CHEESEHEAD 2019

449 MHz Radar Wind Profiler Data Report

NCAR/EOL Integrated Sounding System

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Earth Observing Laboratory
In situ Sensing Facility

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OVERVIEW:

This document describes data from the EOL 449 MHz Modular Wind Profiler radar at the CHEESEHEAD field project. In the event that information from this document are used for publication or presentation purposes, please provide appropriate acknowledgement to NSF and NCAR/EOL and make reference to *Brown, W.O.J. (2020): CHEESEHEAD 2019 NCAR/EOL ISS 449 MHz Radar Wind Profiler Data Report.*

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CHEESEHEAD data archive: https://data.eol.ucar.edu/master_lists/generated/cheesehead/
ISS Operations and quicklook plots: https://www.eol.ucar.edu/content/iss-operations-cheesehead
ISS Homepage: https://www.eol.ucar.edu/observing_facilities/iss

CITATIONS:

If data from the EOL wind profilers are used for research resulting in publication, please acknowledge EOL and NSF and include the following citations in your paper as appropriate:

- NCAR/EOL In-situ Sensing Facility. 2020. NCAR/EOL ISS 449 MHz Radar Wind Profiler, 5 and 30 Minute Winds. Version 1.0. UCAR/NCAR - Earth Observing Laboratory. https://doi.org/10.26023/JGAE-2956-K101. Accessed Date.

- NCAR/EOL In-situ Sensing Facility. 2020. NCAR/EOL ISS 449 MHz Radar Wind Profiler Moments. Version 1.0. UCAR/NCAR - Earth Observing Laboratory. https://doi.org/10.26023/P7PZ-NR8G-500Z. Accessed Date.

INTRODUCTION

NCAR/EOL deployed the 449 MHz Modular Wind Profiler radar for the CHEESEHEAD (Chequamegon Heterogeneous Ecosystem Energy-balance Study Enabled by a High-density Extensive Array of Detectors) field campaign in June - October, 2019 [1]. The profiler was operated as part of the Integrated Sounding Systems (ISS) [2] at a site in Price County, northern Wisconsin, approximately 12 km east of the town of Park Falls and 1.6 km west of the WLEF tall tower. The site was a farmers field on the corner of route 182 and East Rd.

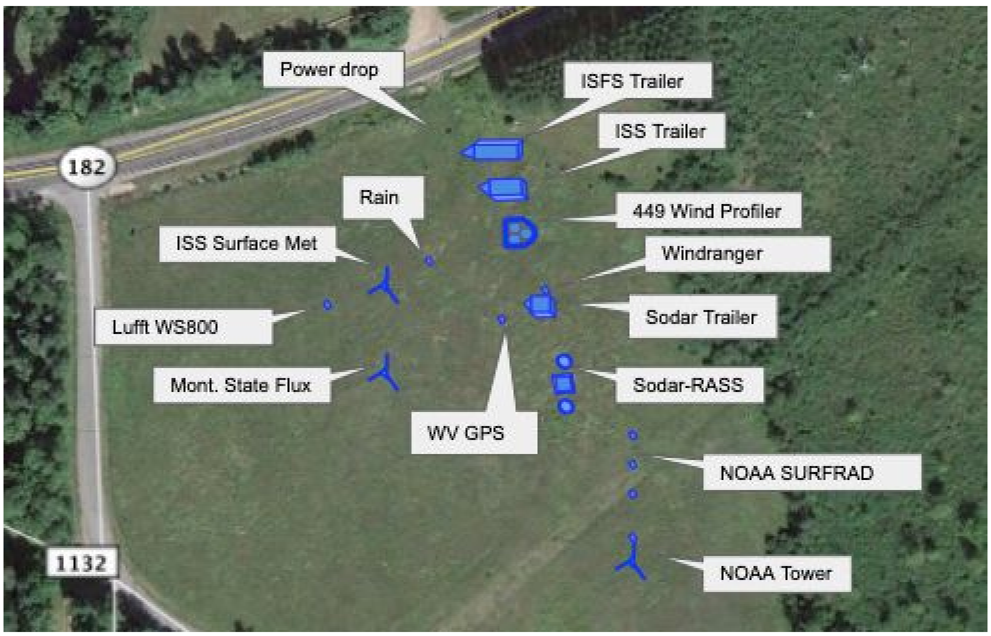

Figure 1: Approximate layout of the ISS site at CHEESEHEAD.

Modular Wind Profiler

The Modular Wind Profiler has a unique modular design enabling the system to be scaled to suit the phenomena being observed. The antenna modules are designed to be separated into multiple small radars if just boundary layer observations are required. Alternatively they can be combined into a large array if measurements are required higher into the atmosphere [3] (Brown et.al. 2007, Cohn et.al, 2009, Lindseth et.al., 2012). CHEESEHEAD focused on the planetary boundary layer so the profiler was deployed in a three antenna module configuration.

The wind profiler's operating parameters for CHEESEHEAD are summarized in table 1. The profiler was driven using a Delta Sigma 2 kW power amplifier, typically at 8% duty cycle. Approx 20% of power was lost to cable and other component inefficiencies. A clutter fence was designed to reduce clutter echoes from the nearby forest and also reduce the effects of radio frequency radiation on passersby (Sobtzak and Wislinsky, 2019).

Wind Profiler	449 MHz Modular Wind Profiler operating as a Spaced Antenna Radar
Location	45.945707°N, 90.293792°W, 463 m MSL
Antennas	3 vertically pointing 18-element phased array modules, approx 10° beamwidth
Power Amp	2 kW peak, 8% duty cycle, 160 W average
Time Sampling	Raw IQ: 150 Hz (IPP 55 μs, NCI 30, 4 channels) Correlations and Spectra: 30 second averages Moments: 30 second averages Winds: 5 minute and 30 minute averages
Range sampling	1 μs pulse with 4 bit complementary phase code 150 m resolution from 300 m to up 6 km AGL

Table 1: Typical operating characteristics of the Modular Profiler as configured for CHEESEHEAD.

Wind Profiler Data

The Modular Profiler is operated as a Spaced Antenna profiler with three receiving antennas. As reflecting targets (e.g., clear-air turbulence eddies) are advected over the array by the wind, backscattered patterns are received on the upwind side slightly before being detected on the downwind side, enabling a measurement of wind speed and direction to be made (eg, Cohn et. al. 2001). Raw IQ data at 150 Hz were retained for the entire campaign, totaling over 8 TB of data. Auto and cross correlation function files were generated at 30 second averaging time using the ICRA intermittent clutter filtering algorithm to reduce the effect of transient targets such as birds. The correlation files are then analysed to generate the daily winds and moment files that make up this archive. The winds files total around 40 MB and the moment files around 800 MB.

Two analysis techniques were applied to the correlation files to determine winds, "Full Correlation Analysis" (FCA, Briggs, 1984) and the "Slope at Zero Lag" (Holloway et.al., 1997) [3] techniques. A series of tests were applied to the data during the QC process to identify samples contaminated with unwanted signals (particularly clutter and bird echoes), and exclude those samples from the averages. The parameters for these tests were determined using a combination of comparisons with soundings and visual inspection. For example, the Signal to Noise Ratio (SNR) of samples that agree with soundings was generally higher than those that disagree (see figure 2). The agreeing population distribution peaked at around 0 dB, whereas the disagreeing population was clustered below -10 dB, leading to a cut-off of -9 dB being chosen for the SNR test. Similar analyses were carried out for a range of parameters such as the spectral width, magnitude and variability of the cross correlation between different receivers, phase differences between receivers, and other parameters. Samples were scored on whether they passed a series of these tests. Those that passed a certain threshold in a pseudo fuzzy logic approach were included in consensus averaging analyses to produce the 30-minute and 5-minute wind data files in this archive.

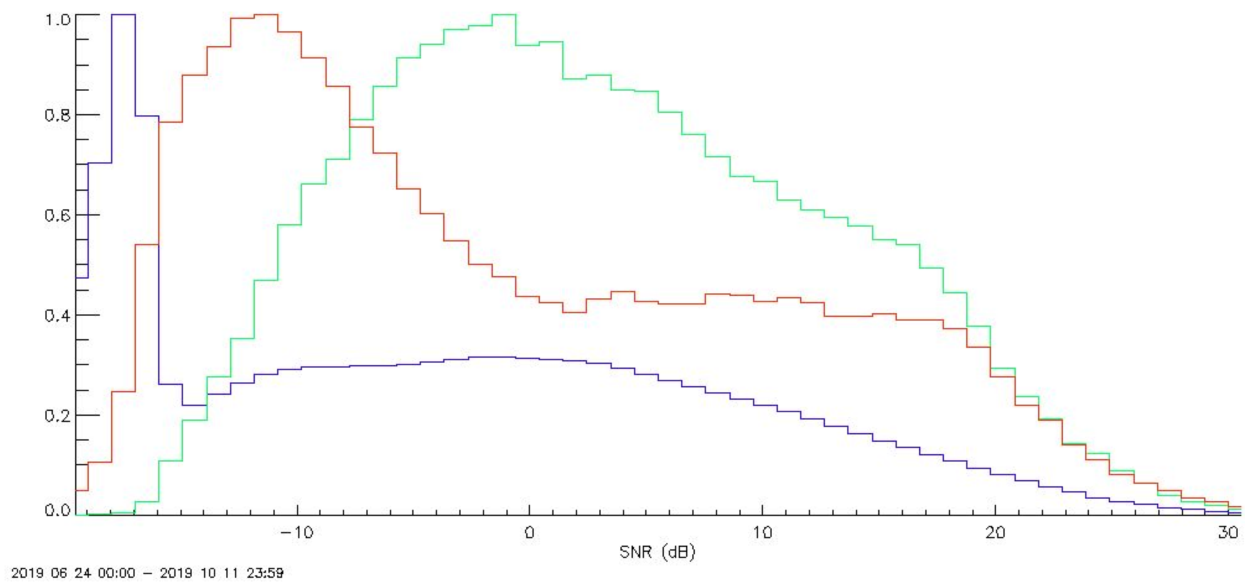

Figure 2: Examples of Signal to Noise (SNR) distributions for samples with wind estimates that agree with soundings (within 2 m/s and 30 degrees in speed and direction) indicated by the green histogram, disagree (red histogram) and the entire population of samples (blue histogram). The analysis includes all 169 soundings launched during the campaign.

The data files are in netCDF format [6]. There are two product file types, wind measurements (files with extension *.winds.*.nc) and spectral moments data (extension *.mom.nc). The *.winds.05.nc and *.winds.30.nc files correspond to the 5 and 30 minute average winds respectively. The data is arranged in time, height coordinates. The wind speed and direction data are contained in the wspd and wdir variables and these are the data that would be used by most users. The direction data follows the usual meteorological convention in that it is the direction the winds are coming from (ie, clockwise from north, with northerlies being 0, 90 being easterlies, 180 being southerlies, and 270 being westerly.

There are also snrw, wvert, spectWid variables containing Signal to Noise Ratio (SNR, related to backscatter signal strength and reflectivity), vertical velocity (positive is upwards) and Doppler spectral width (can be used to estimate turbulence with lots of caveats). We generally recommend that only experienced profiler users analyze these data. These data are also in the moments data files, derived from zeroth, first, and second moments of the Doppler spectra at approx 30 second intervals. The moments files have confidence indicators. Use only those data points for which the corresponding confidence level exceeds the chosen threshold confidence level. Usually we use a threshold confidence level of 0.5.

Performance and Comparisons

Wind profilers detect scattering from precipitation and from clear-air refractivity gradients (such as those due to turbulence and inversions). The strength of the scattering (reflectivity) and thus ability to measure wind is a complicated function of temperature, humidity, turbulence, precipitation, and the presence of unwanted signals (radio interference, clutter echoes from the vehicles, trees, power lines, birds, etc). At CHEESEHEAD, the primary unwanted signals were clutter echo clutters from trees in the lowest range gates (typically below 400m) and birds (typically at night during the migratory season).

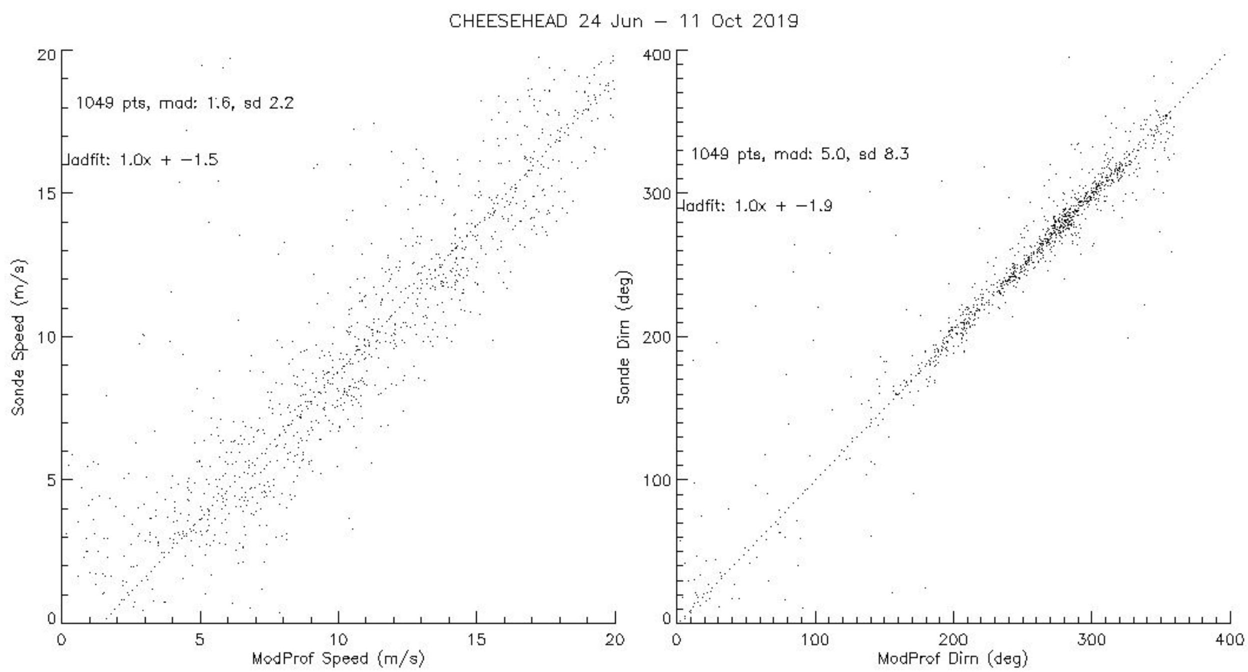

Figure 3: Comparison between the Modular Wind Profiler 30-minute consensus winds and sounding winds over the 1 - 2 km height range. All 169 soundings launched during the campaign were included.

At CHEESEHEAD the Modular Profiler reported quality controlled winds at the 1 km level over 90% of the time during the day and 75% of the time at night. Winds are available up to about 2.5 km about 75% of the time during the day and 2.2 km at night. The profiler winds compared well with sounding winds (Figure 3), with a median absolute deviation of around 1.6 m/s in speed and 5^{o} in direction (standard deviation of around 2.2 m/s and 8^{o} respectively). A similar comparison with an anemometer on the WLEF tower 1.6 km to the east at the 400 m level shows a std dev of 3.6 m/s and 23^{o} in speed and direction respectively. The agreement statistics were similar for day and night, and for each IOP.

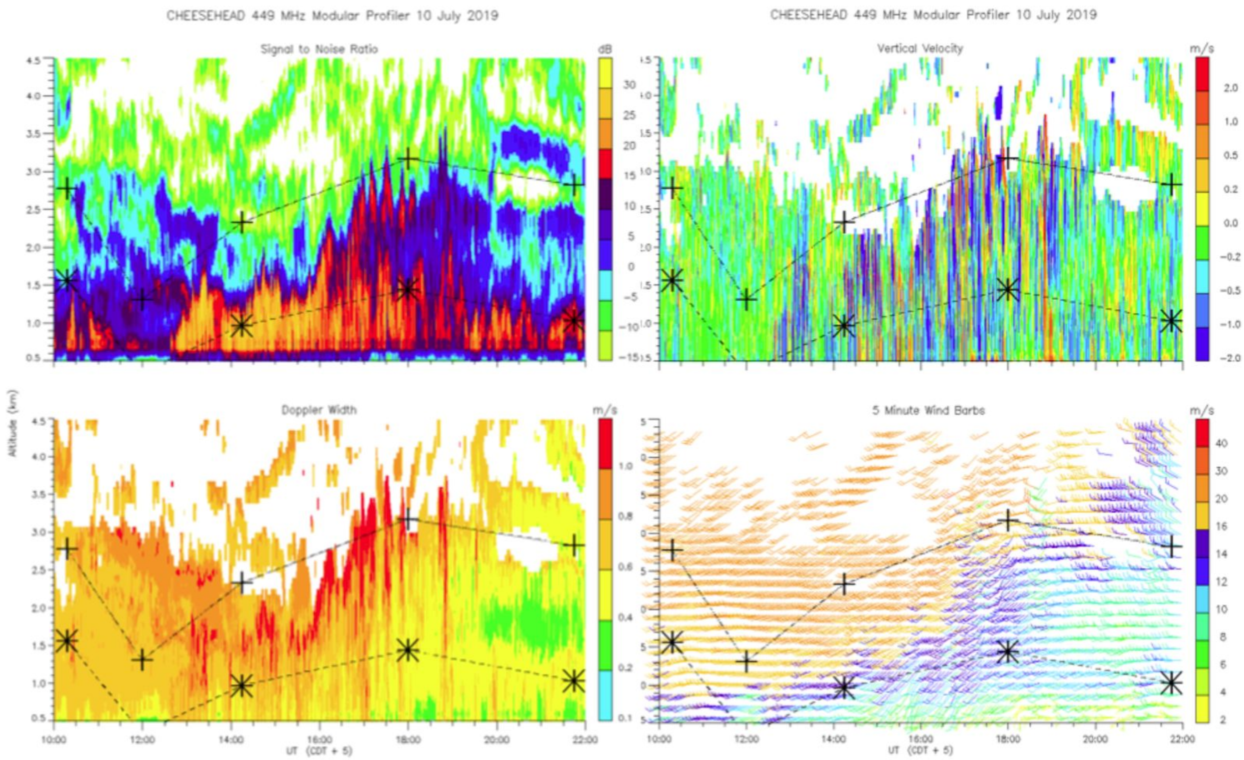

*Figure 4: Example of 449 MHz Modular Profiler measurements at CHEESEHEAD. The panels show time-height plots of Signal to Noise Ratio, Vertical Velocity, Doppler Spectral Width and Winds on July 10. The dashed lines show boundary layer analyses of radiosonde soundings using RAOB procedures (* for Stull analysis and + for Mixing Layer depth analysis). Brown, et.al. 2020.*

A typical day of measurements is shown in Figure 4. The day is July 10 (during IOP 1) with a strong boundary layer growth. The SIgnal to Noise plot (upper left) shows strong boundary growth as the clear-air reflectivity of the atmosphere intensifies and deepens. Clear-air radar reflectivity is a complicated function of temperature and relative humidity gradients, as well as turbulence. Vertical velocity is shown in the upper right panel, and the deepening rapidly fluctuating vertical velocity measurements indicate the development of convective boundary layer plumes. The bottom left panel shows Doppler spectral width which is indicative of turbulence and the plot suggests enhanced turbulence at the top of the boundary layer. Wind barbs are shown in the bottom right panel, and stronger winds can be seen in the free troposphere above the growing boundary layer.

Known Data Issues

Table 2 summarizes major events, data interruptions and days with significant issues.

June 15 - 23	Setup period, some data available however various interruptions for testing and calibration
June 24	First day of operations
July 6 16:30 - 17:50 UTC	Interruptions for testing and calibration
July 8 17:00 - 20:40 UTC	Interruptions for testing and calibration
July 9 - 12	IOP 1
July 15 03:30 - 18:20 UTC	Power failure due to storms
July 20 00:08 - 04:52 UTC	Power failure due to storms
July 28 13:11 - 15:19 UTC	Amplifier failure due to power interruption
Aug 18 15:10 - 15:25 UTC	Diagnostic tests, range sampling adjusted
Aug 19 - 24	IOP 2
Aug 29, 30, 31	Days with significant bird clutter during night
Sept 3 10:15 - 15:05 UTC	Power failure due to storms
Sept 13 00:00 - 13:40 UTC	Power failure due to storms
Sept 5, 7, 16, 19, 20, 24, 26	Days with significant bird clutter during night
Sept 23 - 28	IOP 3
Oct 4, 7, 8	Days with significant bird clutter during night
Oct 11	Last day of operations

Table 2: Notable events and data interruptions

Clutter: The ICRA routine and other filtering removed most intermittent clutter signals, however there is occasional evidence of nocturnal migrating bird echoes remaining in the profiler data. Table 2 lists the nights that experienced the most significant issues. Caution should be exercised if using night time data, particularly for the nights listed. There was also occasional clutter from trees on windy days at some lower range gates.

Data Gaps: The Modular Profiler operated continuously, however there were occasional gaps for equipment tests and power outages. There were five days with gaps longer than one hour due to power outages and these are noted in Table 2.

Vertical resolution: There appears to be a range resolution issue, likely related to pulse coding. The range resolution is nominally 150 meters, however if there are sharp vertical gradients in reflectivity (such as with an inversion layer, or at the top of the boundary layer), there may be some smearing or biasing of the measurements in adjacent range gates.

Range Sampling: On August 18 (just prior to IOP 2), an adjustment was made to the range calibration and sampling strategy. Prior to this time, the raw data was oversampled however there was a problem in the lowest range gates with partial pulse decoding. The oversampling was removed which enabled the lowest useful range gate to be lowered from around 400m down to about 300m.

Heavy rain: During heavy rain events the profiler wind speeds tend to be underestimated by 10 to 40%. No corrections for this biasing have been applied for this data set.

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[1] CHEESEHEAD

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[2] ISS Integrated Sounding System

Website:https://www.eol.ucar.edu/observing_facilities/iss

DOI: http://dx.doi.org/10.5065/D6348HF9

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[3] Modular profiler refs

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[6] <u>NetCDF</u>: UCAR/Unidata netcdf web site:
http://www.unidata.ucar.edu/content/software/netcdf/

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