The NCAR/ARM Multiple Antenna Profiler

W.O.J. Brown, S. A. Cohn, M. E. Susedik, C. L. Martin, G. Maclean, and D. B. Parsons
National Center for Atmospheric Research
Atmospheric Technology Division
Boulder, Colorado

Introduction

National Center for Atmospheric Research/Atmospheric Technology Division (NCAR/ATD), with the support of the U.S. Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) Program, is developing an advanced wind profiler radar known as Multiple Antenna Profiler Radar (MAPR) (Cohn et al. 1997, 1998). The radar is a highly modified 915-MHz profiler (Radian LAP-3000) and is designed to measure wind and turbulence at a rate considerably faster than traditional wind profilers. The radar has four vertically pointing closely spaced receiving antenna and uses spaced antenna techniques to measure winds (essentially by tracking the motion of the atmosphere over the radar [Briggs 1984; Doviak et al. 1996]). The radar continuously points vertically so it can monitor small-scale fluctuations in wind and capture rapidly evolving events.

Recent developments include software and hardware upgrades. The radar can now use complementary pulse coding, which has increased its sensitivity. New control and data collection software has made the radar easier to use and more reliable. Robust wind analysis routines allow the radar to now carry out wind analysis and graphically present the results on the World Wide Web in near real-time at http://www.atd.ucar.edu/sssf/facilities/mapr/home.html. Analysis results and graphics are automatically collated in a central archive.

Field Deployment

Over the last 6 months, the radar has been making observations at the National Oceanic and Atmospheric Administration/Environmental Technology Laboratory's (NOAA/ETL's) boundary-layer studies facility at the Boulder Atmospheric Observatory (BAO). This facility includes a 300-meter instrumented tower; a NOAA 449-MHz Doppler beam swinging (DBS) wind profiler, and an NCAR Cross-Chain Loran Atmospheric Sounding, System (CLASS) radiosonde sounding system were also deployed there. A variety of weather events have been observed allowing the radar to be tested under a range of conditions.

Comparisons with Anemometers

An example of comparisons between MAPR and tower anemometer wind measurements is given in Figure 2. The radar was 600 meters from the base of the tower and considering that the anemometers and radar have very different sampling characteristics, there is very good agreement between the two sets of measurements. Over extended periods, it has been found that in light to moderate winds, they

Figure 1. MAPR deployed at the NOAA/ETL BAO site (the white box with sloping sides is the ground clutter screen protecting the MAPR antenna, the foreground antenna is not in use).

agree to within 2 m/s 80% to 90% of the time. In strong winds, swaying of the tower and other ground targets adds low frequency components to the Doppler spectrum, which can be removed using spectral filtering.

Comparisons with Soundings

MAPR was deployed with various instruments that make up an NCAR Integrated Sounding System (ISS). This includes a CLASS radiosonde sounding system. Figure 3 shows examples of comparisons between MAPR and radiosonde wind measurements. The measurements agree well (note that the sondes can drift a considerable distance during their flights).

Comparisons with DBS

We have also carried out comparisons with a standard DBS wind profiler operated by NOAA/ETL. This profiler uses a 449-MHz, 6-kW transmitter (about 10 times more powerful than MAPR) with a much larger antenna. Figure 4 shows hourly averaged wind measurements from MAPR and the DBS system. As can be seen, the two radars agree very well.

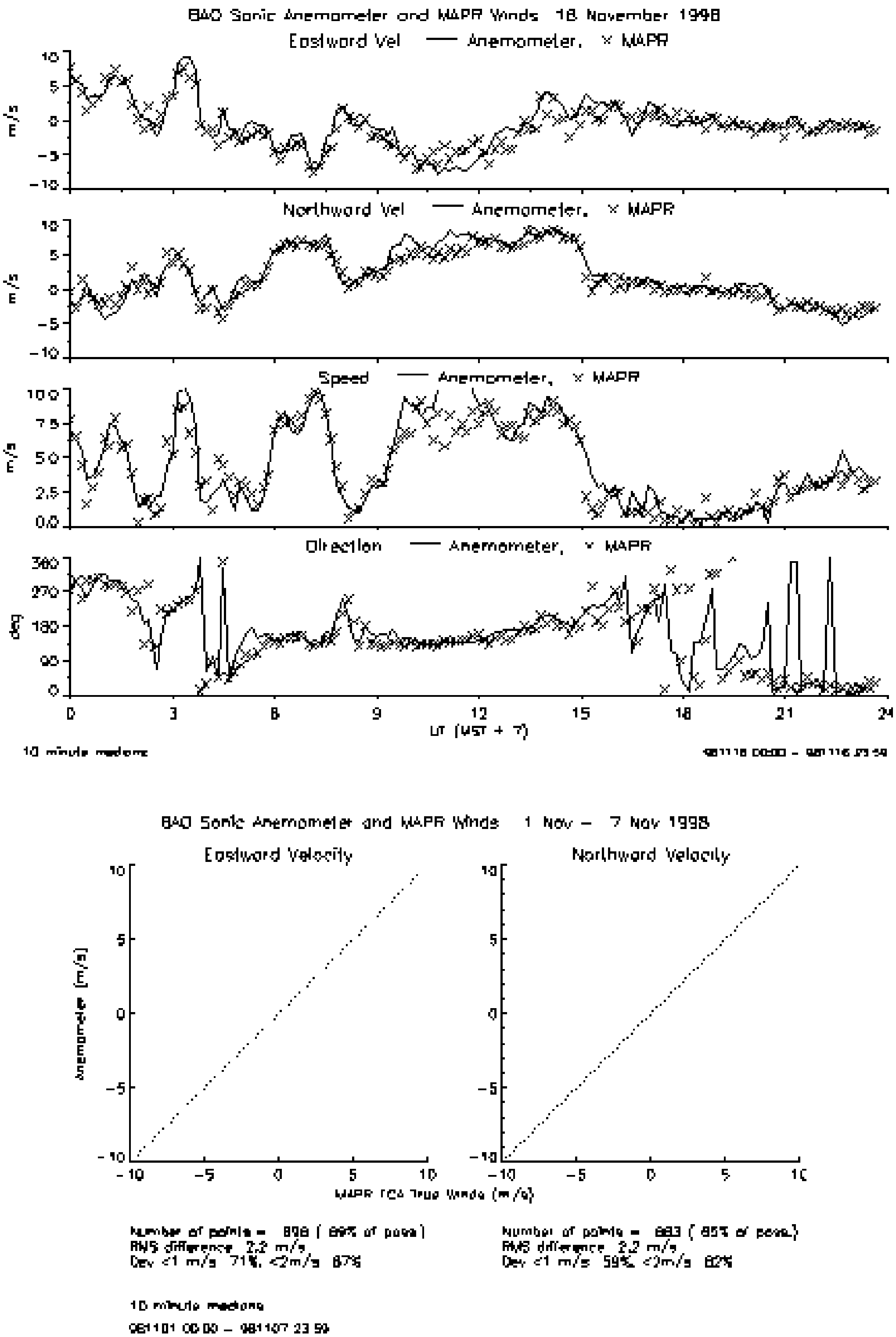

Figure 2. Wind measurements for an anemometer at 300 meters and MAPR.

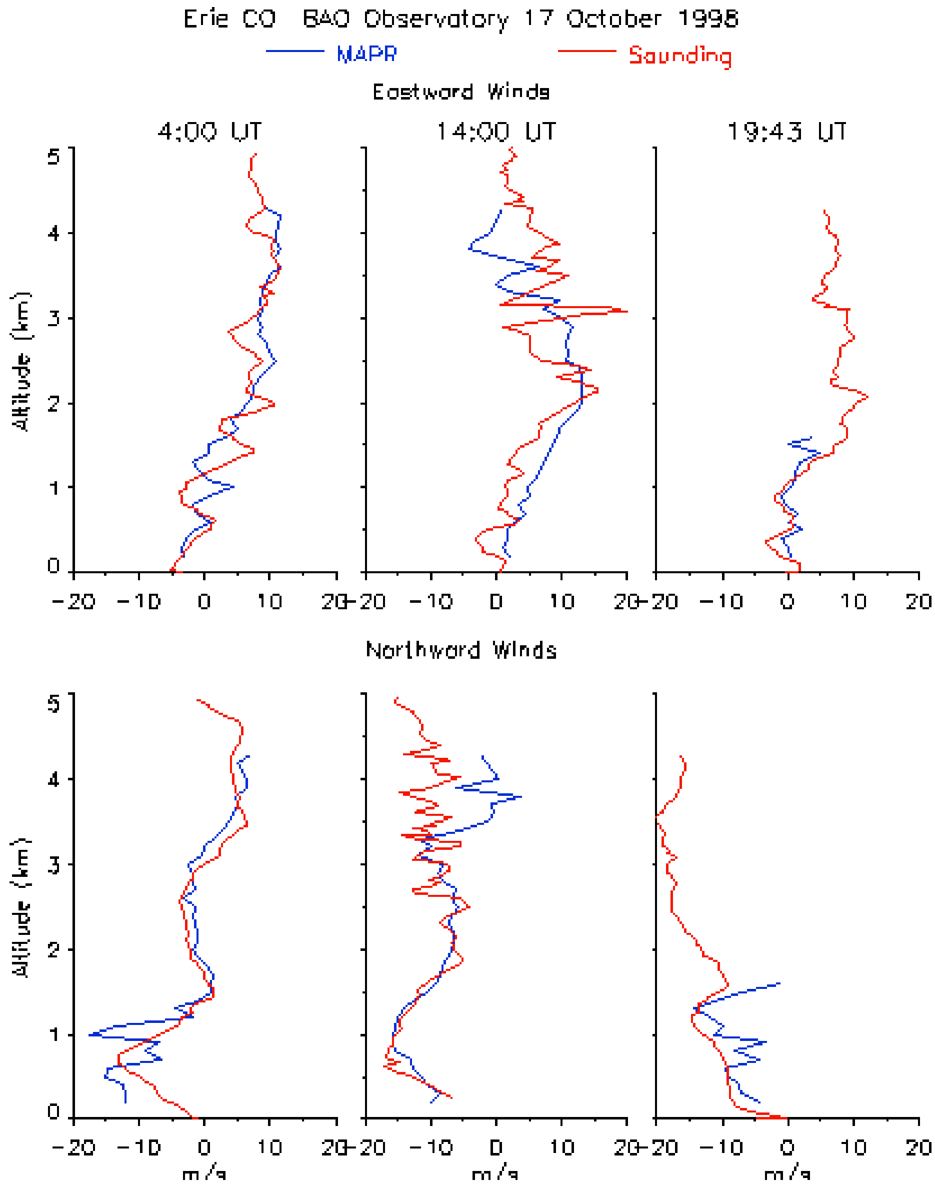

Figure 3. MAPR and radiosonde wind profiles.

Cold Front Case Study

Many weather events have been observed using the radar during its six-month deployment and a particularly interesting example is depicted in Figure 5. On December 18, 1998, a Pacific cold front followed by an intense Arctic front passed over the radar. The figure shows observations during the passage of the Arctic front. The top panel shows the echo signal strength, the middle panel shows vertical velocity, and the bottom panel shows wind measurements at 30-second intervals. The temperature at the surface is over-plotted on the top panel.

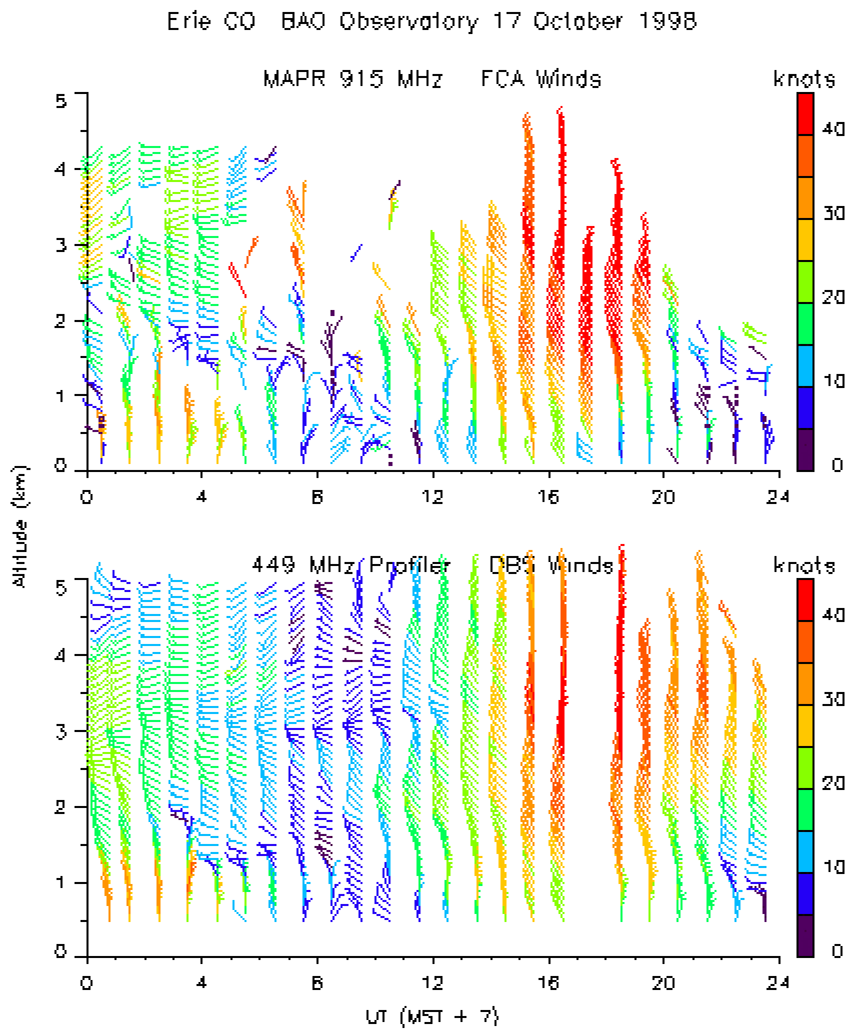

Figure 4. Comparison between MAPR and a 449-MHz DBS profiler (note that the 449-MHz system is considerably more powerful than MAPR).

The blue regions in the top two panels indicate snow being brought in by the front. The region of red in the middle panel shows a brief powerful updraft where vertical velocities peaked at about 3 m/s. The temperature started dropping about the same time. The updraft seems to be a surge of cold air pushed along by the front. The northerly winds pick up and the Doppler spectral width increases (not shown), suggesting increased turbulence. This example demonstrates the utility of MAPR. A conventional wind profiler probably would not see such a brief updraft because it has to dwell in oblique directions for much of its sampling cycle. MAPR can make 3-dimensional wind measurements 20 to 50 times faster than conventional profilers and so can capture the fine structure of rapidly evolving events.

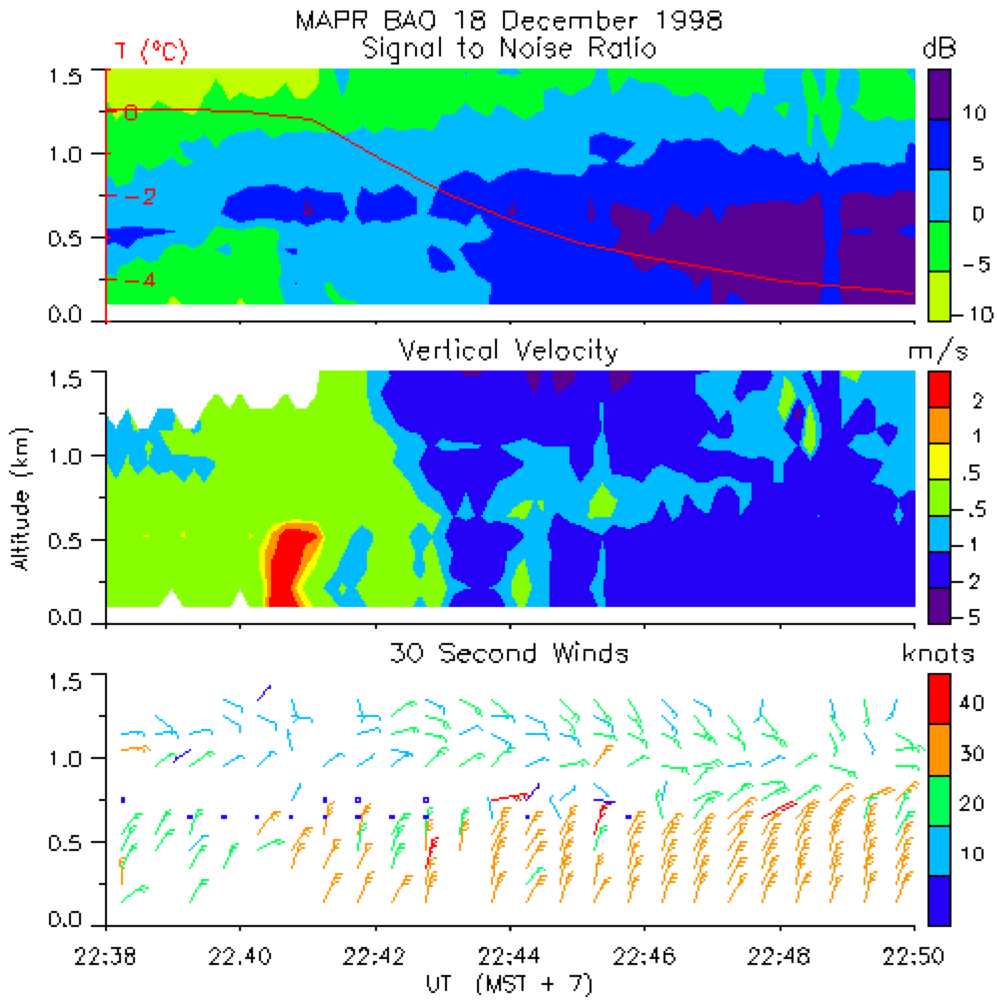

Figure 5. High resolution observations of a cold front.

Future Plans

Development of the radar will continue. The data cards will be upgraded to enable faster and longer time series of data to be collected. This will allow advanced echo characterization routines such as wavelet analysis (Jordan et al. 1997) to be used. Such routines will be very useful in separating atmospheric and ground or sea clutter echoes.

The radar will also participate in the DOE/ARM Nauru99 campaign in the Tropical Western Pacific this summer (June 1999). The radar will be operated on the Japanese research vessel the Mirai. The radar will provide regular wind profiles and, with the Radio Acoustic Sounding System (RASS), virtual temperature profiles. It is expected that the radar may have some advantages over conventional profilers in this setting because it points vertically only and because it can make multiple measurements within the typical pitch and roll cycle of the ship.

Acknowledgments

This work is supported by DOE/ARM (grant DE-AI05-90ER61070). NCAR is operated by the University Corporation for Atmospheric Research under the sponsorship of the National Science Foundation. The authors wish to thank J. Jordan, C. Russell, and B. Templeman of NOAA/ETL for their assistance with the BAO deployment.

References

Briggs, B. H., 1984: The analysis of spaced sensor records by correlation techniques. *Handbook for MAP*. **13**, 166-186, SCOSTEP Secrt., Uni Illinois, Urbana, Illinois.

Cohn, S. A., C. L. Holloway, S. P. Oncley, R. J. Doviak, and R. J. Lataitis, 1997: Validation of a UHF spaced antenna wind profiler for high resolution boundary layer observations. *Radio Sci*, **32**, 1279-1296.

Cohn, S. A., M. Susedik, C. L. Martin, C. L. Holloway, and R. J. Doviak, 1998: Development of the NCAR/ARM Multiple Antenna Wind Profiler (MAPR). In *Proceedings of the Eighth Atmospheric Radiation Measurement (ARM) Science Team Meeting*, DOE/ER-0738, pp. 173-176. U.S. Department of Energy, Washington, D.C.

Doviak, R. J., R. J. Lataitis, and C. L. Holloway, 1996: Cross correlations and cross spectra for spaced antenna wind profilers. *Radio Sci.,* **31**, 157-180.

Jordan, J. R., R. J. Lataitis, and D. A. Carter, 1997: Removing ground and intermittent clutter contamination from wind profiler signals using wavelet transforms. *J. Atmos & Ocean Tech.,* **14**, 1280-1297.