PECAN

Plains Elevated Convection At Night

NCAR/EOL Integrated Sounding System 915 MHz Radar Wind Profiler Data Report

William Brown, NCAR/EOL[1]

Version dated 15 March 2016

The MISS and FP5 915 MHz radar wind profilers during an intercomparison check on July 18, 2015 at Brewster, KS.

This document describes Quality Controlled (QC'ed) data from three 915 MHz radar wind profilers at the PECAN 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. (2016): PECAN 2015 NCAR/EOL ISS 915 MHz Radar Wind Profiler Data Quality Report.

[1] The National Center for Atmospheric Research and the Earth Observing Lab are managed by the University Corporation for Atmospheric Research and are sponsored by the National Science Foundation.

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:

- UCAR/NCAR - Earth Observing Laboratory. 2016. FP4 NCAR/EOL ISS QC 915 MHz Profiler 30 Minute Consensus Winds and Moments, Version 1.0. *http://dx.doi.org/10.5065/D6RV0KXH*. Accessed 15 March 2016.
- UCAR/NCAR - Earth Observing Laboratory. 2016. FP5 NCAR/EOL ISS QC 915 MHz Profiler 30 Minute Consensus Winds and Moments, Version 1.0, *http://dx.doi.org/10.5065/D6H993DQ* . Accessed 15 March 2016.
- UCAR/NCAR - Earth Observing Laboratory. 2016. MP4 NCAR/EOL MISS 915 MHz Profiler 30 Minute Consensus Winds and Moments and ISS Surface Meteorology Data, Version 1.0. UCAR/NCAR - EOL http://dx.doi.org/10.5065/D6RJ4GPJ. Accessed 12 Apr 2016.

INTRODUCTION

NCAR/EOL deployed three 915 MHz radar wind profilers for the PECAN project in May and June of 2015. The profilers were operated with EOL ISS (Integrated Sounding Systems)[2] at PECAN PISA (PECAN Integrated Sounding Array) sites FP4, FP5 and MP4. These profilers are LAP3000 (Radian/Vaisala) type profilers operating in DBS (Doppler Beam Swinging) mode [2,3]. A 449 MHz wind profiler was also operated by EOL at FP3, however that is the subject of a separate document.

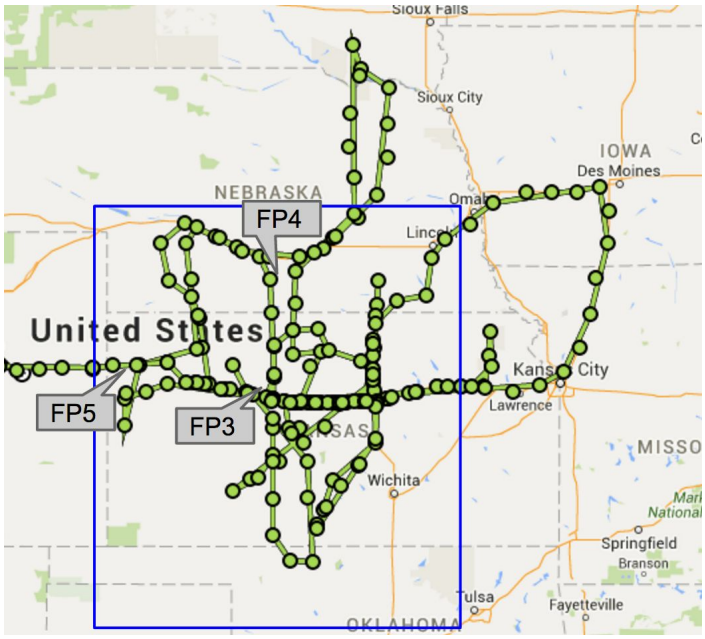

Figure 1: Map showing the PECAN domain (blue box), the FP3, FP4 and FP5 sites. The green trail indicates the roving of MP4 (MISS & MGAUS) system on their way to IOP deployments.

FP4: Minden NE

Photo of ISS2 at FP4 (Minden NE) looking towards the SSW.

FP4 Location: 40°30'55"N, 98°57'2"W, alt: 658m
404 E 21st St, Minden, NE. Township Range: 68959, S6 T6N R14W
Profiler: ISS2 915 MHz LapXM version 2.3, X-plane orientated at 293º, elevation 69º.
Identifier: doi:10.5065/D6RV0KXH Link: http://dx.doi.org/10.5065/D6RV0KXH

The FP4 site used ISS2 at Pioneer Village Field Airport on the north edge of Minden, NE. The site was an open field with county fairgrounds were to the north, hangers to the east, a golf course to the south (and the town beyond that), and a water treatment plant to the west. An ISFS flux 10m tower, along with 4-component solar radiation, rain gauge, temperature, relative humidity, and pressure were deployed 90 m to the south of the profiler. A Water Vapor GPS, web camera, ceilometer and ARM AERI were deployed adjacent to the ISS trailer. 109 RS92 radiosondes were launched at the site. Quick look plots are on the PECAN field catalog and at http://www.eol.ucar.edu/isf/projects/pecan/iss/realtime/summary/fp4/

FP5: Brewster KS

FP5 Location: 39°21'27"N, 101°22'14"W, alt: 1037m
1625 County Road 2/KS-184, Brewster KS 67732. Township Range: S17 T8S R36W.
Profiler: ISS3 915 MHz LapXM version 2.3, X-plane orientated at 254º, elevation 69º.
Identifier: doi:10.5065/D6H993DQ Link: http://dx.doi.org/10.5065/D6H993DQ

The FP5 used ISS3 at the former Hutton agricultural airfield, just southeast of Brewster, KS. There were open fields to the north, through east and to the south; hangers immediately to the west, and the town to the northwest. A ISFS flux 10m tower, along with 4-component solar radiation, rain gauge, temperature, relative humidity, and pressure were deployed 70 m to the southeast. A Water Vapor GPS, web camera and ARM AERI were deployed adjacent to the

ISS trailer. 112 RS92 radiosondes were launched at the site. Quick look plots are on the PECAN field catalog and at
http://www.eol.ucar.edu/isf/projects/pecan/iss/realtime/summary/fp5/

Photo of ISS3 at FP5 (Brewster KS) looking towards the SE.

MP4: Mobile PISA 4

MP4 MISS Mobile Integrated Sounding System, various locations
Profiler: 915 MHz Radian POP version 4.53
X-plane orientated directly out from right side of the trailer, elevation 69°.
Identifier: doi:10..5065/D6RJ4GPJ Link: http://dx.doi.org/10.5065/D6RJ4GPJ

MP4 consisted of the EOL MISS (Mobile ISS) and MGAUS (Mobile GAUS sounding system) which were based in Hays, KS. The systems roved around the PECAN domain (and beyond, see Figure 1), driving over 7500 miles to multiple sites with MISS participating in 25 missions (Table 1). Note that unlike the FP4 and FP5 ISS, the MISS wind profiler used a Radian data system running POP4. In addition this profiler did not use a clutter screen, so lower range gates occasionally were affected by clutter signals.

For most IOPs MISS was accompanied by the MGAUS sounding system, although there were a few occasions where they were separated. A WXT surface meteorology sensor was also deployed with MISS. Quick look plots are on the PECAN field catalog and at
http://www.eol.ucar.edu/isf/projects/pecan/iss/realtime/summary/mp4/

Photo of MISS and MGAUS MP4 deployed for IOP 29 at Beloit, KS.

IOP / Date (2015)	**Location**	**Lat, Lon**
IOP 1 (test) June 2	Hoxie, KS	39°21'37"N 100°26'29"W
IOP 3 (MCS) June 4	Olsburg, KS	39°25'43"N 96°37'13"W
IOP 4 (Bore) June 5	Hays, KS	38°54'29"N 99°19'00"W
IOP 5 (Bore) June 6	Penokee, KS	39°20'32"N 99°58'26"W
IOP 6 (CI) June 8	Gove City, KS	38°57'52"N 100°29'10"W
IOP 7 (LLJ) June 10	Hoisington, KS	38°32'13"N 98°53'08"W
IOP 8 (MCS) June 11	York, NE	40°48'50"N 97°36'00"W
IOP 9 (MCS) June 12	Minneola, KS	37°29'19"N 100°01'04"W
IOP 10 (MCS) June 15	Alva, OK	36°47'54"N 98°38'41"W
IOP 11 (MCS) June 17	Hayes Center, NE	40°30'38"N 101°00'59"W
IOP 13 (LLJ) June 22	Olmitz, KS	38°32'10"N 98°56'35"W
IOP 14 (CI-LLJ) June 24	Beatrice, NE	40°18'16"N 96°44'46"W
IOP 15 (MCS) June 25	Osceola, IA	41°01'27"N 93°47'55"W
IOP 17 (MCS) July 1	Falls City, NE	40°04'06"N 95°37'20"W
IOP 18 (CI) July 4	Tribune, KS	38°27'06"N 101°45'07"W
IOP 19 (Bore) July 5	Hershey, NE	41°09'19"N 101°00'06"W
IOP 20 (MCS) July 6	Alexandria, SD	43°39'18"N 97°47'18"W

UFO 11 (CI) July 8	Ellis, KS	38°57'28"N 99°34'28"W
IOP 22 (CI) July 9	Bennington, KS	38°57'47"N 97°38'23"W
IOP 24 (CI-LLJ) July 10	Alva, OK	36°47'58"N 98°38'39"W
IOP 25 (Bore) July 11	Chester, NE	40°00'05"N 97°36'48"W
IOP 26 (CI-LLJ) July 12	Bennington, KS	38°57'47"N 97°38'23"W
IOP 29 (CI) July 14	Beloit, KS	39°28'47"N 98°06'44"W
IOP 30 (CI) July 15	Smith Center, KS	39°47'09"N 98°47'07"W
IOP 31 (MCS) July 16	Bennington, KS	38°57'46"N 97°38'22"W

Table 1: Locations for MP4 MISS (note that the MP4 MGAUS sounding system was occasionally separated from MISS).

Wind Profiler Hardware

The wind profilers are standard Radian / Vaisala (now Scintec) LAP-3000 915-MHz boundary layer radars. They all used 4-panel phased antenna arrays, capable of being electronically steered to vertical and elevation angles of 69º in orthogonal directions. The characteristics of the profilers are summarised in Table 2 and typical operating parameters in Table 3.

	MP4 MISS	**FP4 ISS2**	**FP5 ISS3**
Location	Roving (see table 1)	Minden NE	Brewster KS
Lat, Lon, Altitude	(see table 1)	40°30'55"N, 98°57'2"W, 658m	39°21'27"N, 101°22'14"W, 1037m
Antenna	64 element phased array	64 element phased array	64 element phased array
Orientation (X-plane)	Right side of trailer	293º	254º
Elevation angle	69º	69º	69º
Version	Radian POP 4.53	Vaisala LapXM 2.3	Vaisala LapXM 2.3
Power amplifier (peak)	400 W	600 W	600 W
Mode	Low mode winds, high mode vertical only	Low & High mode winds	Low & High mode winds

Table 2: Characteristics of the EOL 915 MHz LAP-3000 wind profilers at PECAN

The profilers used the standard DBS (Doppler Beam □Swinging) technique to measure winds. Raw Doppler spectra data were recorded every 30 seconds in SPC files as the radar □antenna was steered along five beam directions. Winds were calculated from spectral moments averaged over 30 minutes. The raw spectra and moments were saved so it is possible to reprocess the data for shorter (or longer) periods, however wind estimates at periods shorter than ten minutes may have significant errors due to inhomogeneities in the wind and the widely separated sampling volumes in the oblique beams.

Parameter	**Low Mode**	**High Mode**
Height resolution	60 meters	200 meters
Height sampling	180 m - 4 km	360 m - 12 km
Interpulse Period	40 microsec	100 microsec
Coherent Integrations	100	40
Spectral Averages	44	30
Pulse Code	4	2

Table 3: Typical 915 MHz wind profiler operating parameters during PECAN

Wind Profiler Data

The FP4 and FP5 sites used Vaisala LapXM data systems with LapXM software version 2.3, whereas the MP4 profiler used an older Radian data system with POP version 4.53 software. All produced similar data products, including raw SPC spectral data. Both LapXm and POP included ICRA intermittent clutter filtering to remove bird echoes. The SPC data was later reprocessed using the □NCAR/RAL NIMA (NCAR Improved Moments Algorithm) [4] which uses image □processing and fuzzy logic techniques to analyze the spectral data □and separate atmospheric echoes from unwanted signals such as radio □interference and clutter. We generally find that NIMA processed wind □measurements agree with radiosonde soundings to around □1.5 m/s (standard deviation). NIMA enables recovery of winds in weak □or noisy data, for example typically extending the range 100 to 300 □meters. NIMA also unwraps Doppler velocities that exceed Nyquist aliasing limits, for example during hail or very high winds. The version of NIMA used is EOL version r7727, which is based on RAL version 2.8.

□□The accompanying data files are in netCDF format [6]. There are two types of data file, wind measurements □(files with extension *.winds_*.nc) and spectral moments data □(extension *.mom.nc). □ The winds data are generally at 30-minute averages and include a correction for a configuration error (see below). The FP4 & FP5 profilers measured winds in both low and high modes (winds_LO.nc and winds_HI.nc), whereas the MP4 profiler only measured low mode winds. The moments data are the zeroth, first, and second □moments of signals from each 30-second dwell of the steered beam. □These moments are the signal strength (here SNR or

Signal to Noise □Ratio which can be used to estimate reflectivity), Doppler shift □(from which the winds are derived), and spectral width (can be used □to estimate turbulence with lots of caveats). We generally □recommend that only experienced profiler users analyze the moment data.

□□The data is arranged in time, height coordinates. For winds (in the *.winds_LO.nc and *.winds_HI.nc files) use variables wspd □and wdir (wdir follows the meteorological convention, ie: the direction □the wind comes from, measured clockwise in degrees from north). □□There is a confidence variable (eg, wind_conf), which □describes the degree of confidence (0-1) that the NIMA algorithm □places in the derived data. These variables have the same dimension □as the wind data. The moments files have similar confidence variables. Use only those data points for □which corresponding confidence level exceeds the threshold confidence □level. Usually we use a threshold confidence level of 0.5. □□

Other data files for the profiler are available on request. These include the raw SPC spectral files, NIMA reprocessed spectral files (netCDF format), raw POP winds (ascii), and raw POP moments (netCDF).

Performance and Comparisons

A typical day of measurements with several features of interest is shown in Figure 2. The time period covers 24 hours from 0Z (18 CST) on June 3, with sunrise around 11Z and sunset around 21Z. “Z” on the SNR plot (top panel) marks the top of a growing convective boundary layer, and the corresponding vertical velocity variability in marked “CBL” on the center panel. There is heavy rain in the early morning (around 11Z to 12Z). During this time, wind measurements become unreliable and aren’t reported (bottom panel). The contour line indicates regions of low confidence in the wind measurements (“Low Conf Winds”), indicating that the uncertainty associated with those samples is high. Preceding the rain is a sharp fluctuation in vertical velocity likely generated by a bore or wave (around 7Z). After the rain is a period of high variable vertical velocity and SNR which may be due to bird echoes. A residual boundary layer (marked “Res BL”) can also be seen in the evening hours, as well as the Low Level Jet (“LLJ”).

The 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). Typically for PECAN the profilers reported winds to the 2 - 2.5km level 75% of the time, with occasional high mode measurements to 10 km during precipitation.

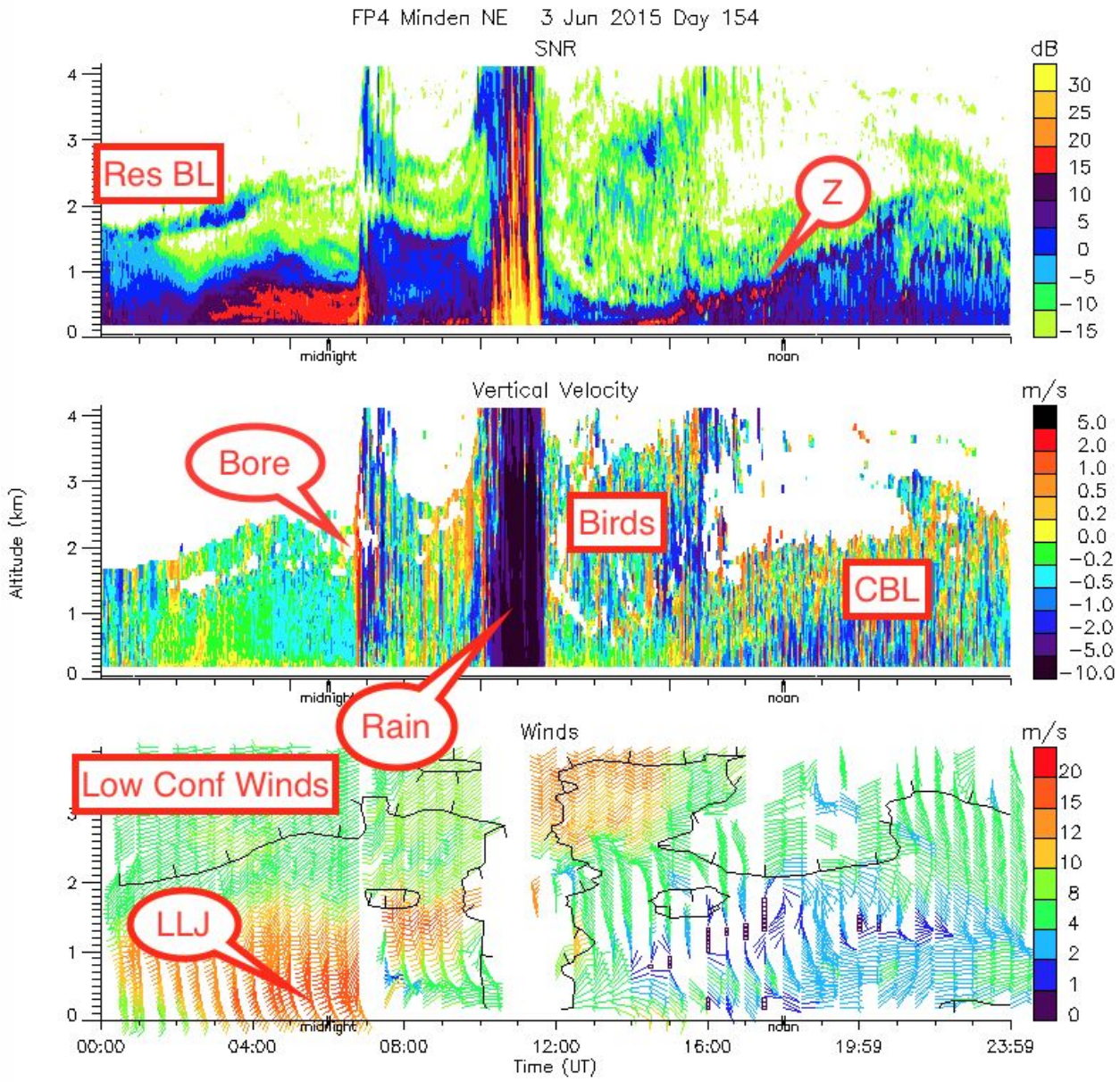

Figure 2: Sample day of wind profiler observations showing Signal to Noise (SNR), Vertical Velocity and Wind measurements. Annotations indicate features discussed in the text.

The winds compared well with sounding winds (Figure 3), with a median absolute deviation of around 1 m/s in speed and 10° in direction (standard deviation of around 1.5 m/s and 12° respectively). It should be noted that many soundings were launched into convective conditions, so some variation between the 30 minute averaged profiler winds and the point measurements of a sounding balloon advected away from the profiler site is to be expected.

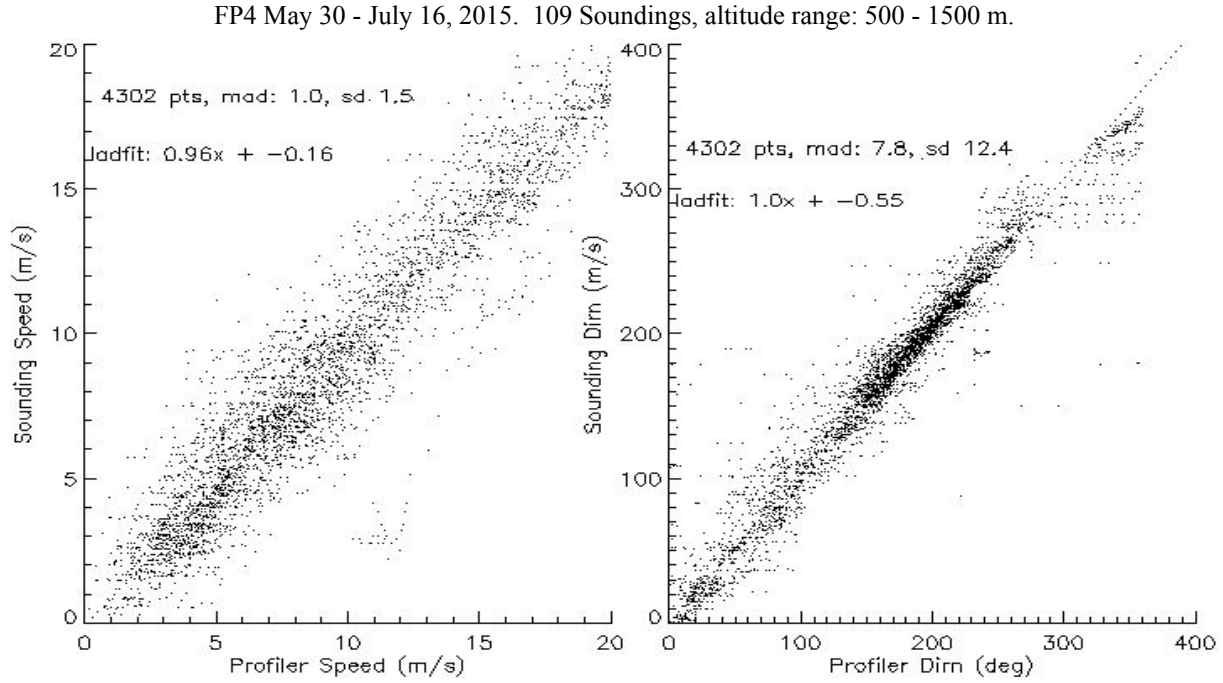

Figure 3: Typical comparison between the 915 MHz wind profiler and sounding winds.

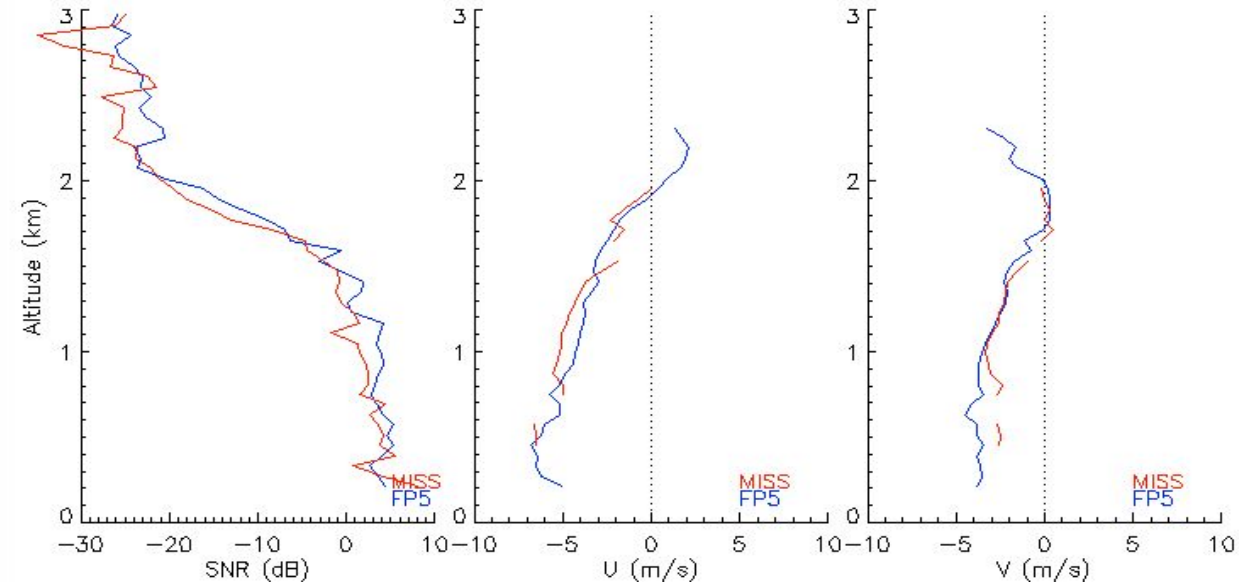

Figure 4: Mean profiles of SNR, eastward and northward winds during a two-hour side-by-side comparison of the FP5 (blue) and MISS (red) wind profilers on July 18, 2015.

A brief inter-comparison between the FP5 and MISS profilers is shown in figure 4. The two systems were operated side-by-side for two hours on July 18 (see photo on the first page of this document). Both profilers use 915 MHz and cannot run simultaneously, so were operating in an

alternating sequence of 30-minute samples. As can be seen the wind and SNR profiles are very similar. The FP5 profiler is more sensitive and also has a clutter screen so the measurements to greater altitude and closer to the ground are as might be expected.

Known Data Issues

Configuration Error: The FP4 and FP5 profilers were upgraded from POP4 data systems to LapXM data systems shortly before the project. There was an inadvertent configuration error in which the oblique beam elevation angles were set to 75^{o} instead of 69^{o} resulting in an overestimation of wind speeds in the raw data set. A correction factor of 0.72 was applied to the wind speeds to compensate in the QC'ed NIMA data. Wind directions and vertical speeds were unaffected. Note that the moment and SPC files were not corrected so should be used with caution. The MP4 MISS profiler was not affected so this data did not require correction.

Clutter: The combined use of both ICRA and NIMA removed most intermittent clutter signals, however there is occasional evidence of migrating bird echoes remaining in the profiler data. This mainly affects the SNR and Vertical Velocity estimates as can seen in Figure 2, the wind estimates from the NIMA processing are expected to be less affected. The MISS profiler was operated without a clutter screen and unwanted echoes from trees and power lines were sometimes evident in the raw profiler data, however most of these effects were successfully removed in the NIMA QC'ed products.

Heavy rain: During heavy rain events the wind estimates from NIMA frequently are either marked with either low confidence or as missing (eg, around 11Z - 12Z in Figure 2). It is possible to derive wind estimates from the moment data, although those values should be used with caution.

Data Gaps: FP4 and FP5 operated continuously, however there were four significant gaps due to technical issues (Table 4). Note that there may be occasional other gaps in the Field Catalog and website plots due to glitches in the data streams, however the raw data was still collected and products were regenerated for the final data set. MP4 only operated while deployed for IOPs (see Table 1) and there are few measurements in between those deployments.

Site	Date/Time	Reason
FP5	8Z 4 June - 1Z 5 June	Reset likely due to lightning strike
FP4	15Z 6 June - 21Z 8 June	LapXM software lockup
FP5	19Z 18 June - 16Z 19 June	LapXM software lockup
FP4	6Z 11 July - 5Z 12 July	LapXM software lockup

Table 4: Significant data gaps for the FP4 and FP5 profilers.

CONTACT:

William Brown, NCAR/EOL
PO Box 3000, Boulder, CO 80307
wbrown@ucar.edu, Ph: 303-497-8774

REFERENCES:

[1] PECAN Overview paper (Geerts et al in preparation for submission to BAMS)
PECAN web site: https://www.eol.ucar.edu/field_projects/pecan

[2] ISS Integrated Sounding System
Website:https://www.eol.ucar.edu/observing_facilities/iss
DOI: http://dx.doi.org/10.5065/D6348HF9
Reference: Parsons, D., W. Dabberdt, H. Cole, T. Hock, C. Martin, A-L. Barrett, E. Miller, M. Spowart, M. Howard, W. Ecklund, D. Carter, K. Gage and J. Wilson, 1994: "The Integrated Sounding System: Description and preliminary observations from TOGA COARE". *Bull. Amer. Meteor. Soc.,* 75, 553–567,
doi:10.1175/1520-0477(1994)075.

[3] Profiler: LAP3000 915 MHz Radar Wind Profiler
Original reference: Ecklund, W. L., Carter, D. A., Balsley, B. B., Currier, P. E., Green, J. L., Weber, B. L., and Gage, K. S., 1990: "Field tests of a lower tropospheric wind profiler", *Radio Sci.*, 25, 899–906. doi: 10.1029/RS025i005p00899
Current manufacturer web site:
http://www.scintec.com/english/Web/scintec/Products/LAP%20Radars.aspx

[4] NIMA (NCAR Improved Moment Algorithm)
Cornman, L. B., R. K. Goodrich, C. S. Morse, and W. L. Ecklund, 1998: A fuzzy logic method for improved moment estimation from Doppler spectra. J. Atmos. Oceanic Technol., 15, 1287–1305. DOI:10.1175/1520-0426(1998)015<1287:AFLMFI>2.0.CO;2
Goodrich, R. K., C. S. Morse, L. B. Cornman, and S. A. Cohn, 2002: A horizontal wind and wind confidence algorithm for Doppler wind profilers. J. Atmos. Oceanic Technol., 19, 257–273. DOI: 10.1175/1520-0426-19.3.257
Morse, C. S., R. K. Goodrick, and L. B. Cornman, 2002: The NIMA method for improved moment estimation from Doppler spectra, J. Atmos. Ocean. Technol., 19, 274-295. DOI: 10.1175/1520-0426-19.3.274
Website: http://www.ral.ucar.edu/technology/profiler/ □□

[5] Software: NIMA 2.8 EOL version r7727 subversion repository available at:
http://svn.eol.ucar.edu/svn/iss/nima/branches/nima2

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