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The NCAR 449 MHZ MODULAR WIND PROFILER PROTOTYPE DEPLOYMENT AND FUTURE PLANS

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1. INTRODUCTION

The Earth Observing Laboratory of the National Center for Atmospheric Research (NCAR EOL) is developing a Modular 449 MHz radar wind profiler as the central instrument of the proposed Modular Profiling Network (MPN). MPN is intended as a next-generation community facility for characterization of the atmospheric boundary layer, but with capabilities that extend also well into the free troposphere. MPN has been previously described in Cohn et al. (2009) and a description of technical progress through 2009 was presented at the previous 34th Radar Meteorology Conference (Lindseth et al. 2009).

In winter 2010-2011 we deployed a prototype 3-antenna version of this modular wind profiler during the Persistent Cold Air Pool Study (PCAPS; Whiteman et al. 2010) in Salt Lake City, UT. The purpose of this article is to provide an update on development progress, our experience so far, and next steps in the development.

2. BACKGROUND

EOL has been deploying wind profilers, as the central part of our three Integrated Sounding Systems (Parsons et al., 1994), in support of community driven research for 20 years. Over time, the experiments requested have become more ambitious and complex. Remote sensing technology and algorithms have also advanced tremendously. Our development of a modular wind profiler is intended to take advantage of technology and signal processing improvements to better meet the increasingly demanding requirements of recent and future experiments. Our specific goals are (1) to field a larger network of boundary layer wind profilers while using a similar staff resources as we use to field our three ISS; (2) to have the ability to measure winds to higher altitudes that our current wind profilers; (3) to improve the time resolution of wind profiles; (4) to simplify equipment setup and move toward more autonomous operation; and (5) to have a flexible testbed for wind profiler algorithm and technique development.

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3. KEY DESIGN FEATURES

Key features of the prototype wind profiler system are its modularity and antenna design. The prototype currently consists of three antenna modules, each of which transmits and uses an independent receiver and data acquisition system. As more modules are constructed, the design will allow us to combine varying numbers of antennas into wind profilers depending on the goals of each experiment or deployment. Our plans are to eventually construct 19 antenna modules (plus spares) which can be configured variously as a single large 19-antenna wind profiler that is powerful and sensitive enough to measure winds through the full troposphere, or assemble the modules into a small network of two 7-antenna wind profilers capable of measuring to the middle of the troposphere, or assemble them as a larger network of six 3-antenna boundary-layer wind profilers with sensitivity similar to the current

Figure 1: *Prototype 3-antenna 449 MHz wind profiler in Boulder, CO, early 2010.*

915-MHz profilers that we deploy - but with better time resolution and other characteristics. A summary of proposed capabilities of these configurations is in Table 1. The antennas also use a unique hexagonal arrangement of circular radiating patches, with an antenna pattern that has very low sidelobe energy bear the horizon. This greatly reduces ground clutter and removed the need for a clutter fence around the new wind profiler. Figure 1 shows an early version of the three-module prototype antenna without their protective radomes. More information on the antenna is described within Lindseth et al. (2011).

4. PROTOTYPE PERFORMANCE AT PCAPS

The fully-functional prototype, seen in Figure 2, was deployed to PCAPS from November 2010 through February 2011.

Figure 2: *Prototype 3-antenna 449 MHz wind profiler, including radomes, in Salt Lake City, UT for PCAPS, November 2010.*

During this first deployment changes were constantly being made to test or improve the equipment, so the data collected is not optimized. However, as described next, the initial results are very promising. The prototype was operated only a few meters from our standard 915 MHz Doppler Beam Swinging profiler (Figure 3), allowing a direct comparison of their performance. The 915 MHz profiler is the same design as the Väisälä LAP-3000.

Figure 3: *Close deployment of both a standard 915 MHz DBS wind profiler and the prototype 3-antenna 449 MHz wind profiler.*

PCAPS took place in challenging conditions for wind profiler operation. Winter air in the Salt Lake Basin can be cold and dry, and therefore Bragg reflectivity is fairly weak. Figure 4 is an example comparing 30-minute winds from both wind profilers over a 24-h period. We were

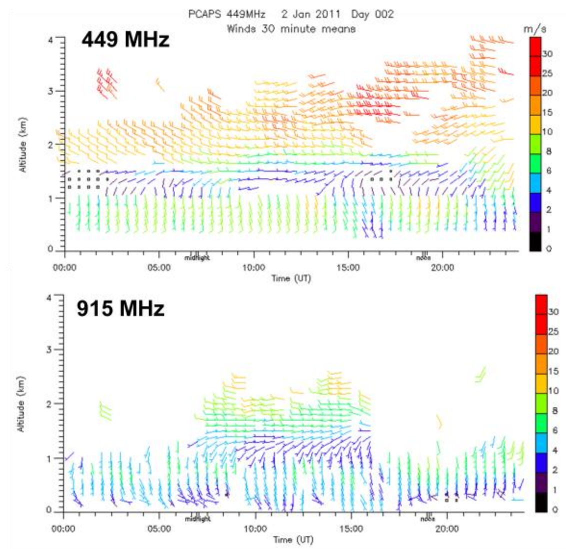

Figure 4: *Comparison of winds from the 915 MHz and 449 MHz wind profilers on 2 January 2011.*

pleased with the 915 MHz results in this cold environment, but the advantages of the higher power and longer wavelength of the 449 MHz prototype are clear on this day. Its sensitivity is greater and it can measure winds above the cold pool inversion, capturing the sweeping daytime westerlies not seen by the 915 MHz profiler. This is especially important for PCAPS because the interface region above the cold pool is a target of the study. It will also be beneficial to many future projects where observing winds above the boundary layer is also important.

Like NCAR’s multiple antenna wind profiler, MAPR (Cohn et al, 2001), the new wind profiler uses the spaced antenna technique to measure wind, rather than Doppler beam swinging. This requires higher SNR to make a measurement, but also allows shorter integration periods. Figure 5 shows 5-minute winds measured at PCAPS. Similar measurements are not possible with DBS.

Although many changes were made during the winter, including to operating parameters, the receiver hardware, and especially testing transmitter amplifiers, a bulk comparison of data

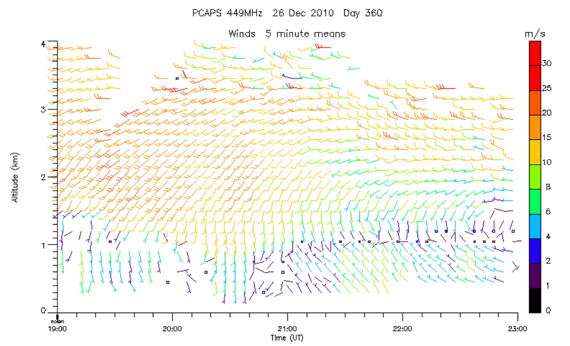

Figure 5: *Example of winds measured at 5-minute resolution with the 449 MHz prototype. This example is for 4 hours on 26 December 2010.*

recovery as a function of height clearly shows the improvement we get from the 449 MHz profiler. Shown in Fig. 6, the 449 MHz profiler (operating with altitude resolution of 150 m) measures winds about 1 km higher than the 915 MHz profiler in “Low” mode (range resolution of 100 m) and also higher than this profiler when in “High” mode (range resolution 250 m). We do note some differences in the measured wind

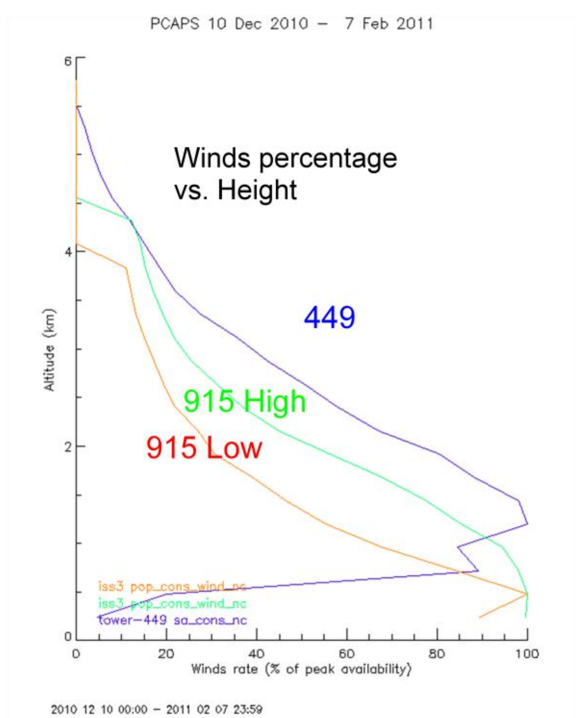

Figure 6: *Wind measurement recovery as a function of height for the period 10 December 2010 through 7 February 2011. The 915 MHz profiler was operated alternately in a “High” mode with a long transmit pulse length and “Low” mode with a shorter pulse.*

speed, and are investigating the spaced-antenna algorithm implementation used. Wind directions appear to agree very well.

One area that we expect to improve on is measurement at the lower altitudes. Improvements in the receiver recovery after the transmit pulse are needed to allow us to measure winds closer to the ground. The issue is seen below 1 km in Fig. 6 and is also clear in Fig. 7 which compares SNR measured with both systems. Signals below about 600 m are strongly attenuated in the 449 MHz system while the 915 measures down to about 250 m. Adjustments to the receive chain should improve this situation as the prototype design progresses.

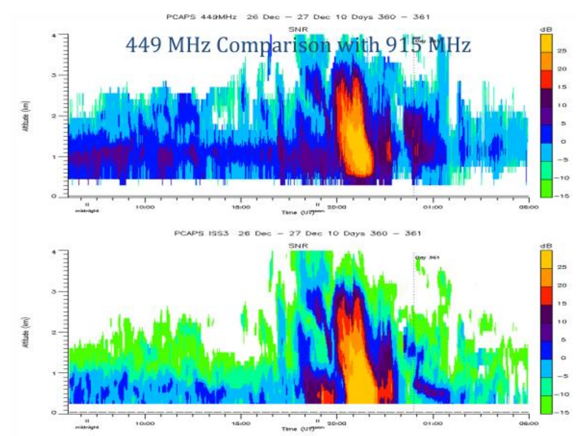

Figure 7: *SNR from both the 915 and 449 MHZ profilers for a 24-h period in late December 2010.*

5. NEXT STEPS

Although there are certainly improvements to be made, we are greatly encouraged by the 449 MHz prototype performance at PCAPS. NCAR/EOL is moving ahead with construction of a 7-antenna prototype which we hope to evaluate beginning next summer. We are discussing further capabilities, although specific plans are not in place. Eventually we would like to create a mobile version which can be deployed in projects where wind profilers move from site-to-site every few days, depending on the weather, rather than operating in a fixed location for weeks or months. This is analogous to our current use of a 915 MHz profiler as part of the Mobile-ISS. We also would like to add Radio Acoustic Sounding System (RASS) capability for boundary layer profiling of virtual temperature, and implement Range Imaging (RIM; e.g. Palmer et al. 1999) to improve the system's altitude resolution. Another challenge will be to operate on ships. Our 915 MHz wind profilers have been deployed aboard ships 11 times, with the antenna mounted to a stabilizing platform. The 449 MHz antennas are larger and less suitable for this mode of deployment, but certainly the demand is present for such use.

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TABLE 1: *Tentative performance targets and modes of operation for the modular profilers*

	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
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.