

P1.8 DEVELOPMENT OF THE MODULAR PROFILING NETWORK (MPN)

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Figure 1: Three components of the MPN stations, a prototype antenna module for the wind profiler (left, photo by Warner Ecklund), a surface flux tower (center), and mini-Doppler lidar (right, HALO-Photonics).

1. INTRODUCTION

The National Center for Atmospheric Research ([NCAR](#)) / Earth Observing Lab ([EOL](#)) and the University of Oklahoma's [Atmospheric Radar Research Center \(ARRC\)](#) in collaboration with engineers from [NOAA/ESRL](#), and with Howard University's [Beltsville Lidar Team](#), are proposing the development of the Modular Profiling Network (MPN). The MPN will consist of up to six stations consisting of a new wind profiler of modular design, surface flux towers, mini-Doppler lidars, GPS receivers for water vapor measurement, and other sensors. The system aims to meet the need in the NCAR user community for atmospheric profile measurements with improved range, spatial and temporal resolution, areal extent, flexibility, and ease of deployment. The modular design of the new wind profiler allows the deployment of radars of varying sizes, depending on the needs of a particular experiment.

2. BACKGROUND

NCAR / EOL currently deploys Integrated Sounding Systems ([ISS](#), Parsons, et al.1994) consisting of boundary layer wind profilers, radiosondes, and surface meteorology stations. The ISS have been involved in more than 30 projects including TOGA-COARE, FASTEX, ACE, CASES, IMPROVE, NAME, IHOP, VTMX, and T-REX, to study surface-atmosphere exchange, precipitation, boundary layer evolution, air quality, airflow in complex terrain and many other topics.

Currently the ISS use three DBS (Doppler Beam Swinging) boundary layer 915 MHz profilers of the classic NOAA Aeronomy Lab design, (Ecklund et al. 1988). These systems are very capable for boundary layer studies; however, they require a clutter screen, and have limited range (typically up to 3 – 4 km) and time resolution (winds every 15 – 30 min).

The ISS does have one advanced 915 MHz wind profiler, [MAPR](#) (Multiple Antenna Profiler Radar; Cohn et al. 2001) developed

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at NCAR / EOL. MAPR uses a spaced antenna to make fast wind measurements (1-5 min), but otherwise has similar performance to the older systems (e.g. an altitude range of 3 or 4 km).

A variety of technological advances enable the development of much more capable wind profilers that will enable a greater range of deployment strategies to better meet the needs of the very diverse range of experiments. For example, some projects could benefit from a wind profiler capable of penetrating deep into the troposphere, whereas others could use a wider network of small boundary layer capable systems.

There are also advances that could improve the near surface observations from the ISS. The lowest sampling height of the wind profilers is typically 150 – 250 m ; currently this data gap is filled using a mini sodar.

The MPN design extends the capabilities and fills these gaps in the present system, as described below.

3. DESIGN OVERVIEW

The proposed MPN stations consist of three key components:

- 449 MHz Modular Wind Profilers
- Mini Doppler Lidars
- Surface Energy Balance Stations

3.1 Modular Wind Profiler

A key feature of the proposed wind profiler system is modularity. The system would consist of a number of modules, each of which is largely self-contained with a transmitter, receiver, antenna, and data acquisition and processing unit. These modules would be assembled together to produce wind profilers of varying sizes. The module and possible configurations are illustrated in Fig. 2. This modularity and other key features of the radar bring together design elements from a number of very successful atmospheric radars:

Modularity: A modular antenna and distributed receiver concept has been used in [AMISR](#) (Advanced Modular Incoherent Scatter Radar), a very large radar used for ionospheric research, and in the University

of Massachusetts Turbulent Eddy Profiler (TEP; Mead, et al. 1998) radars allowing the systems to be readily reconfigured depending on the application. Each panel would be ~2 m across, include a transmitter and receiver and could operate independently or together with other panels.

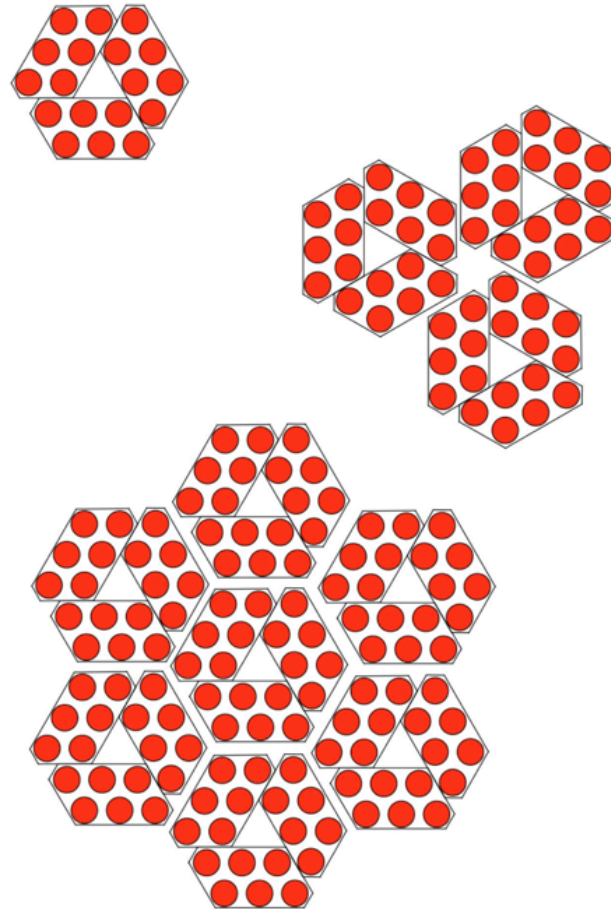


Figure 2: The antenna module (upper left) and layouts for boundary layer operations (3-modules, upper right) and mid-troposphere operations (7-modules, lower left).

449 MHz (67-cm wavelength): Profilers in this frequency band are used by the National Weather Service (NWS) in the NOAA [Profiler Network](#) and by NOAA Earth System Research Laboratory (ESRL) for their superior range and high sensitivity.

Multiple Receivers: MAPR and TEP, as well as the Australian Bureau of Meteorology wind profilers incorporate multiple receiver spaced antenna techniques in order to

measure the wind much more rapidly than traditional Doppler Beam Swinging wind profilers.

Hexagonal Antenna Modules: This shape is used in VHF radar such as the large [MU](#) radar in Japan, and in UHF radar such as the wind profiler on NOAAs *R/V Ronald H Brown*, (Law et.al. 2002). The panels can be fitted together as in a honeycomb (Fig. 2), yet retain the basic uniform outline producing an even antenna pattern with reduced sidelobes (Fig. 3).

3-element 2.887-lambda array of 18-element 0.667-lambda subarrays

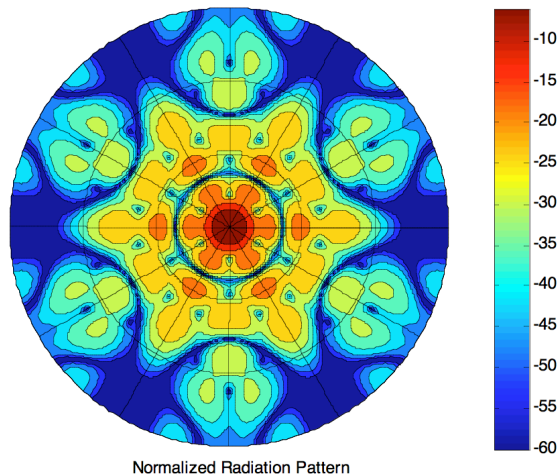


Figure 3: Theoretical antenna pattern for the 3-module boundary layer configuration. Spacing of individual modules is 2.887 wavelengths; spacing of antenna elements is 0.667 wavelengths.

Solid-state transmitter units: Each module would use solid-state transmitter units. Similar transmitters are used behind each antenna element in AMISR, and are also used in the NOAA/ESRL “quarter-scale” 449-MHz radars.

Digital Receivers with Software Defined Radio (SDR): These FPGA (Field Programmable Gate Array) receivers are used in a number of radars (e.g., Applied Technologies 449-MHz Aerostat profilers) for their superior signal processing capabilities.

Other features being investigated are Range IMaging (RIM, Palmer et.al., 1999, Yu and

Brown, 2004) to improve the range resolution of the radars; adaptive clutter mitigation using spatial filtering with additional wide field-of-view antenna modules (Le et al. 2007); and RASS (Radio Acoustic Sounding System) for virtual temperature profiling.

3.2 Mini Doppler Lidar

The MPN proposes to use a mini Doppler lidar to provide winds from the surface up into the boundary layer. The lidar being considered is a HALO-Photonics lidar, an off-the-shelf scanning eye-safe system operating at 1.5 microns (Fig. 1). In addition to providing low-level winds, these systems are capable of measuring turbulence, and tracing features such as thermals, boundaries, gusts, and boundary layer top. An evaluation study of the lidar is being proposed for the Beltsville Research Site of Howard University.

3.3 Surface Energy Balance

Three surface stations will be deployed with each MPN station to measure all components of the surface energy balance. These include eddy-correlation measurements of the fluxes of temperature, moisture, momentum, four-component radiation, and soil heat flux and moisture.

3.4 Additional Components

The stations will be deployed with GPS receivers for water vapor measurements and will also be capable of hosting radiosondes systems and additional user supplied instruments.

Table 1 presents the expected performance in each of the principle configurations (the right-most column is the current 915 MHz DBS profiler capability). The proposed full-troposphere configuration should have altitude coverage comparable to the large U.S. National Profiler Network (NPN) operational systems (Benjamin et al. 2004), and the Mid-Troposphere configuration should have altitude coverage similar to the NOAA quarter-scale profiler (White et al. 2007). All options will have much better time and altitude resolution and will be easily deployable for research programs.

4. CURRENT STATUS

4.1 Preliminary Tests

An initial design study is being conducted. A prototype test antenna has been manufactured (see Fig. 1, Ecklund *pers. com.*). It was connected to the electronics of a NOAA / ESRL 449-MHz radar for two days in December 2007 in Boulder, Colorado. Observations of snow are shown in Fig. 4, along with observations from a collocated 915 MHz wind profiler. Neither radar used a ground clutter screen. The difference in reflectivity between the 915-MHz and 449-MHz observations is close to the theoretically expected 11 dB. The signals from the prototype antenna were very clean and showed none of the ground clutter seen by the near-by 915-MHz system.

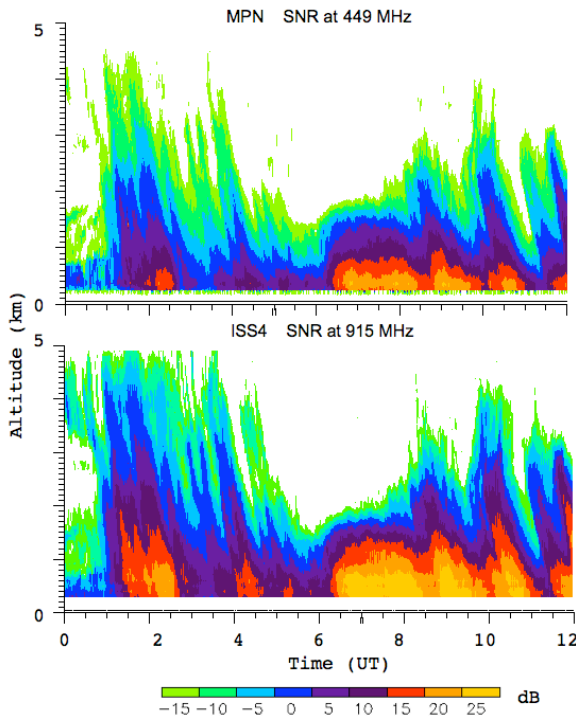


Figure 4: Observations of snow made in Boulder, Colorado, at 449 MHz (upper panel) using a prototype MPN antenna, and at 915 MHz (lower panel) with a standard wind profiler. Dec 11, 2007.

The radiation pattern of the prototype antenna was also measured at the Marshall antenna test range just south of Boulder. Preliminary results from these tests are shown in Fig. 5. The measured one-way antenna pattern at the horizon is around 40

– 50 dB below the main lobe, which is close to that predicted by theory. The antenna performs very well and it appears that the profiler will indeed be able to be deployed without a clutter screen.

4.2 The Next Steps

Initial design work and component testing is continuing. A preliminary proposal to the National Science Foundation to build the MPN has been submitted. Comments and/or expressions of interest from the community are welcomed.

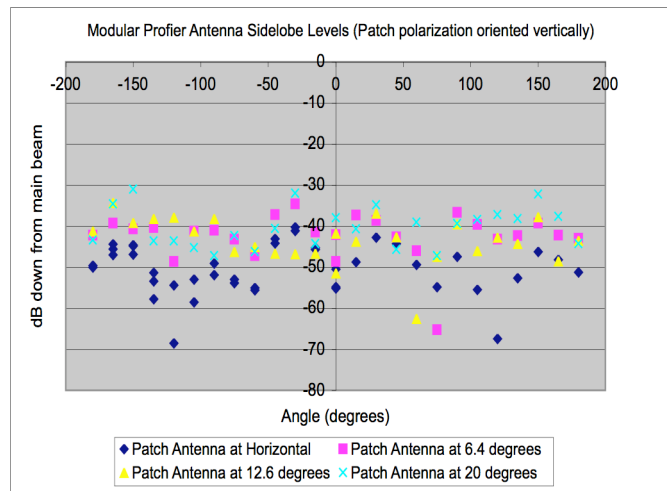


Figure 5: Preliminary antenna test range measurements of the beam pattern of a prototype single antenna module (pointed vertically) showing one-way signal at, or near, the horizon as a function of azimuth angle.

REFERENCES:

- Benjamin, S. G., B. E. Schwartz, E. J. Szoke, and S. E. Koch, 2004: The value of wind profiler data in U.S. weather forecasting. *Bull. Amer. Meteor. Soc.*, **85**, 1871–1886.
- Cohn, S. A., W. O. J. Brown, C. L. Martin, M. S. Susedik, G. Maclean, and D. B. Parsons, 2001: Clear air boundary layer spaced antenna wind measurements with the Multiple Antenna Profiler (MAPR), *Annales Geophysicae*, **19**, 845–854.

- Ecklund, W., D. Carter, and B. Balsley, 1988: A UHF Wind Profiler for the Boundary Layer: Brief Description and Initial Results. *J. Atmos. Oceanic Technol.*, **5**, 432–441.
- Law, D.C., S.A. McLaughlin, M.J. Post, B.L. Weber, D.C. Welsh, D.E. Wolfe, and D.A. Merritt, 2002: An Electronically Stabilized Phased Array System for Shipborne Atmospheric Wind Profiling. *J. Atmos. Oceanic Technol.*, **19**, 924–933.
- Le, K.D., R.D. Palmer, T.-Y. Yu, G. Zhang, S.M. Torres, and B.L. Cheong, 2007: Adaptive array processing for multi-mission phased array radar. 33rd Conference on Radar Meteorology (AMS), Cairns, Australia, Aug 2007 (paper P7.2, this volume).
- Mead, J.B., G. Hopcraft, S.J. Frasier, B.D. Pollard, C.D. Cherry, D.H. Schaubert, and R.E. McIntosh, 1998: A Volume-Imaging Radar Wind Profiler for Atmospheric Boundary Layer Turbulence Studies. *J. Atmos. Oceanic Technol.*, **15**, 849–859.
- Parsons, D. B., and Co-Authors, 1994: The Integrated Sounding System – Description and preliminary observations from Toga-COARE, *Bull. Amer. Meteor. Soc.*, **75**, 553-567.
- Palmer, R. D., T.-Y. Yu, and P. B. Chilson, 1999: Radio imaging using frequency diversity, *Radio Sci.*, **34**, 1485-1496.
- White, A. B., C.J. Senf, R.M., and R.M. Banta, 1999: A comparison of the mixing depths observed by cloud-based wind profilers and an airborne lidar. *J. Atmos. Ocean. Tech.*, **16**, 584-590.
- Yu, T-Y and W.O.J. Brown, 2004: High-resolution atmospheric profiling using combined spaced antenna and range imaging techniques, *Radio Science*, **39**, doi:10.1029/2003RS002907.

TABLE 1: Proposed performance targets and modes of operation for the MPN stations.

	Configuration-1 Boundary Layer	Configuration-2 Mid-Troposphere	Configuration-3 Full-Troposphere	Current 915 MHz BL Profiler (DBS)
Number of Stations ¹	6	2	1	3
Modules per station	3	7	19	
Expected Altitudes ²	0.15 to 4 km	0.20 to 7 km	0.30 to 15 km	0.15 to 4 km
Altitude Resolution ³	30-m	30-m to 200-m	100-m to 200-m	60-m to 100-m
Time resolution	~1-min	~1-min	~5-min	30-min
T _v coverage (RASS) ⁴	~1 km	~2 km	~4 km	~1 km

¹ Proposed number of wind profilers that NCAR/EOL will be able to deploy

² A Doppler lidar will fill in winds down to 30-m AGL with good time resolution

³ High-resolution is achieved in the boundary layer through the RIM technique, with lower resolution required at higher altitudes.

⁴ Radio Acoustic Sounding System (RASS) is an add-on to wind profilers which measures virtual temperature through radar measurement of the speed-of-sound.