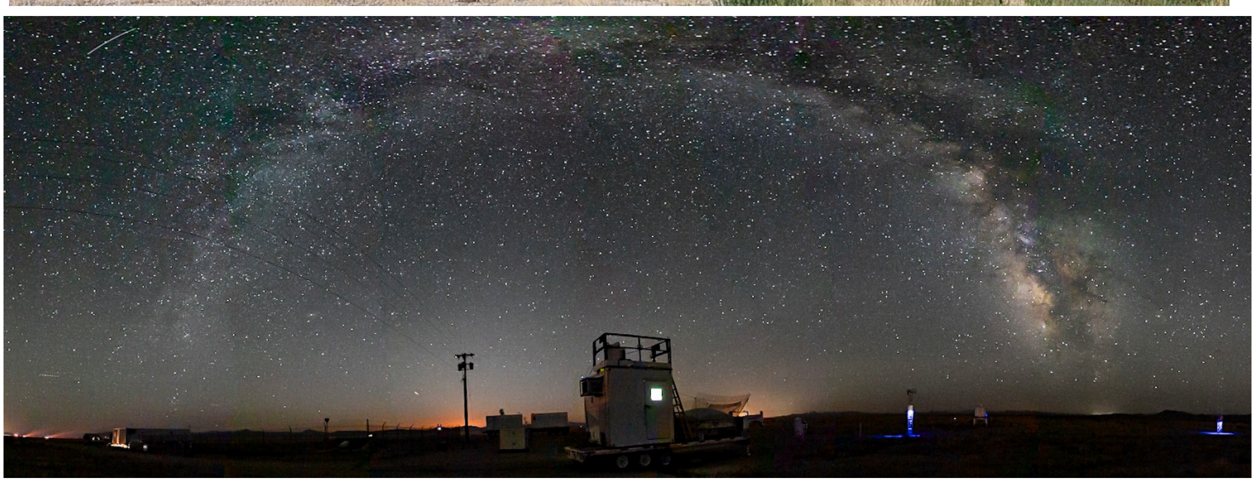
M2HATS

NSF NCAR/EOL ISS Wind Lidar Data Report

Prepared by Jacquelyn Witte (ISF Data Manager), William Brown (ISS Science Lead)

Earth Observing Laboratory
In-situ Sensing Facility

National Science Foundation
National Center for Atmospheric Research
Boulder, Colorado, USA



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M2HATS Principal Investigators

Chenning Tong - Clemson University, South Carolina
Shane Mayor - California State University Chico, California

EOL ISS Staff

ISS Lead Scientist: William Brown <wbrown@ucar.edu>
Engineers: Gary Granger, Isabel Suhr, David Ortigoza, Samuel Raizman
Technicians: Josh Storm, Antonio Vigil
Data Managers: Jacquelyn Witte <jwitte@ucar.edu>, Matthew Paulus

Web References

M2HATS Homepage	https://www.eol.ucar.edu/field_projects/m2hats
ISS Operations during M2HATS	https://www.eol.ucar.edu/content/iss-operations-m2hats
Realtime preliminary visualizations plots:	https://archive.eol.ucar.edu/docs/isf/projects/m2hats/iss/realtime/summary/iss1
ISS Homepage	https://www.eol.ucar.edu/observing_facilities/iss
Windcube lidar PPI and RHI plots on the EOL Instrument Field Catalog	https://catalog.eol.ucar.edu/operations/lidar
ISS VAD wind processing scripts	https://github.com/NCAR/iss-lidar
LROSE (Lidar Radar Open Software Environment)	http://lrose.net/

Dataset Version Control

Version	Date	Author	Change Description	Data Status
1.0	March 2024	J. Witte, W. Brown	Added VAD and consensus data products	Final
1.0	11 Mar 2024	J. Witte	Initial Release	Final

Dataset Citation

If these data are used for research resulting in publications or presentations, please use the following citation:

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The ISS Platform Citation

Please acknowledge EOL/ISS and NSF by including the following citations, as appropriate:

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Acknowledgment

Users of EOL data are expected to add the following acknowledgment to all of their publications, reports, and conference papers that use those data:
"We would like to acknowledge operational, technical, and scientific support provided by NCAR's Earth Observing Laboratory, sponsored by the National Science Foundation."

Overview

M2HATS (Multi-point Monin-Obukhov similarity horizontal array turbulence study) was conducted at Tonopah, Nevada during the summer of 2023. The Integrated Sounding System (ISS) system for M2HATS provided profiling observations of fundamental meteorological variables (P-T-U, winds, etc) within the atmospheric boundary layer. These measurements, combined with energy and mass balance observations from flux towers, provided benchmarks of the most reliable approaches testing the multi-point Monin-Obukhov similarity hypothesis.

As part of the integrated suite of sensors, ISS operated three lidars: Vaisala/Leosphere Windcube 200S scanning lidar, and two leased Halo-Photonics Streamline wind lidars at the Tonopah municipal airport. Each lidar operated with a specified set of scan strategies to capture a 360 view of the surrounding environment.

In addition to the suite of ISS instruments, the NCAR/EOL ISFS (Integrated Surface Flux System) group deployed a 30-m telescoping tower and a line of fifty 5-m towers with sonic anemometers and other sensors nearby. Also the Raman-shifted Eye-safe Aerosol Lidar (REAL) was operated by California State University Chico and two Micro-pulse Differential Absorption Lidar (MicroPulse DIAL) were operated by NCAR/EOL.

Time period: 23 July - 23 September 2023
Location: Tonopah, Nevada, USA

Set-up

The three lidars were set-up close to each other and within half a mile southwest of the ISFS towered flux array (see **Schematic 1** for a top down view of the overall set-up). Also at the site were surface meteorology stations at 3m and 10m, 449 MHz and 915 MHz wind profilers, and a Vaisala CL61 ceilometer. Radiosondes were launched daily at 10am and 3pm local time. Refer to **Photo 1** for a photographic view of the set-up of the lidars relative to the other instruments.

The two brands of lidar used in this project

1. Vaisala/Leosphere WindCube 200S lidar - NCAR owned
2. Halo-Photonics Streamline XR wind lidars (leased)
    a. University of Virginia (UVA) leased - Dr. Stephen de Wekker (UVA)
    b. Metek (Germany) leased Halo-Photonics Streamline wind lidar

Vaisala Windcube 200S	NCAR / EOL	38.04042°, -117.08807°, 1641.0 m
Halo Photonics Streamline XR	University of Virginia	38.04049°, -117.08791°, 1639.8 m
Halo Photonics Streamline XR	Metek GmbH	38.04066°, -117.08797°, 1643.2 m

The Windcube 200S lidar was set-up on a small platform about 20 meters SSW of the 915 MHz profiler and trailer (MISS) and west of the UVA Halo and CL61 ceilometer (refer to **Schematic 1**). The primary scan for this lidar was to make continuous 360° PPI (Plan-Position Indicator) conical scans for VAD (Velocity-Azimuth Display) wind profiles.

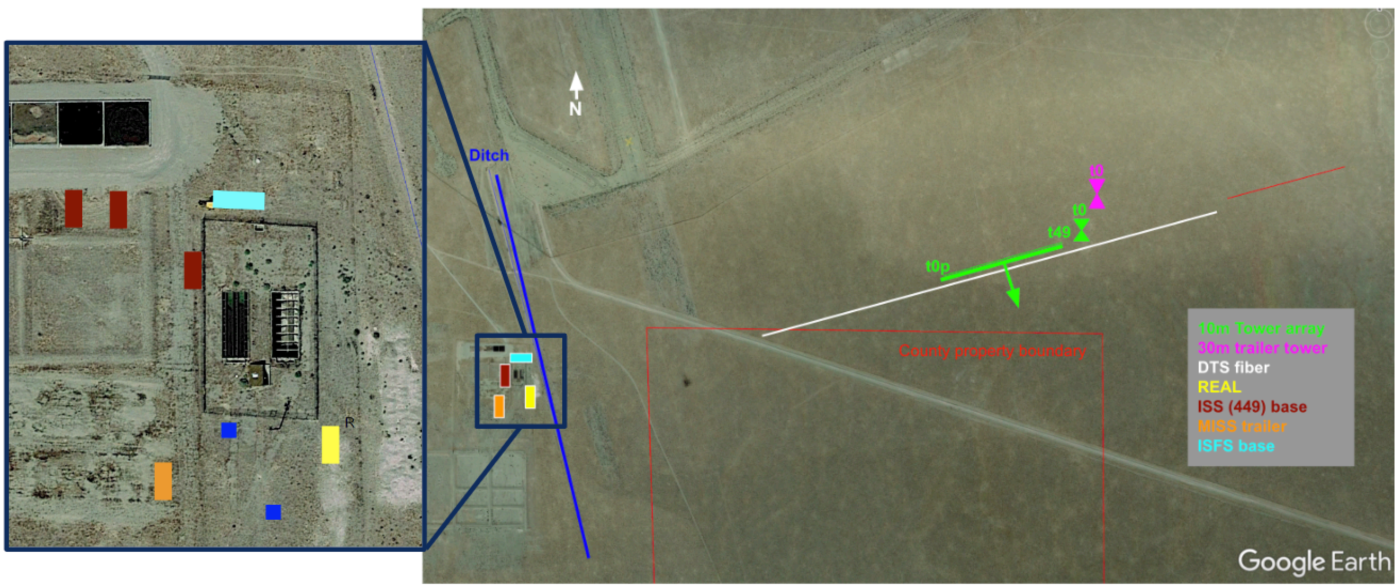
The UVA Halo was set-up on a pallet on the ground about 15 meters south of the MISS trailer, and the ceilometer is about 3 meters northwest from that (refer to **Photo 1**). The primary scan was to look vertically (Stare mode) during the campaign.

The Metek Halo lidar was installed on an elevated platform on top of the MISS container at about 4m ALG to have a line of sight towards the ISFS towered array to the east (**Schematic 1**, green). However, during operations, the level indicator in the lidar revealed that it was moving off target at around 0.1-0.2 degrees which corresponds to about 5 meters displacement at the range of the ISFS array which meant that the lidar missed detecting the returns from the ISFS array. However, the returns easily detected the REAL trailer (**Schematic 1**, yellow) which we used as targets. The best setting was to use an azimuth of 79 deg and elevation of 0.12 deg.

We performed a test where all three lidars (the two Halos and the NCAR Windcube) were initially run in similar modes for a few hours to compare performances. During this time the lidars were all pointed vertically most of the time with similar gate range modes, and VAD wind scans once every 10 minutes. The Windcube was in the same 6-point VAD scan mode as the Halos for winds. Overall the UVA Halo and the Windcube had similar performance, typically seeing up to about 2.5 km, whereas the Metek Halo saw up to about 2km. The Windcube showed more definition in the backscatter than the Halos.

The lidars were set into their operation modes from about 23 July, 2300 UT. These were:

- NCAR Windcube: continuous PPI winds scans at 35 deg elevation followed by hourly short vertical stares, N-S and E-W RHI scans, and 0 elevation sector scans over the study area (from east to south).
- Metek Halo: continuous stares to the east along the ISFS tower array and the REAL, followed by hourly VAD winds.
- UVA Halo: continuous vertical stares, followed by hourly VAD winds

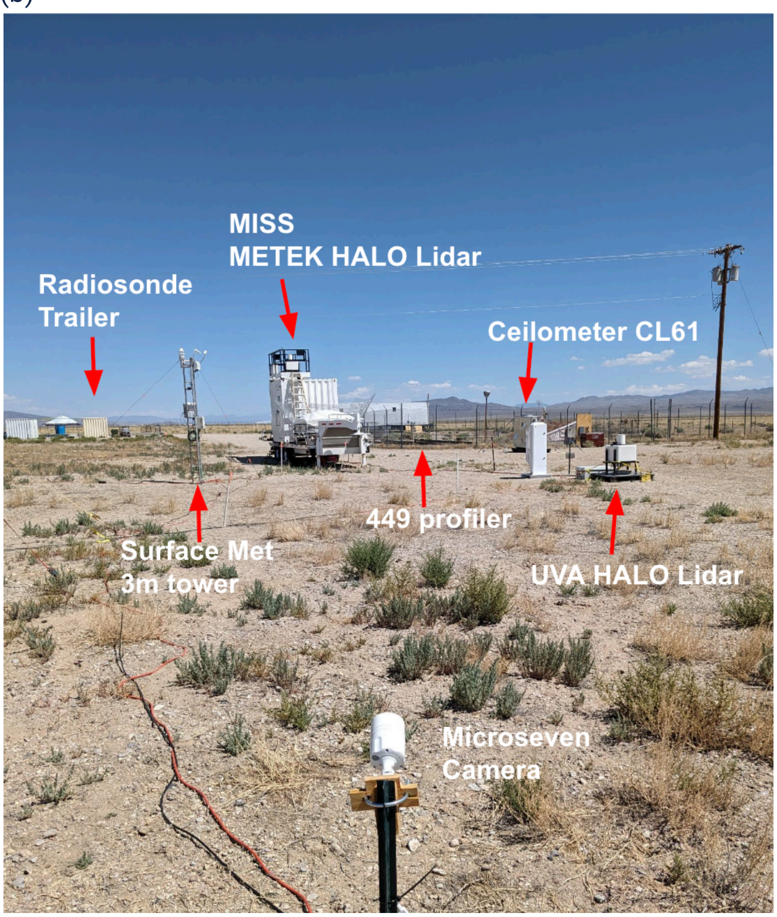


Schematic 1. Schematic of the overall set-up, in terms of ISS trailer and instrument suite location relative to the ISFS towered flux array.

(a)


WindCube
Metek Halo
UVA Halo

(b)


MISS
METEK HALO Lidar
Radiosonde
Trailer
Ceilometer CL61
449 profiler
Surface Met
3m tower
UVA HALO Lidar
Microseven
Camera

(c)

Photo 1. (a) Photographic views of the three Lidars relative to each other is shown in the top montage. (b) Photo was taken from the perspective of the WindCube lidar looking north at the suite of ISS and PI instruments. Note that both WindCube (NCAR owned) and UVA Halo lidars (leased from Dr. Stephen de Wekker at UVA) were operated from the ground while the Metek Halo Lidar operated on top of the MISS (Mobile Integrated Sounding System) trailer. (c) A gust front is pictured approaching the WindCube from the south around 17 July, 2:30pm PDT. We adjusted the windcube lidar scanning strategy to observe the front and saw gusts around 12 - 15 m/s - 27 - 33 mph)

Instrument Description

Vaisala/Leosphere Windcube 200S Scanning Lidar

The Vaisala/Leosphere Windcube 200S scanning lidar is a commercial instrument designed to measure wind and aerosol backscatter at distances up to 10 km across a variety of scanning geometries. The scanning strategies and measurement parameters are customizable to perform a wide range of research applications.

Instrument Fact Sheet:
https://www.vaisala.com/sites/default/files/documents/WEA-MET-WindCube-Scan-Lidar-Product-Spotlight-B212058EN-A.pdf

The ISFS 30-m telescoping tower was used as a hard target for calibrating the azimuthal orientation of the Windcube lidar. Initially, the 30-m tower was at 576 m range, bearing 199.1 deg azimuth from the MISS, then from July 25 the tower was moved to 1628 m range, bearing 77.0 deg. Narrow PPI sector scans were made daily to check that the lidar did not move during the campaign. These data are available in the archive, (referring to **Table 2**) these scans have ID numbers 158, 159, and 185). The level can be checked by examining RHI scans (such as scan ID 187) and comparing the CNR signal to topography. In principle, the Doppler velocities from the Windcube could be compared to measurements made by the sonic anemometers on the tower; however, this comparison has not been done yet.

Quick look plots were generated in near real-time using the LROSE Hawkeye tool and are available on the M2HATS ISS1 realtime plot page and the EOL Field Catalog lidar operations page.

Halo-Photonics Streamline wind lidars

The technical specifications for both leased Halo lidars can be found at their website: https://halo-photonics.com/lidar-systems/streamline-vs/. The final data products have been processed using their proprietary processing software.

The Halo lidars also scanned the ISFS towers to check their orientation since there were small errors in the pointing angles. This was particularly important for the Metek Halo which was intended to look along a line just south of the line of 5-m ISFS towers (hence it was placed on top of the MISS trailer at approximately 4 meters AGL). The bearing of this line with respect to the Metek lidar was 80 degrees azimuth, 0 degree elevation, however artifacts were observed in the lidar data when pointed directly along this line. The divergence of the main beam of the lidar is specified to be just 33 μrad (0.002 deg) with a focus at about 500 meters range, but it appears that the actual divergence may be larger. There seems to have occasionally been appreciable scatter from hard targets (such as the REAL trailer, the towers, and the ground) outside of the main beam, either due to a wider divergence than specified or some other distortion, or due to variations in the pointing angle. Some examples of such hard target scatter episodes are noted in the "Notable Events" table below on August 5, 11, & 28.

After experimentation, it was found that the optimum stare bearing was at azimuth 79 degrees and elevation 0.1 degrees. The azimuth uncertainty appears to be around 0.3 deg in azimuth and 0.1 degree in elevation. In addition, although the MISS trailer was stabilized, it did appear to wobble slightly in windy conditions. Also, the ground may have settled slightly, particularly after rain such as when the remnants of Tropical Storm Hilary passed over the site on Aug 20. Regular narrow PPI sector scans across the towers, and narrow RHI scans along the tower line, were made to enable these issues need to be diagnosed further.

Quick look plots were generated by making screenshots of the Halo computers every ten minutes and are available on the M2HATS ISS1 realtime plot page. The connection and interface were occasionally unstable so there may be periods when these images were unavailable but the data was being collected.

Notable Events

May 15 - June 6	Pre-project measurements with UVA Halo at Tonopah Airport FBO
July 8 - 22	Set up period, preliminary measurements on the Windcube and UVA Halo from July 14, and the Metek Halo from July 16
July 23	Coordinated 6-point VAD scans for intercomparisons 18 - 22 UTC
July 23	Running operational scans on all 3 lidars from about 23 UTC Windcube: continuous VAD scans, with hourly RHIs, vert, sector scans UVA Halo: continuous vertical stare, with hourly VAD Metek Halo: continuous stare along ISFS tower array, hourly VAD
July 25 & 29	Minor adjustments to scan strategies
Aug 2	UVA and Metek Halo lidar screenshots available
Aug 3	Example of a dust devil in Windcube PPI vel scan 1956 UTC
Aug 5	Example of Metek Halo scatter from ground (202308050540_screenshot)
Aug 6	Change to Windcube RHI scanning
Aug 7	WIndcube: 01 - 02 UTC: extra slow PPI & RHI scans for calibrations 0214 UTC: windcube clock 47 seconds slow, updated NTP server
Aug 11	Example of Metek Halo scatter from REAL (202308111700_screenshot)
Aug 15	Metek Halo adjustments: hourly VAD ends, extra PPI & RHI scans for calibration, increased averaging time from 1 to 2 sec ~01 UTC
Aug 19 - 20	Post-tropical storm Hilary passed over site
Aug 28	Example of Metek Halo scatter from towers (202308282330.screenshot)
Sep 24 - 25	Final measurements as the campaign ends

Downloadable Datasets

Downloadable files from the archive	Scan mode	tar.gz file size	File type
m2hats_iss_lidar-**halo-metek**_stare_hpl.tar.gz	Stare	8 Gb	hpl ascii
m2hats_iss_lidar-**halo-uva**_stare_hpl_202307.tar.gz m2hats_iss_lidar-**halo-uva**_stare_hpl_202308.tar.gz m2hats_iss_lidar-**halo-uva**_stare_hpl_202309.tar.gz	Stare	38 Gb 129 Gb 98 Gb	hpl ascii
m2hats_iss_lidar-**windcube**_ppi_cfradial.tar.gz m2hats_iss_lidar-**windcube**_rhi_cfradial.tar.gz m2hats_iss_lidar-**windcube**_ver_cfradial.tar.gz	PPI RHI VER	13 Gb 272 Mb 281 Mb	cfradial netCDF
m2hats_iss_lidar-**windcube**_vad_cfradial.tar.gz	VAD	85 Mb	cfradial, netCDF
m2hats_iss_lidar-**windcube**_vad30min_cfradial.tar.gz	VAD 30 min averages	4.4 Mb	cfradial, netCDF

Vaisala Windcube Data Products

Data Collection and Processing

The windcube raw data were converted into the CfRadial (CF-1.7) compliant, netCDF4 format included in this data release. This format conversion was performed in near real-time by RadxConvert, which is part of a **Lidar Radar Open Software Environment (LROSE)** data processing package (http://lrose.net/)

Lidar control and data processing was performed by proprietary Vaisala/Leosphere Windcube software (see versions in **Table 1**). The raw data produced by the lidar software was stored directly to a disk drive at the lidar location and transmitted to servers at EOL for archival and added back-up.

Lidar Hardware	Windcube 200S	S/N: WLS200s-181
Lidar Software	Package	20.e
	WindForge	3.3.3
	API	1.2.0
	Tools	1.1.0

	OS	3.2.0
VAD/Consensus Processing	Software	1.1

Table 1. Windcube lidar model, serial number, and software versions.

Windcube Scan Modes and Sequence

During M2HATS a variety of scan strategies were employed for the Vaisala/Leosphere WindCube lidar. These included Plan Position Indicator (PPI) conical scans at various elevations, sectors, and resolutions; Range Height Indicator (RHI), vertical slice scans at various azimuths, and Vertical stares (VER). A summary of lidar parameters for each scan strategy is included in **Table 2**. During the first week of operations, calibration scans were conducted (see **Table 2**).

The primary mode was continuous 360° PPI scans at a fixed 35° elevation and 50 m averaged resolution. VAD (Velocity-Azimuth Display) winds were calculated from these scans. In a nutshell:

- RHI scans were conducted hourly
- PPI scans were continuous
- VER scans were conducted hourly

At the hour, the Windcube performed a sequence of the following scans

1. **Wipe** - len is cleaned.
2. **RHI West-to-East** - Horizon-to-horizon sweep from West to East until 6 August 2023 then reversed - **RHI East_to-West.**
3. **PPI Sector Scan** - South to East, zero elevation PPI scan.
4. **RHI South-to-North** - Horizon-to-horizon sweep from South to North until 6 August 2023 then reversed - **RHI North-to-South.**
5. **PPI** - Surveillance scan.
6. **Vertical (VER) scan** - Line of Sight vertical scan for 2 minutes to compare with the UVA HALO lidar.

After that sequence, continuous PPI scans resume.

The WindCube mapped RHI scans on a vertical plane from horizon to horizon using the LROSE software. The initial directions, from West to East and from South to North, were reversed on 6 August because the LROSE processing software had difficulty plotting the previous orientation.

The bulk of the scans were PPI scans at 35 degree elevation angle, and these were the scans used to derive VAD winds (scan ID 178 in **Table 2**).

In addition, there were hourly PPI horizontal sector scans. These typically scanned across the ISFS array and south across the viewing area of the CSU REAL lidar. (e.g., scan IDs 162, 171, 180 in **Table 2**). It may be useful to correlate the Doppler velocities.

SCAN ID	Type	Elevation Angle (deg)	Azimuth (deg)	Angular Resolution (ray_angle_res) (deg)	Typical Scan Duration per file	Dates
42*	PPI	35.302	2 - 360	2	90 s	July 23-29
132**	PPI	0	80 - 170	1	45 s	July 23
158**	PPI	0	190 - 210	0.05	3 min	July 23 (5 files)
159**	PPI	0	195 - 205	0.05	1.5 min	July 23, 25
162**	PPI	0	75 - 200	1	1 min	Aug 24-26
171	PPI	0	75 - 180	1	1 min	July 23 - Aug 6
178*	PPI	35.302	2 - 360	2.5	1 min	July 29 - Sept 23
180	PPI	0	180 - 75	1	1 min	Aug 8 - Sept 23
185	PPI	0	75 - 80	0.05	1 min at 1200 local time	Aug 7- Sept 23
174	RHI	2 - 180	260, 280	2	1 min	July 29 - Aug 6
176	RHI	2 - 180	170	2	1 min	July 29 - Aug 6
182	RHI	2 - 180	350	2	1 min	Aug 7- Sept 23
183	RHI	2 - 180	80	2	1 min	Aug 7- Sept 23
187	RHI	0 - 6	77	0.1	30 s	Aug 7- Sept 23
126	VER***	90	0	0	2 min	Entire period
168	VER	90	180, 360	0	1 min	July 24-29

*Scans used to calculate VAD winds in July. This switched to scanID 178 for the remainder of the project.
**Calibration scans.
***Vertical stare scans.

Table 2. Windcube lidar settings according to the scan ID. The scan duration is what was typical for the entire project. Please note, expect some variability in all of the parameters. For eye safety reasons, the RHI horizon-to-horizon scans start at 2 degrees elevation for the north and east start directions.

Atmospheric Structure variable

In addition to standard Doppler radial velocity, spectral width, and backscatter data, much of the scan data also includes a variable called atmospherical_structures_type. This is a variable derived from Leosphere's WALS atmospheric condition and cloud algorithm which analyzes CNR and radial velocity data to make inferences about the atmosphere. These data have not been verified for this campaign and should be used with caution, however they may provide some useful information about the boundary layer depth and other parameters.

Atmospherical_structures_type value	meaning
0	No data
20	Residual layer
30	Mixed layer
200 - 400	Clouds
2000 - 4000	Aerosols

CF-Radial Files

Data format: NetCDF4, each scan strategy assigned numeric Scan ID
File frequency: single file per sweep/stare/surveillance
Resolution: variable depending on scan strategy, see Table 2
Measurement Freq.: Continuous

Scan Mode	File Format	File Res.
PPI	cfrad.YYYYMMDD_hhmmss_WLS200s-181_scanID_PPI_<range in m>.nc	1 min
RHI	cfrad.YYYYMMDD_hhmmss_WLS200s-181_scanID_RHI_<range in m>.nc	30 min
VER	cfrad.YYYYMMDD_hhmmss_WLS200s-181_scanID_VER_<range in m>.nc	Hourly

Derived Velocity-Azimuth Display (VAD) Winds

File Format	FIle Freq.	Resolution
VAD_YYYYMMDD.nc	1 daily file per PPI scan strategy	variable depending on scan strategy, see Table 2

In addition to the CfRadial data, a Velocity-Azimuth Display (VAD) wind profile product was generated and is available as part of this dataset. These data are available in daily files, calculated using select PPI scans (refer to **Table 2**). These netCDF files follow the convention produced by the U.S. Department of Energy Atmospheric Radiation Measurement (ARM) user facilities (Newsom et al. 2015).

The GitHub repository of processing scripts that generate ISS VAD wind products is publicly accessible at: https://github.com/NCAR/iss-lidar

To create the VAD product, profiles of wind speed and direction are calculated from radial velocities, using an algorithm adapted from ARM (Newsom et al. 2015). The quality of the fit is provided as the residual and correlation coefficient quantities using standard numerical matrix inversion methods. The quality of the least squares fit is assessed using the fit residual and the linear correlation coefficient. This process is repeated at each range gate (and corresponding height) to produce a profile of winds. We are still developing the error products on the vector wind components (u, v, w).

The following thresholds were applied to the VAD algorithm based on comparisons of preliminary data with winds from radiosondes launched at the site:

- CNR > -33 dB
- mean_snr > -28 db
- Residuals < 2.25 m/s
- Correlation coefficient > 0.8
- Percentage of beams used > 75%

Figure 1 shows a scatter plot of the Windcube VAD winds (final product) with those from radiosondes. The agreement is similar to comparisons from previous projects. VAD winds and soundings are matched in closest height and to within 4 minutes of a radiosonde launch. **Figure 2** includes the statistical summary of the wind speed and direction for the VAD and soundings and the differences between them. Overall, the statistics (**Table 3**) compare very well, however there are large differences between the lidar and sounding wind speeds, as seen in **Figure 2 (right)**. We isolated dates where the wind speed differences were greater than 5 m/s and found that all samples were from a single lidar profile on 2023-07-24 21:59:47 UT. **Figure 3** shows a curtain plot of VAD winds for that day with the radiosonde profile overlaid. One can see that the radiosonde winds are showing much more layers and complexity than the VAD winds could produce.

	lidar_wspd	lidar_wdir	sonde_wspd	sonde_wdir
count	6552.000000	6552.000000	6552.000000	6552.000000
mean	6.088631	189.547501	6.208150	189.244293
std	3.086452	58.240887	3.292135	59.032291
min	2.004140	1.193051	0.200000	0.200000
25%	4.021035	164.246616	4.000000	158.874996
50%	5.328538	180.804245	5.400000	179.199997
75%	7.485211	212.859825	7.700000	208.600006
max	22.103548	359.742035	19.000000	356.100006

Table 3. Statistics based on sonde/lidar comparisons.

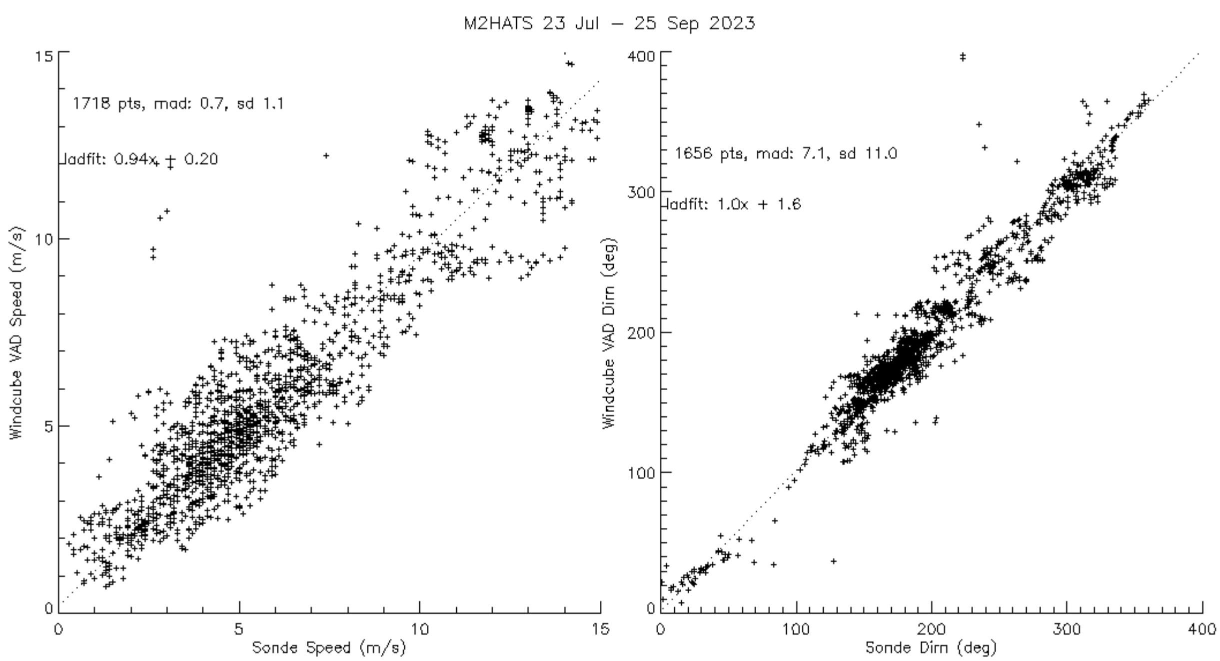


Figure 1. Scatter plot of Windcube VAD winds versus sounding data for the recalculated VAD based on the above thresholds. The median absolute deviation between the VAD winds and the soundings was 0.72 m/s and 7.1 degrees for speed and direction respectively.

Windcube VAD 30-minute Consensus Winds

File Format	FIle Freq.	Resolution
30min_winds_YYYYMMDD.nc	daily	30 min

As a companion to the Velocity-Azimuth Display (VAD) wind profile product, a 30-minute consensus average wind product was generated. These data were calculated from the quality-controlled VAD wind profiles described in the preceding section. These netCDF files again follow the convention produced by the U.S. Department of Energy Atmospheric Radiation Measurement (ARM) user facilities.

These data were created by consensus averaging the VAD winds, which were calculated using the mean value of all data points that lie within a given window size (5 m/s) of each other. The final values used in the average are chosen as the subset of values in the data having the most points and smallest spread in values. Included in the data files are the u, v, and w wind components, separately consensus averaged; wind speed and direction calculated from the consensus average u and v; the number of points used in the averaging; and median values of the residual, correlation, and mean SNR from the indices of points used to calculate the w consensus average.

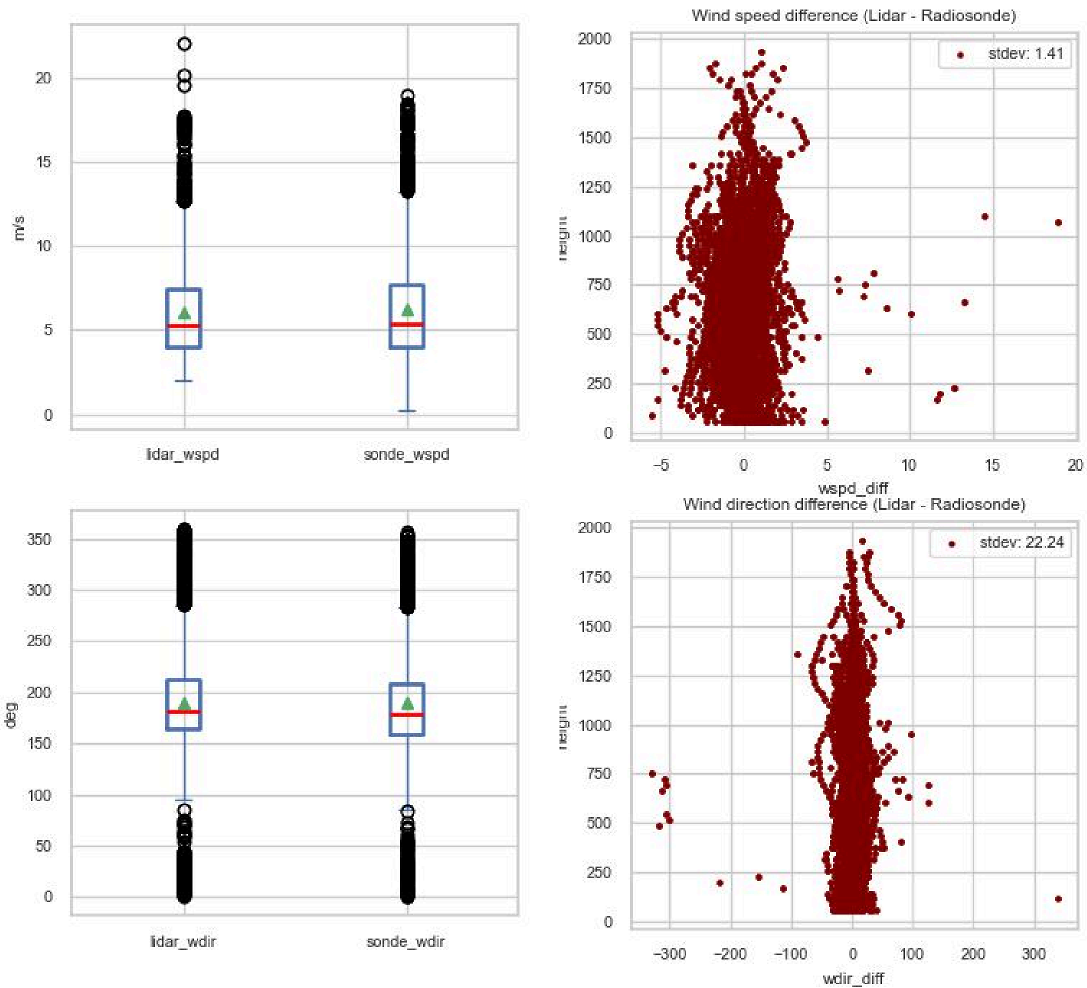


Figure 2. (left) Box-and-whisker plots of lidar and sounding wind data. Red lines denote the medians and green triangles show the means. (right) Different plots of (lidar - soundings) for wind speed (top) and direction (bottom).

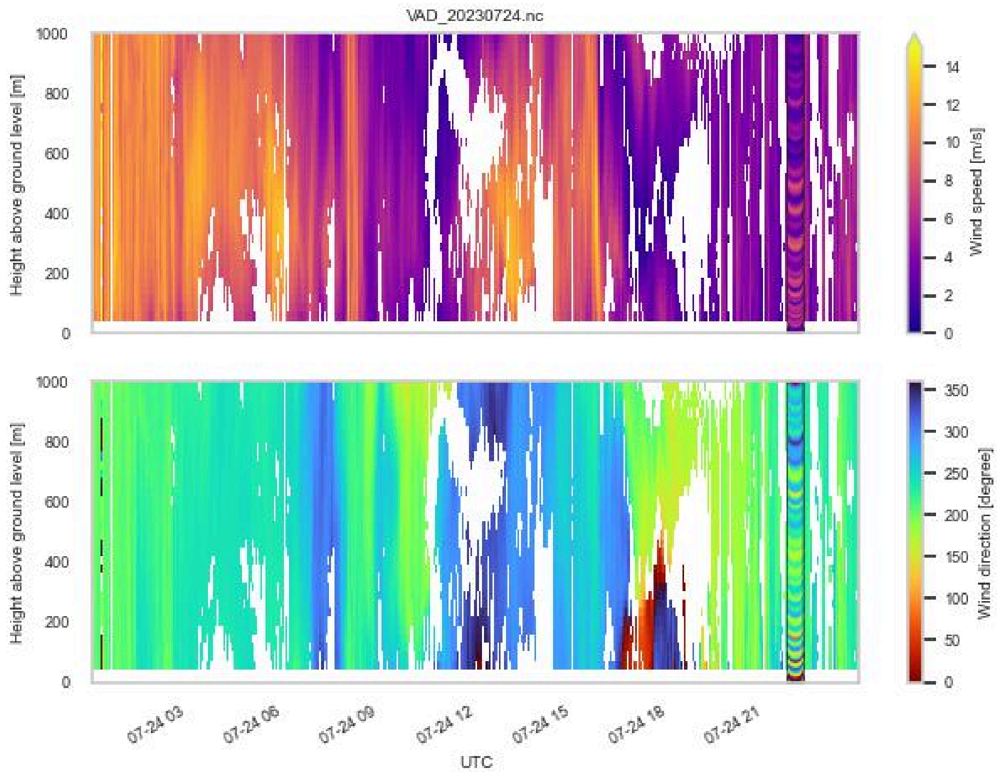


Figure 3. Curtain plot of VAD winds for 2023-07-24. The radiosonde launch is shown within the black lines.

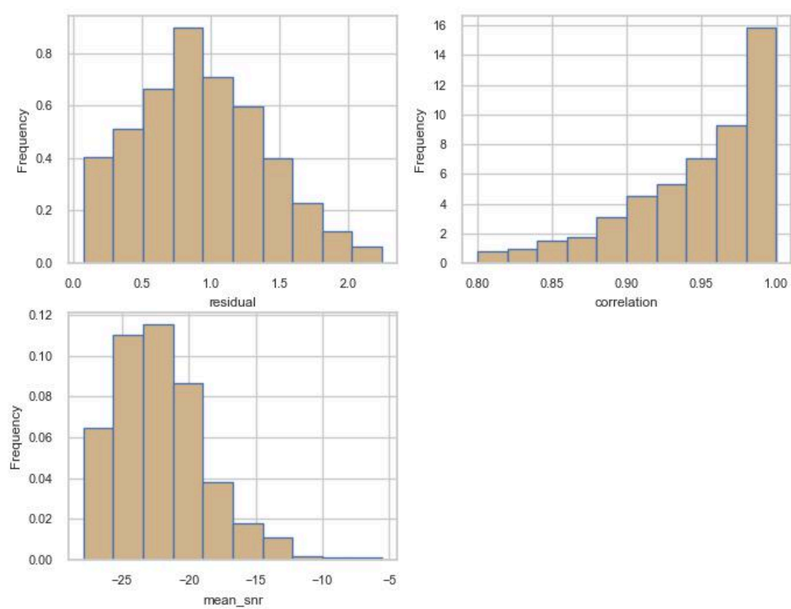


Figure 4. Histograms of the final VAD diagnostic variables.

UVA and Metek Halo Stream Lidars (leased)

Both leased Halo lidars predominantly operated in stare mode (**Table 4**), although other modes were run for inter-comparison purposes. Scan parameters are provided in **Table 5**.

Data Format	HPL (ASCII)
File frequency	Metek = Hourly UVA = 30 min
Scan mode	Metek: Continuous stares to the east along the ISFS tower array and REAL trailer. UVA: Continuous vertical stares.
Filename	Stare_<scanID>_yyyymmdd_hh.hpl
Measurement Freq.	Continuous

Table 4.

System ID	UVA Halo (Serial # 122)	Metek Halo (Serial # 162)
Number of gates	3990	200
Range gate length (m)	30	30
Gate length (pts)	10	20
Resolution (m/s)	0.0382	0.0764
Scan type: Stare		
Azimuth (degrees)	90	79.00
Elevation (degrees)	90	0.12
Instrument spectral width	0.229	6.879677

Table 5. Summary of leased Halo lidar scan parameters.

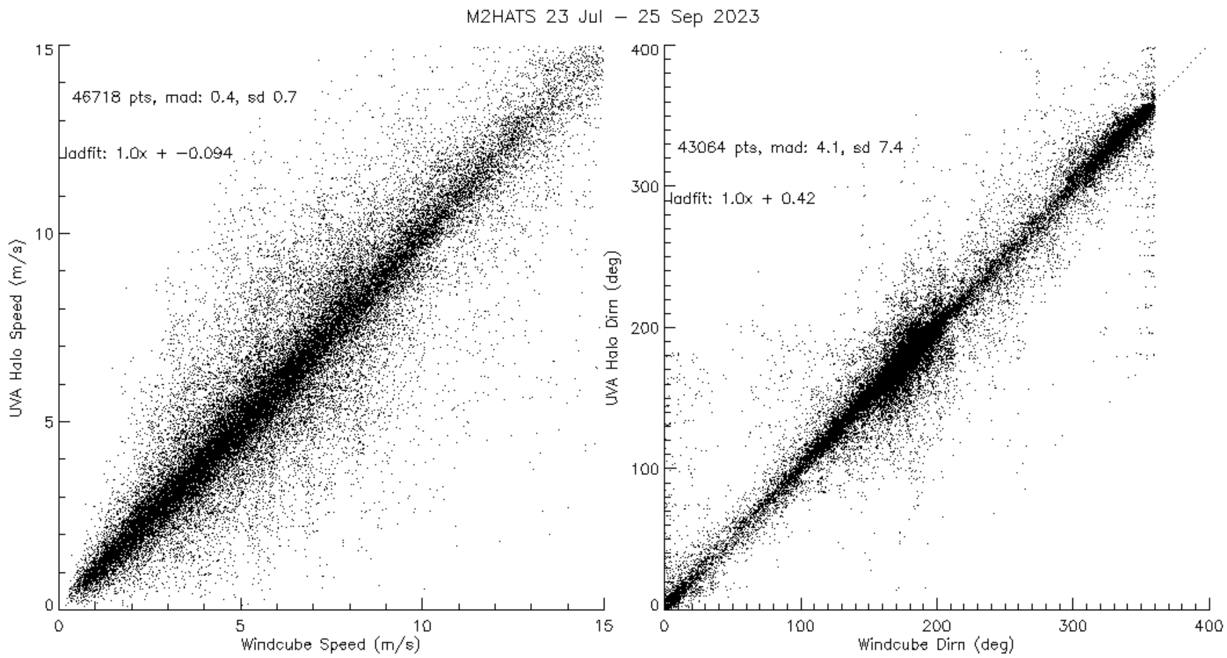


Figure 5: Scatter plots comparing the Windcube VAD winds and the UVA Halo winds for the 0 - 1 km height range. Wind speeds are compared on the left and wind directions on the right.

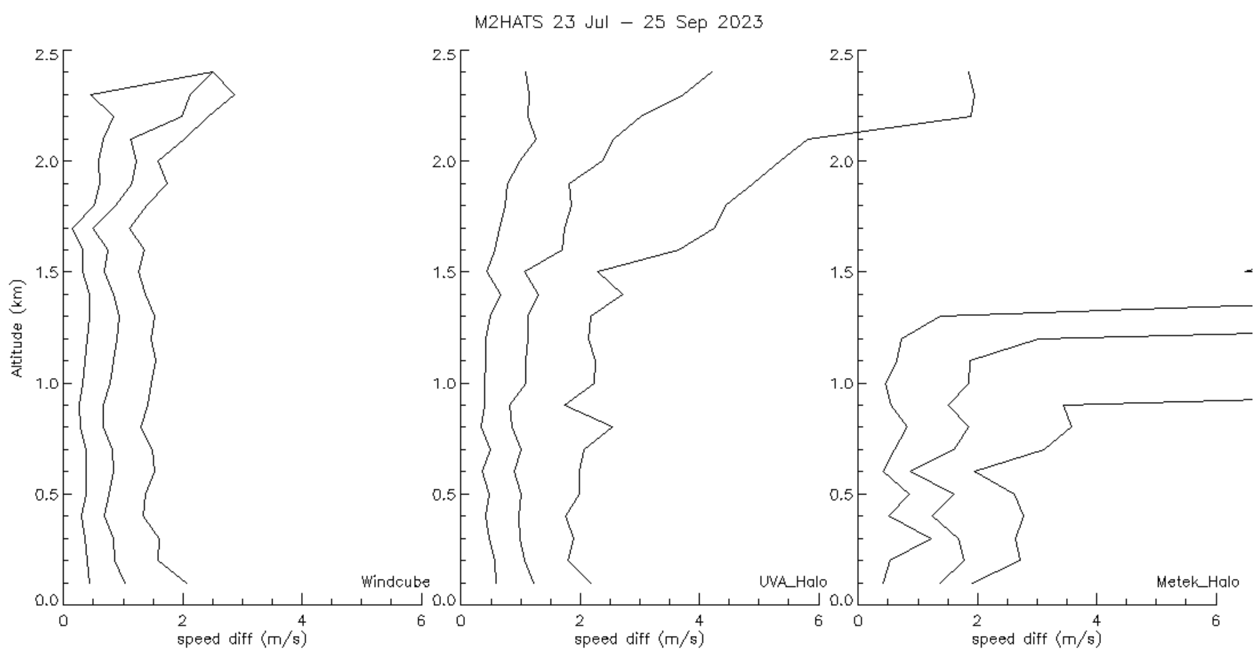


Figure 6: Profiles of wind speed differences between VAD measurements on the three lidars and soundings (Windcube on the left plot, UVA Halo on the center plot, and the Metek Halo on the right plot). The three profile lines on each plot show the lower quartile, median, and upper quartiles of the speed differences.

As discussed above, the Halo lidars primarily operated in stare mode. They regularly switched modes away from those stares for calibration and intercomparison purposes. For example, every hour they performed a quick VAD scan. The Metek Halo performed hourly VAD scans from July 23 to August 15, whereas the UVA Halo performed hourly VAD scans for the entire campaign. The lidars compared well with each other and with soundings. **Figure 5** shows a scatter plot comparing VAD wind speed and direction from the Windcube and the UVA Halo. The median absolute deviations were about 0.4 m/s and 4 degrees for speed and direction respectively. **Figure 6** shows profiles in height above ground of the differences in speeds between the three lidars and soundings. All three lidars have median differences of around 1 m/s or better at low levels, the Metek lidar started diverging around the 1 km level, the UVA Halo around the 1.5 km level, and the Windcube around the 2 km level. However, given the variations in sampling and data processing strategies between the three lidars, interpreting these differences in performance should be done cautiously.

References

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