DOE/SC-ARM-TR-209

Scanning ARM Cloud Radar—Advanced—Velocity Azimuth Display Value-Added Product

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DISCLAIMER

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Acronyms and Abbreviations

AGL	above ground level
ARM	Atmospheric Radiation Measurement
DOE	U.S. Department of Energy
ENA	Eastern North Atlantic
HSRHI	horizon-to-horizon range height indicator
NetCDF	Network Common Data Form
SACR	Scanning ARM Cloud Radar
SACR-ADV-VAD	Scanning ARM Cloud Radar-Advanced-Velocity Azimuth Display
VAD	Velocity-Azimuth Display
VAP	value-added product

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1.0 Introduction

Spatial distribution of horizontal winds is an important meteorological property to understand mesoscale and cloud scale dynamics of cloud and precipitation systems. The most popular wind measurement is performed by soundings. The sounding observation is generally conducted 1-4 times per day, which may not be enough to observe detailed in-cloud structure.

Doppler weather and cloud radars can perform frequent measurements of radial velocities of cloud/precipitation particles in clouds. The weather radar community has historically used the Velocity-Azimuth Display (VAD) technique to retrieve in-cloud wind properties (direction and speed) from radial velocity (e.g., Lhermitte and Atlas, 1961).

The U.S. Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) Climate Research Facility's Ka- and W-band Scanning ARM Cloud Radars (SACRs) collect volume observations of mean Doppler velocity with horizon-to-horizon range height indicator (HSRHI) scans every 30-60 minutes. The SACR ADVanced Velocity-Azimuth Display (SACR-ADV-VAD) Value-Added Product (VAP) extends the VAD technique to cloud radar observations. The VAP provides time series of vertical profiles of in-cloud wind fields at higher temporal and vertical resolutions, which can augment sounding wind measurements.

2.0 SACR HSRHI Input Data

The HSRHI scan strategy consists of six horizon-to-horizon scans spaced by 30 degrees in azimuth (Kollias et al., 2014). This strategy is typically repeated every 30-60 min and thus the temporal resolution of the product will be ~30-60 min. While the product could be created using either Ka- or W-band SACR observations, so far only Ka-band data have been used.

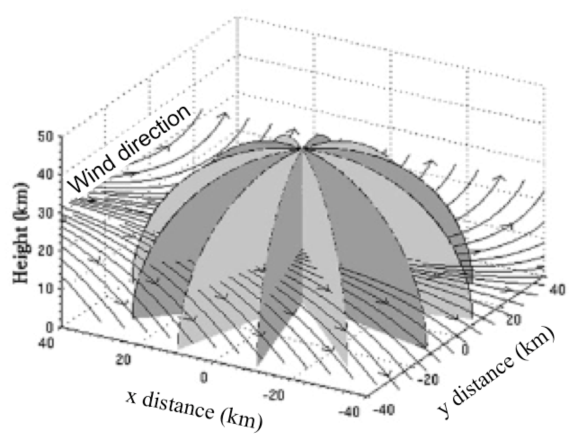


Figure 1. Schematic representation of SACR HSRHI scan (based on Figure 3 of Kollias et al., 2014).

The SACR-ADV-VAD VAP may be run using calibrated SACR data as input (kasacrcorhsrhi*.c1 datastreams) or uncalibrated SACR data (kasacrhsrhi*.a1). When processing calibrated data, SACR-ADV-VAD produces kasacradvvad*.c1 output products. When processing uncalibrated data, SACR-

ADV-VAD produces kasacradvvad*.c0 output products. Note, relative calibration offsets do not impact the quality of the VAD products. However, select velocity dealiasing and associated retrieval quality control measures to ensure accurate VAD estimates are only available within 'c1' product streams. The 'c0' versions are available on an expedited timetable and are based on uncorrected SACR data. As a result, they may reflect some additional noisiness and velocity aliasing in faster wind speeds.

Table 1. Input variables.

Input Variables	
kasacrcorhsrhi*.c1	**kasacrhshri*.a1**
mean_doppler_velocity_corrected	mean_doppler_velocity
reflectivity_corrected	reflectivity
snr	snr
spectral_width	spectral_width
nyquist_velocity	nyquist_velocity
radar_beam_width_h	radar_beam_width_h
sweep_end_ray_index	sweep_end_ray_index
sweep_start_ray_index	sweep_start_ray_index
antenna_transition	antenna_transition
azimuth	azimuth
elevation	elevation
fixed_angle	fixed_angle
altitude_agl	altitude_agl
velocity_unfolding_flag	

3.0 Algorithm and Methodology

3.1 Velocity Azimuth Display (VAD) Technique

The traditional VAD technique uses radial velocity measurements at a constant elevation angle and a constant range through azimuth from 0° to 360°. In a region of homogeneous wind flow, the observed radial velocity would exhibit a sinusoidal pattern when plotted versus azimuth at a fixed elevation and constant height above the ground. The sinusoid's maximum amplitude is equal to the horizontal wind speed and the phase location indicates the wind direction. The offset of the sinusoid from zero velocity is a measure of vertical hydrometeor motion.

3.2 Algorithm Flow

In the SACR-ADV-VAD application of the technique, we typically have at most 12 azimuth points contributing data to the algorithm (see Figure 1) from the endpoints of the six horizon-to-horizon scans.

The SACR-ADV-VAD process is straightforward, pulling in a full day of HSRHI scan input files and outputting the product in a single file for each day. No input other than the HSRHI data is required. Each HSRHI scan file provides the measurements needed to produce a single time profile of in-cloud horizontal wind speed and direction as a function of height. Figure 2 presents a flowchart of the algorithm.

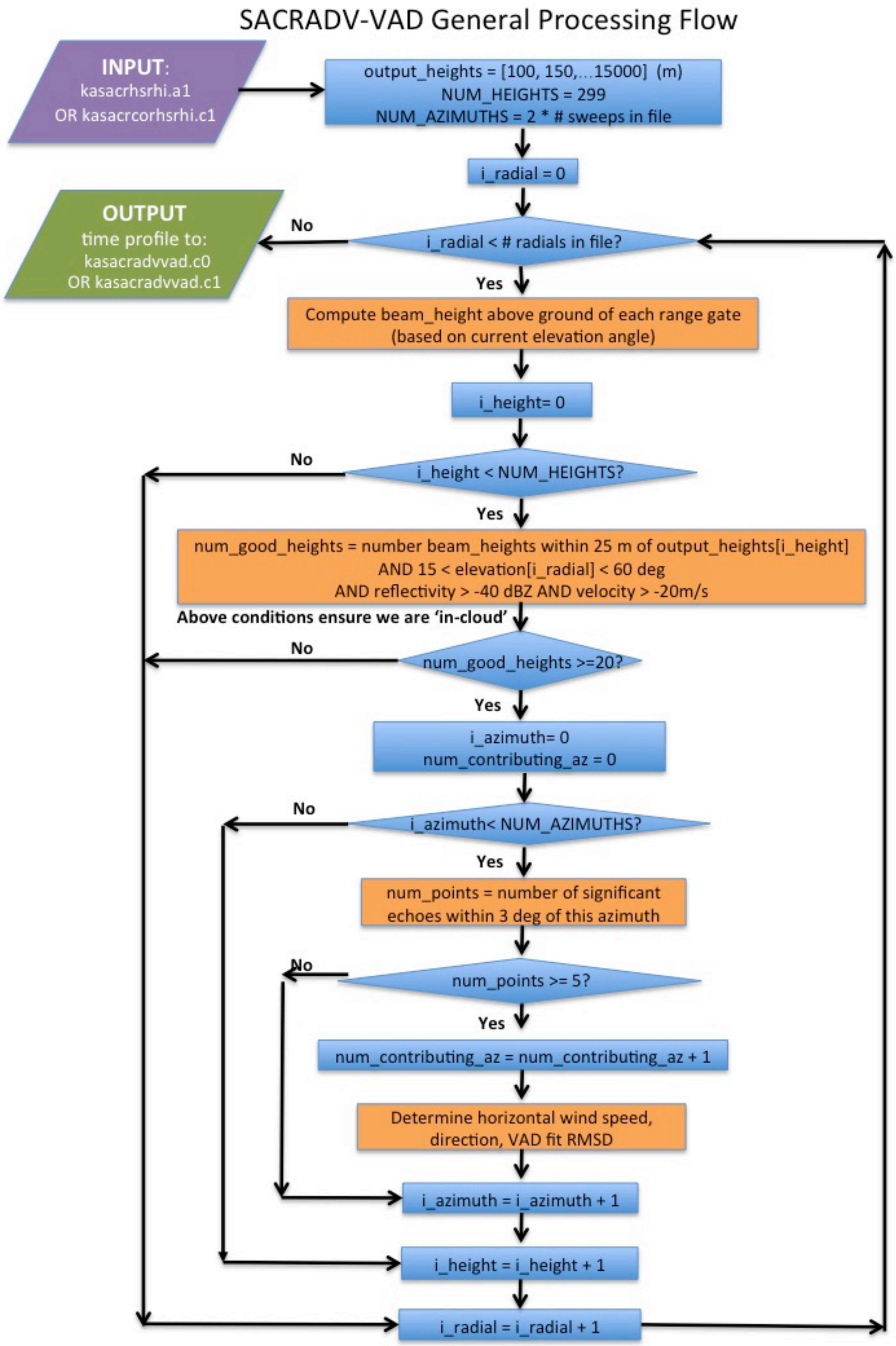


Figure 2. Flowchart describes the processing of a single SACR HSRHI scan input data file. For each processing date, there will typically be many HSRHI input files, so this algorithm would be repeated for each input file, producing one output time profile for each input HSRHI file.

4.0 Output Data

This VAP outputs a daily NetCDF file containing one time profile of cloud-level horizontal wind speed and direction derived from each HSRHI scan sequence performed on that date. (Note that this could result an irregular time stamp.) This product is produced at a 50 m height resolution, for heights from 100m to 15000m AGL.

Table 2. Major output variables from SACR-ADV-VAD.

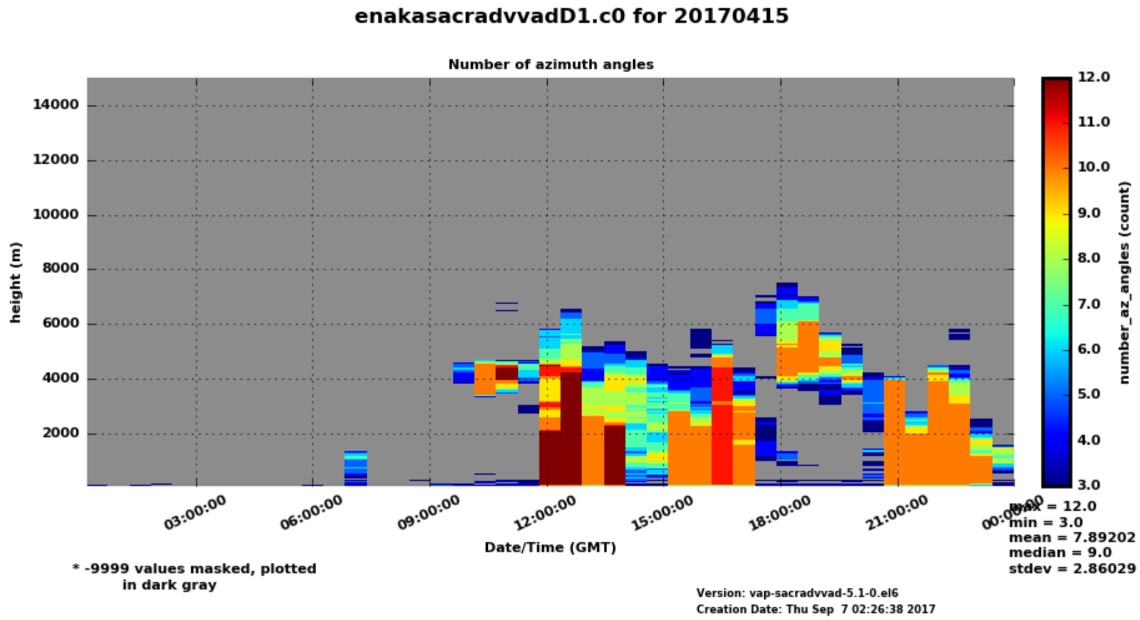
Datastream kasacradvvad fields
horizontal_wind_magnitude_at_cloud_level (time, height) horizontal_wind_direction_at_cloud_level (time, height) vad_fit_rmsd (time, height) number_az_angles (time, height)

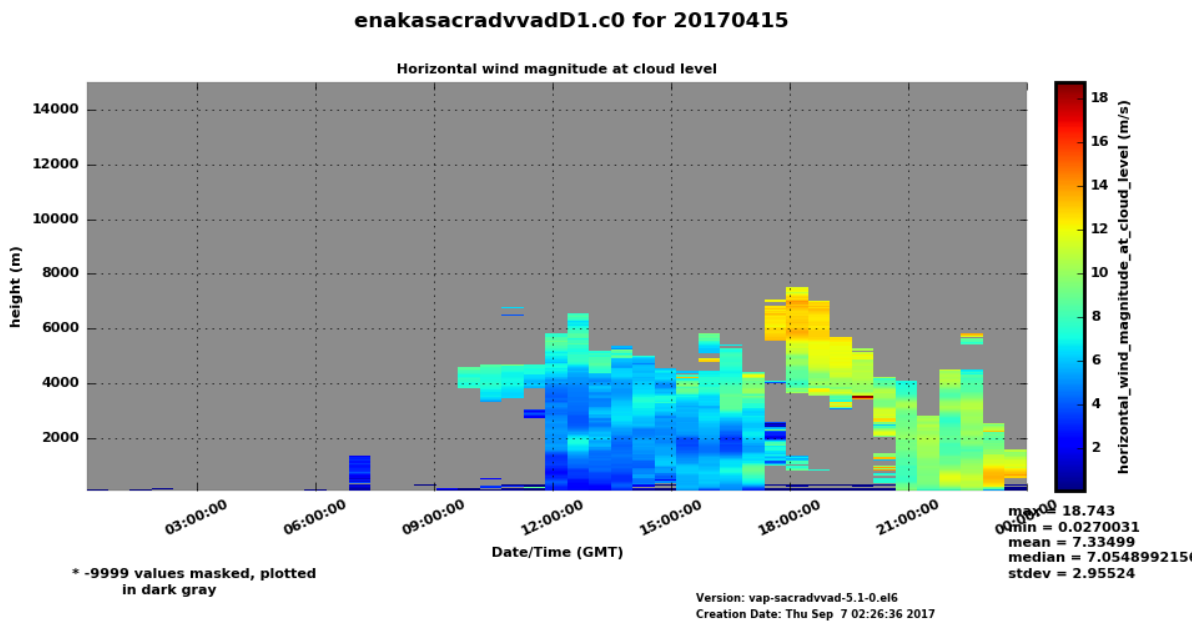
5.0 Summary

The SACR ADVanced Velocity-Azimuth Display (SACR-ADV-VAD) product is intended to complement infrequent soundings by providing profiles of horizontal wind speed and direction in cloud. The Velocity Azimuth Display (VAD) technique was historically used to retrieve wind field properties using weather radars (Lhermitte and Atlas, 1961). This VAP relies on SACR radial mean Doppler velocity observations corrected for aliasing, producing a daily NetCDF file containing profiles of cloud-level horizontal wind speed and direction derived every time the HSRHI scan strategy is performed.

6.0 Example Plots

Quicklook images are produced for each day of SACR-ADV-VAD processing. Figure 3 presents a sample output.


enakasacradvvadD1.c0 for 20170415
Number of azimuth angles
height (m)
Date/Time (GMT)
number_az_angles (count)
max = 12.0
min = 3.0
mean = 7.89202
median = 9.0
stdev = 2.86029
* -9999 values masked, plotted in dark gray
Version: vap-sacradvvad-5.1-0.el6
Creation Date: Thu Sep 7 02:26:38 2017


enakasacradvvadD1.c0 for 20170415
Horizontal wind magnitude at cloud level
height (m)
Date/Time (GMT)
horizontal_wind_magnitude_at_cloud_level (m/s)
max = 18.743
min = 0.0270031
mean = 7.33499
median = 7.0548992156
stdev = 2.95524
* -9999 values masked, plotted in dark gray
Version: vap-sacradvvad-5.1-0.el6
Creation Date: Thu Sep 7 02:26:36 2017

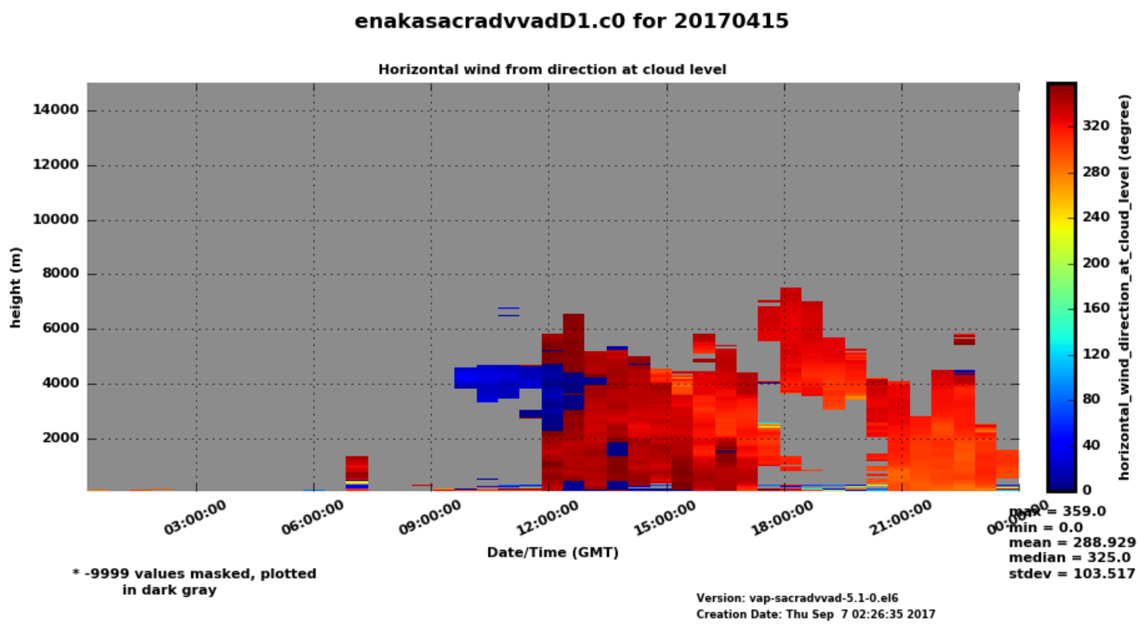


Figure 3. Quicklook image produced by the SACR-ADV-VAD VAP for ARM's Eastern North Atlantic (ENA)-C1 observatory on 20170415. The top image is number of azimuth angles. The middle image is wind speed and the bottom image is wind direction.

7.0 References

Kollias, P, N Bharadwaj, K Widener, I Jo, and K Johnson. 2014. "Scanning ARM cloud radars. Part I: Operational Sampling Strategies." *Journal of Atmospheric and Oceanic Technology* 31(3): 569-582, doi:10.1175/JTECH-D-13-00044.1.

Lhermitte, RM, and DA Atlas. 1961. "Precipitation motion by pulse Doppler." Proceedings of the 9th Weather Radar Conference, Boston, American Meteorological Society, Boston, Massachusetts, 498-503.

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