than the 1.5 - 2.0 m s^{-1} vector differences that were found between the same radiosonde system and a reference high-precision radar during a radiosonde intercomparison experiment (ref. 1). These statistics also compare favorably with the results of another study (ref. 2) in which the standard deviation of the differences in the east-west and north-south wind velocities measured by a wind profiler and rawinsondes were found to be about 2.5 m s^{-1}.

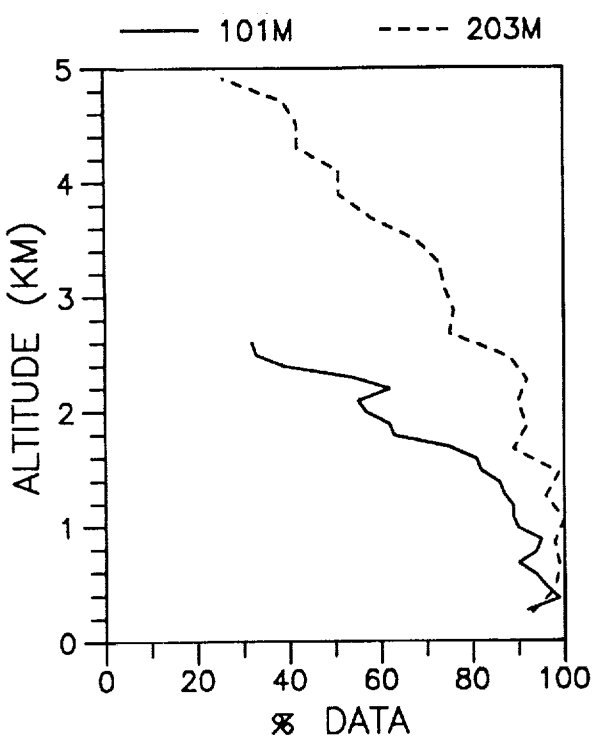

Figure 1. Percent of time wind data were successfully collected by the UHF wind profiler at 101-m (solid line) and 203-m (dashed line) resolutions.

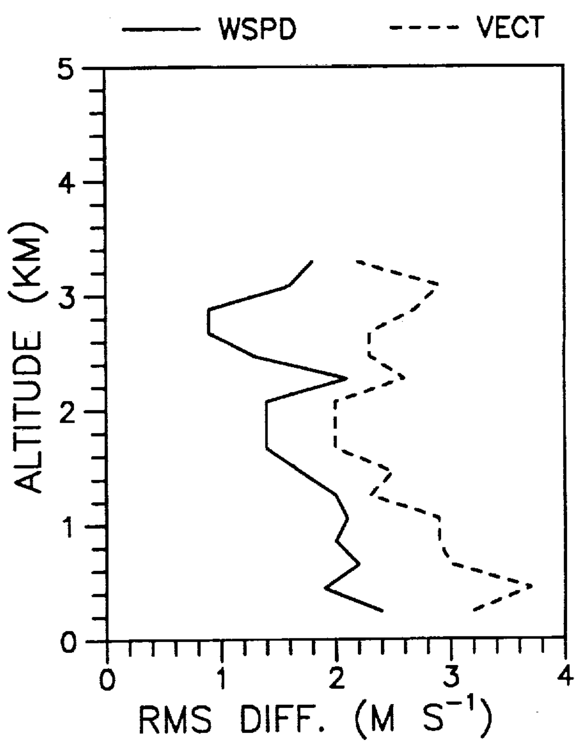

Figure 2. Rms wind speed differences (solid line) and vector wind differences (dashed line) of concurrent UHF wind profiler and rawinsonde data.

Because the strength of the backscattered sodar signal is largely a function of the intensity and scale of the temperature fluctuations in the region being probed, the sodar height ranges vary greatly with atmospheric conditions. Using 15-minute-averaged wind data collected by the A0 and PA2 sodars between July 21 - 29, the success rate of data collection was computed as a function of altitude and is shown in Figure 3. The PA2, as expected, had a greater range. At 600 m, for example, the A0 and PA2 sodars obtained a measurement approximately 40% and 85% of the time, respectively.

Using this same data set, the comparability of the two sensors was studied by calculating statistics of the differences between their simultaneous measurements. The number of concurrent data points ranged from 616 at 100 m to 300 at 600 m. The rms wind speed and vector wind differences, plotted in Figure 4, were close to 2 and 3 m s^{-1}, respectively, at all altitudes. Means and standard deviations of the differences in wind speed and direction, shown in Figure 5, were also calculated for comparison with the results of an earlier analysis of 20-minute-averaged wind data collected by two collocated A0 sodars (ref. 3). The mean differences found in that study are comparable in magnitude to the JAPE statistics, but their wind speed and direction standard deviations of 1.1-1.4 m s^{-1} and 22 - 32°, respectively, are somewhat smaller. The poorer JAPE statistics may be partially due to the 4.5 km separation of the two sodars.

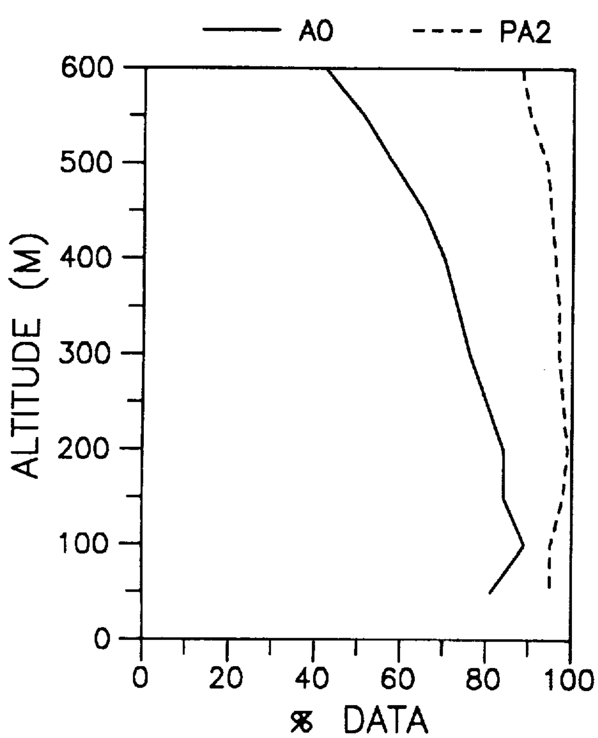

Figure 3. Percent of time horizontal wind data were successfully collected by the A0 (solid line) and PA2 (dashed line) sodar.

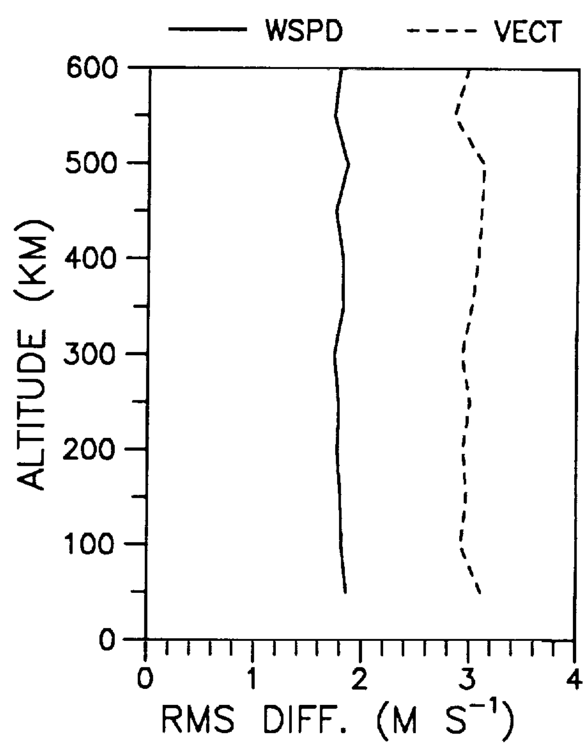

Figure 4. Rms wind speed differences (solid line) and vector wind differences (dashed line) of concurrent A0 and PA2 sodar wind data.

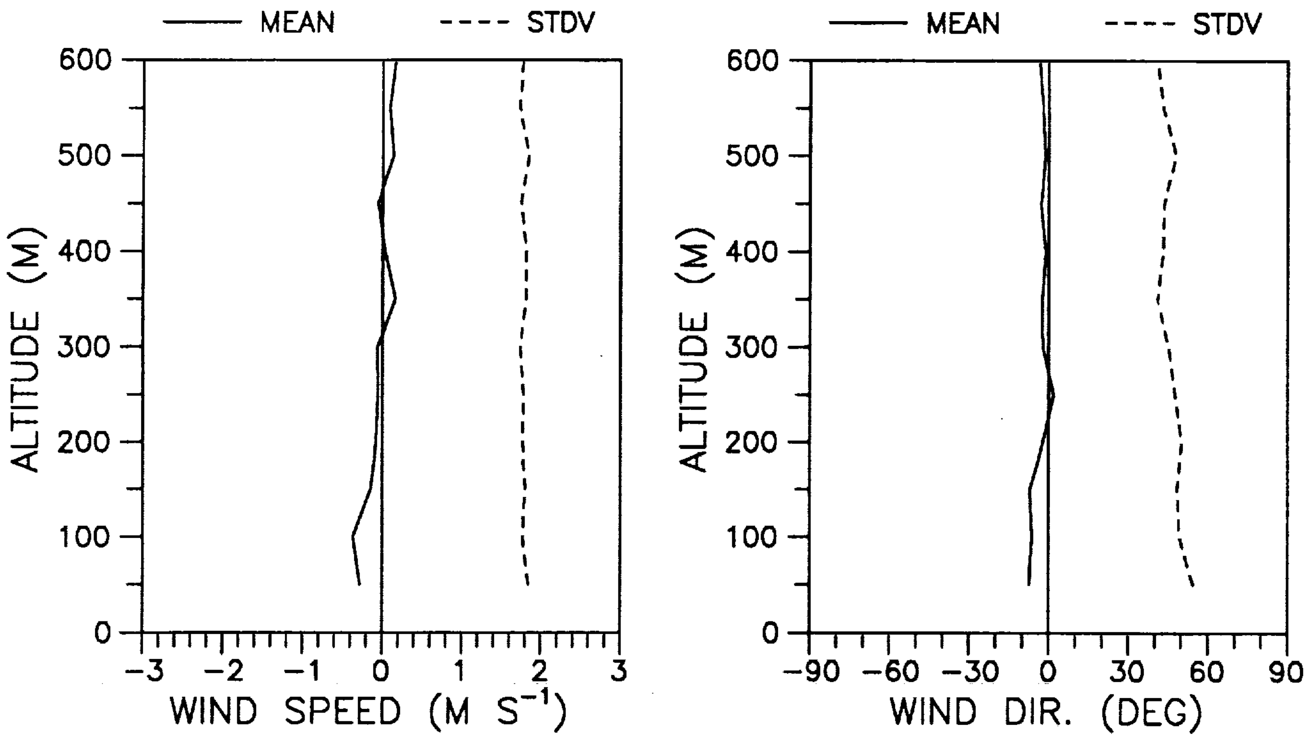

Figure 5. Means (solid lines) and standard deviations (dashed lines) of the differences in concurrent A0 and PA2 sodar wind speeds and directions.

A similar comparison of concurrent sodar and wind profiler measurements was also conducted. The sodar data were first averaged over one-hour periods and vertically interpolated to the profiler heights. Statistics of the differences between simultaneous one-hour sodar and profiler data were then calculated using only those periods when data were available from all three sensors. The rms wind speed and vector wind differences are shown in Table I. The A0 sodar, which was at the same site as the wind profiler, was found to be in better agreement with the profiler than the more distant PA2.

Radio Acoustic Sounding System (RASS)

The height range of the RASS, which consists of a sodar and a radar, also varies with atmospheric conditions. The data collection success rate, calculated with measurements from both the July and August phases of JAPE, is shown in Figure 6. Almost no data were obtained above 652 m. Measurements up to this level were statistically compared with virtual temperatures computed from 22 radiosonde soundings, which were released within 30 minutes of one of the RASS interrogation times. Means, standard deviations, and root-mean-squares of the differences are printed in Table II. The rms differences of .7 - .9 °C are comparable with those found in an earlier study (ref. 4).

Table I. Sodar-UHF Profiler Rms Differences

ALT (m)	WIND SPEED A0-UHF (m s^{-1})	WIND SPEED PA2-UHF (m s^{-1})	VECTOR WIND A0-UHF (m s^{-1})	VECTOR WIND PA2-UHF (m s^{-1})	NPTS
268	1.5	2.0	1.9	2.5	25
369	1.5	2.0	1.9	2.5	15
471	1.4	1.9	1.7	2.5	13

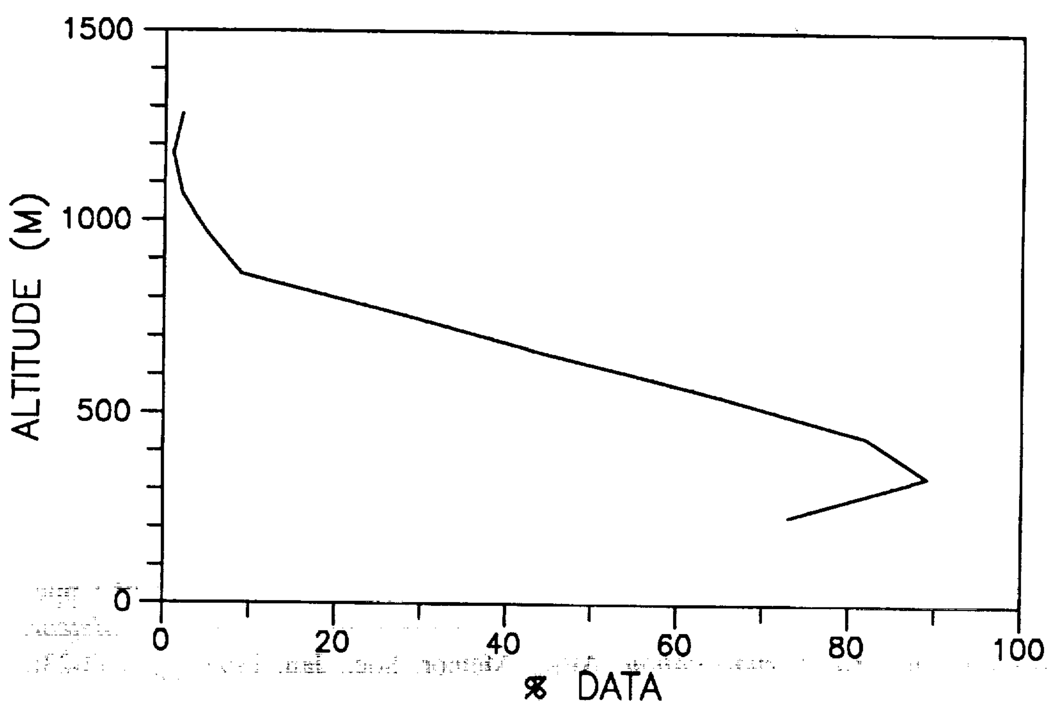

Figure 6. Percent of time temperature data were successfully collected by the RASS.

Table II. RASS-Radiosonde Differences in Virtual Temperature

ALT (m)	MEAN	SDEV (°C)	RMS	NPTS
233	.0	.7	.7	20
338	.3	.7	.8	22
442	.6	.7	.9	21
548	.5	.6	.8	17
652	.4	.7	.8	12

CONCLUSIONS

Statistical agreement between the radiosonde data and the wind profiler and RASS measurements collected at JAPE was comparable with the results of other similar studies. The rms temperature and vector wind differences between concurrent measurements were approximately .8 °C and 2.5 m s^{-1}, respectively. Standard deviations of the differences in the sodar wind speeds and directions, however, were somewhat greater than those that were found between two collocated sodars in a previous study. This may be partially due to the 4.5 km separation of the two sensors. The sodar rms vector wind differences were about 3 m s^{-1}.

Data were successfully collected at least 50% of the time at all heights below 600 m by the A0 sodar, below 652 m by the RASS, and below 2.3 and 4.3 km by the UHF wind profiler at 101-m and 203-m vertical resolutions, respectively. More than 85% of the PA2 data were collected at all altitudes up to 600 m.

REFERENCES

1. Olsen, R. O.; Okrasinski, R. J.; and Schmidlin, F. J.: Intercomparison of Upper Air Data Derived from Various Radiosonde Systems. In *Preprints: 7th Symp. on Meteor. Observations and Instrumentation*, Amer. Meteor. Soc., Jan. 1991, pp. 232-236.

2. Weber, B. L.; and Wuertz, D. B.: Comparison of Rawinsonde and Wind Profiler Radar Measurements. *J. Atmos. Oceanic Technol.*, vol. 7, no. 1, Feb. 1990, pp. 157-174.

3. Chintawongvanich, P.; Olsen, R. O.; and Biltoft, C. A.: Intercomparison of Wind Measurements from Two Acoustic Doppler Sodars, a Laser Doppler Lidar, and In Situ Sensors. *J. Atmos. Oceanic Technol.*, vol. 6, no. 5, Oct. 1989, pp. 785-797.

4. May, P. T.; Moran, K. P.; and Strauch, R. G.: The Accuracy of RASS Temperature Measurements. *J Appl. Meteor.*, vol. 28, no. 12, Dec. 1989, pp. 1329-1335.

DISCLAIMERS