ADPT: ARIES ST Radar Data Processing Tool

Samaresh Bhattacharjee[1,2], Manish Naja[1], and Kishan Singh Rawat[2]
[1]Aryabhatta Research Institute of Observational Sciences, Nainital, Uttarakhand, India
[2]Graphic Era (Deemed to be University), Dehradun, Uttarakhand, India

Abstract

A customized tool is developed for deriving the scientific products from the data of ARIES ST Radar located at Nainital (29.4ºN; 79.2ºE; 1793 m amsl) in the central Himalayan region. This tool enables the tracking of Doppler echo in neutral air as well as in precipitation condition. Several customized features are also discussed.

1. Introduction

Wind Profiling Radar (WPR) is an efficient system for atmospheric research and its application for understanding dynamics for different atmospheric phenomenon like summer monsoon, extreme weather event, precipitation etc. ARIES ST Radar (29.4ºN; 79.2ºE; 1793 m amsl) is first WPR of its kind in the Himalayan region and operates at 206.5 MHz in VHF band. The radar scans the atmosphere towards different directions in Doppler Beam Swinging (DBS) mode and receives echo with Doppler shift from atmospheric back scattering and generates a Doppler profile with respect to height. This profile is processed and digital data is saved in the raw (*.r) / spectra (*.d) format for further scientific research [1]. The steps of finding the outcomes can be streamlined through processing the data in a user-friendly way by utilizing features of a customized tool. In that reference, a Graphical User Interface (GUI) based data processing tool named ASTRAD Data Processing Tool (ADPT) has been developed for processing the ASTRAD data. The tool follows the standard steps of WPR data processing for deriving the neutral air wind parameters. In addition to those standard steps, customized steps are incorporated to handle data of different atmospheric conditions like precipitation. Customized digital filters are also employed to clean the data for improving the SNR (Signal to Noise Ratio). In next sections different features of the tool are discussed.

2. Steps of Processing: Front Panel

The different blocks for off-line processing of the radar data are shown on the front panel of the ADPT (Figure 1). Each block does a specific work and jointly retrieves the desired scientific information from the radar data.

a. Process Panel: This is the most important panel of the tool, and its primary function of the panel is to track the atmospheric echo from a noisy Doppler spectrum by utilizing following different functions/commands.

- Select Data File - The user can select any raw (*.r)/ spectra (*.d) file for processing.
- Run - After selecting the data file, it runs the function to calculate/retrieve the Doppler profile of a particular cycle that is being processed. The cycle no is set in the filed “Cy-no”.
- Clean **-** This command does one-time spectrum cleaning and removes noise to a maximum extent.
- Frame_Process **-** This command transfers control to beam after beam processing. It also keeps track of the no of times one beam is processed.
- Beam_Direction **-** This sub-panel controls five radio buttons for selecting five directions of the main beam of the radar (North, South, Zenith, East and West). The user will select the beams one by one for processing.
- Image **-** This sub-panel is called when the image beam of opposite direction is tracked within a window of FFT Doppler points.
- Select_Beam **-** Once the beam is identified in Beam_Direction block, the data of that beam is selected and transfer control for processing.
- Process_Beam **-** Once the beam is selected, this command processes the data and plots it on the plot window with a marking on the Doppler peak.
- Accept_Beam **-** If the Doppler profile with respect to height has been traced correctly, then the user can accept the beam.
- Less-Dopp **-** The user can set the starting point of tracking the Doppler profile on the frequency axis.
- Reset **-** This operation suspends the present process and allows users to start from the beginning if required.

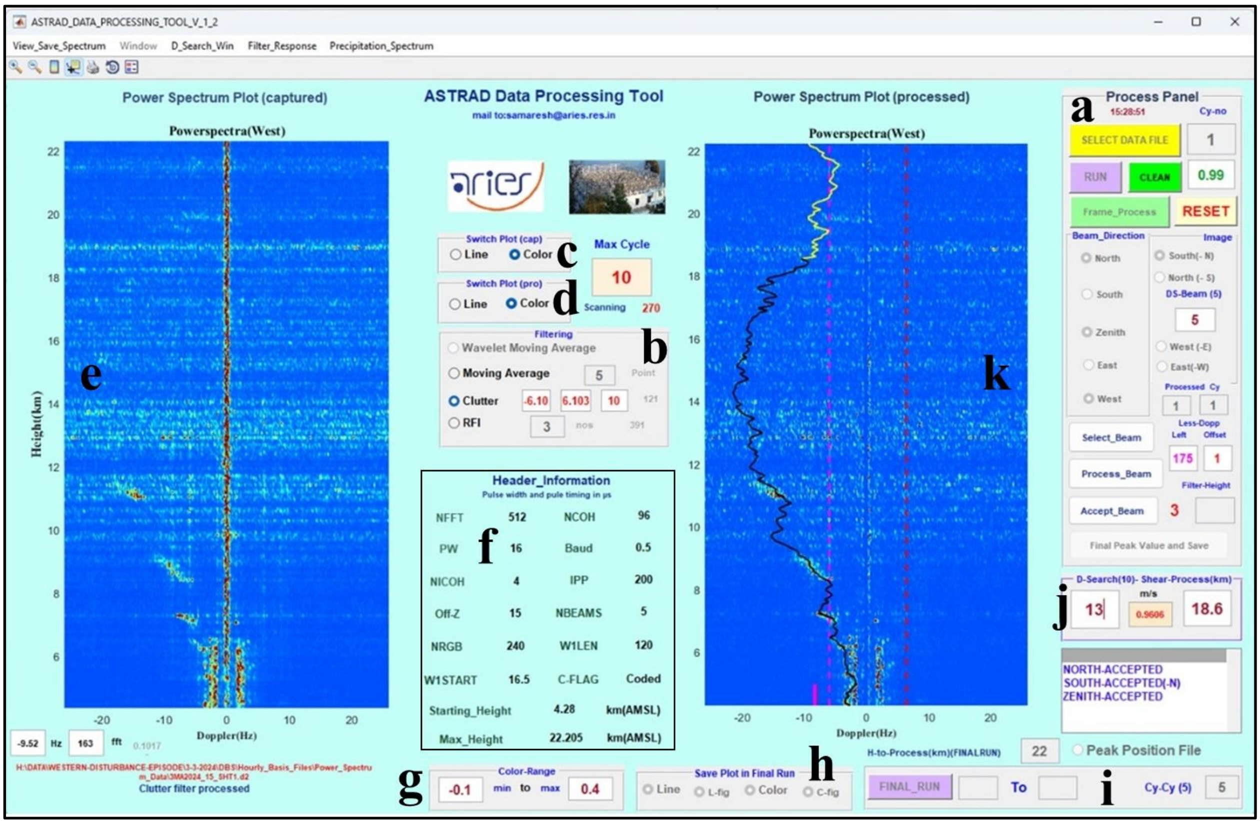


Figure 1. The front panel of the ADPT with marking of the blocks.

b. Filtering: The second most crucial block is Filtering. The ASTRAD data is sometimes contaminated by clutter or Radio Frequency Interference (RFI). This contamination affects the tracking of the Doppler profile and leads to erroneous estimation of the atmospheric wind.
This filtering block helps to remove the clutter and RFI without tampering with the data. In addition, this block also has a low pass filtering of the moving average to improve SNR.

c. Switch plot (cap.): ADPT read the digital data and plot the wind profile. This selection of radio button switches the plot between color and line plot of captured data on the left axis Power Spectrum Plot (captured).

d. Switch plot (pro.): This selection the similar switch of plot type of the plot after processing with Doppler peak tracking on Power Spectrum Plot (Processed) on the right axis of the front panel.

e. Power Spectra Plot (captured): This is the left axis on the front panel to plot the profile obtained from the captured data.

f. Header_information: The header information of the data file is displayed here. It contains the value of parameters of Experimental Specification File (ESF) like NFFT: No of FFT points; PW: Pulse width; NICOH: No of incoherent integration; Off-Z: Off zenith scan angle; NRGB: No. of range bin; W1START: Data window start; NCOH: No. of coherent integration; Baud: Baud length of coded pulse; IPP: Inter Pulse Period (IPP); NBEAMS: No. of beams; W1LEN: Length of data captured window; C-FLAG: Coded/Uncoded; Starting_Height: The height from where data display starts; Max_height: Maximum height coverage

g. Color range: In this block a user can set the color range for plotting to change color combination of the plot on the plot axis.

h. Save Plot in Final run: This radio button in this block determines whether the wind profile plot will be saved after processing or not.

i. Final_Run: In this block the push button is used for processing a set of cycle of the data file and estimation of basic parameters like Zonal, Meridional, Vertical wind components and different moments. While processing the set of cycle the peak search is done within a window which can be given as user input in Cy-Cy field in the block. After processing all data and plots are saved in a particular folder in the same directory what the data is stored.

j. D-Search-Shear-Process (km): This block let user set values of parameters for adaptive tracking of the Doppler profile by adjusting Doppler search point corresponding to a particular wind shear and height region where this searching applied.

k. Power Spectra Plot (processed): This plot axis displays the Doppler profile after processing.

3. Tracking of Doppler Profile

The tracking of the Doppler profile of neutral air by applying functions/commands in the Process Panel is presented in Figure 2. The profile displayed on the left (Figure 2 (a)) was captured on 3 March, 2024 at 15:28 hrs. The trace of the profile is clearly visible upto 12 km.

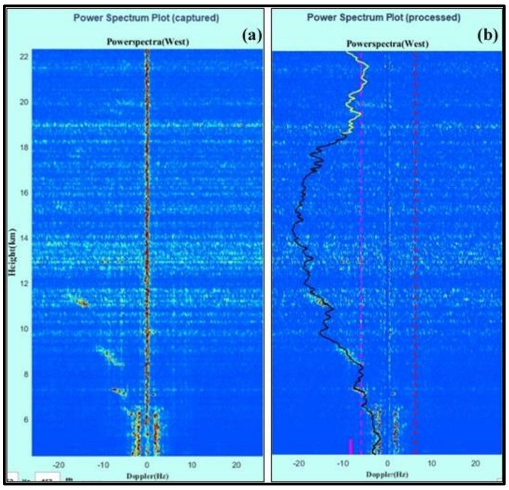
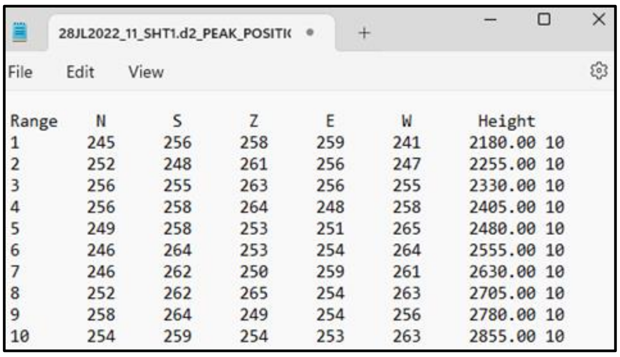


Figure 2. Doppler profile of neutral air (a) as captured and (b) tracked after processing.

Above 12 km the Doppler profile at some height region is merged with the noise floor. On the right side (Figure 2 (b)), the Doppler profile after tracking up to a height of 22 km is depicted. This tracking is achieved by applying peak search within the Doppler search window set in D-Search-Shear-Process (km) block, corresponding to wind shear up to a particular processing height. Once tracking is completed up to the set processing height, the profile is locked and marked with a black colour. The tracking is considered finalized at this locked height, and further peak searching is not applied within the height region. In the next iteration, peak searching with the D-Search window for wind shear is performed from the next height up to the maximum height and is set in yellow colour for identification. Once the tracking is completed, the Doppler profile of the beam direction is accepted, and peak points are stored. This tracking process can be considered an adaptive tracking process where the Doppler profile of neutral air captured by ASTRAD is tracked by applying a wind shear window within a height range with reference to the peak point searched in the previous range as per height resolution set in the Experimental Specification File (ESF). A sample file of peak positions for first 10 range bins shown in Figure 3. This file contains the peak positions at each height and



28JL2022_11_SHT1.d2_PEAK_POSITIC

File Edit View

Range	N	S	Z	E	W	Height
1	245	256	258	259	241	2180.00 10
2	252	248	261	256	247	2255.00 10
3	256	255	263	256	255	2330.00 10
4	256	258	264	248	258	2405.00 10
5	249	258	253	251	265	2480.00 10
6	246	264	253	254	264	2555.00 10
7	246	262	250	259	261	2630.00 10
8	252	262	265	254	263	2705.00 10
9	258	264	249	254	256	2780.00 10
10	254	259	254	253	263	2855.00 10

Figure 3. The peak position file of five beams at each range and height.

corresponding range bin in terms of the FFT point. Anytime this text file can be called at later stage, and a group of cycles can be processed for the estimation of atmospheric wind and other scientific parameters. In multiple cycle processing, peak is searched within the cycle-to-cycle search window set in Cy-Cy in the final run sub-panel marked as ‘i’ in Figure 1.

4. Estimation of Basic Scientific Parameters

FINAL_RUN command calls a subroutine in the tool, which calculates all basic scientific parameters like Zonal (U), Meridional (V), Vertical (W), Wind speed & Direction, and Moments (m0, m1, and m2) and stored in a text file. The plot of each scientific parameter is also saved. The saved plot of Moments and Wind parameters of data file at 1500 hrs on 3 March 2024 is shown in Figure 4(a) and 4 (b) respectively.

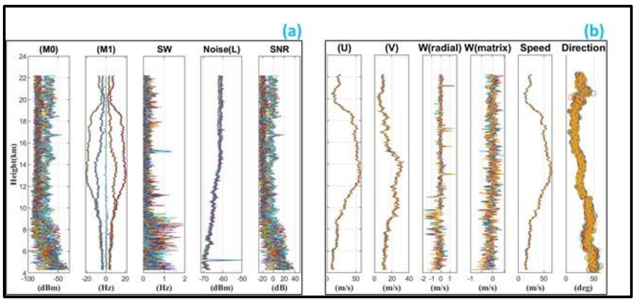


Figure 4. Plot of basic scientific parameters of 3 March 2024 (a) Moments and (b) Wind parameters.

5. Precipitation Spectrum

The ASTRAD frequency of operation is also sensitive to Rayleigh scattering which produces signals from precipitation and hydrometeors. A similar spectrum of North beam is depicted in Figure 5(a) and marked in the white box. The backscattered signals from hydrometeors can provide valuable scientific insights, such as rainfall intensity, terminal velocity etc. To identify and analyse the spectrum, an algorithm has been devised and integrated with ADPT which is accessible in the toolbar under menu ‘Precipitation_Spectrum’. It has two sub-menus.

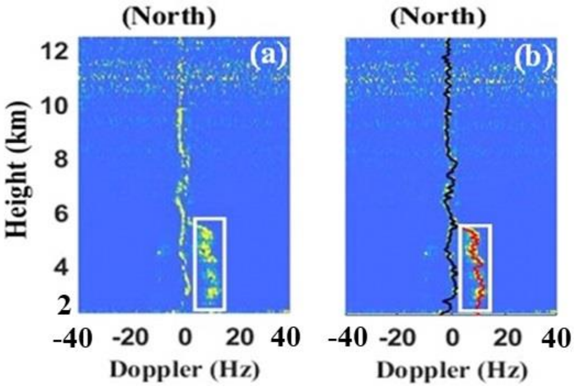


Figure 5. (a) Doppler profile with precipitation spectrum in white box; (b) Bragg scattering response marked as black and Rayleigh scattering in red within the white box.

i. **Set_Parameters:** This menu opens a window named "Precipitation Signal Separation Parameters" to set parameters for separation and select the Doppler spectrum of Rayleigh scattering.

ii. **Select:** This menu, select the peak of the precipitation spectrum, and then based on the selection rest parameters like moments, terminal velocity of the precipitation spectrum is estimated

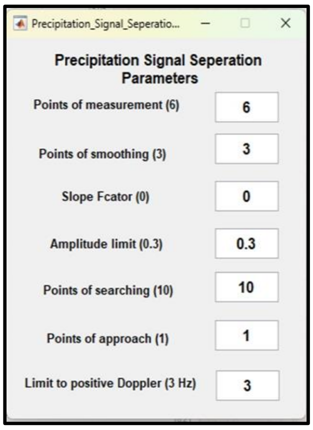


Figure 6. Precipitation Signal Separation Parameters of North beam of Figure 5.

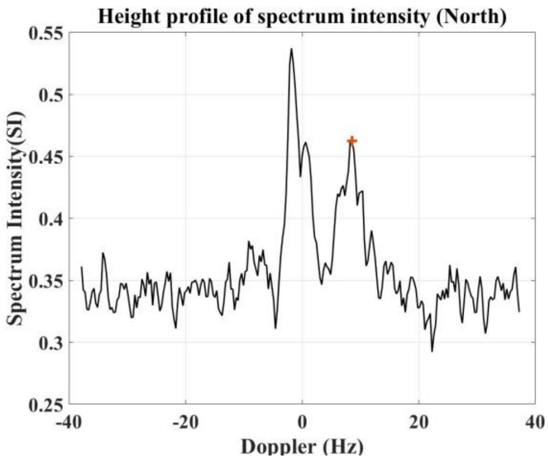


Figure 7. Spectral Intensity with respect to FFT points of the North beam of Figure 5(a).

This algorithm of identification of precipitation spectrum (PS) works based on calculating the Spectral Intensity (SI) profile and then search of peaks as per the Precipitation Signal Separation (PSS) Parameters. The SI of the beam depicted in Figure 5(a) is shown in Figure 7. It illustrates the total power intensity at each FFT point with respect the height. The position of the PS on SI profile is identified and marked "+". PSS parameters used for this identification is shown in Figure 6. Following the generation of this SI profile, the "Select" menu trace the spectrum along the height until the spectrum of Bragg scattering (marked in red colour within the white box in Figure 5(b)). After identification the basic scientific parameters of the PS like moments and fall velocity can be estimated following the standard process in WPR.

6. View of Profile

This View_Save_Spectrum menu on the toolbar called the following sub-panel to plot and save Doppler spectra to check the spectrum before processing.

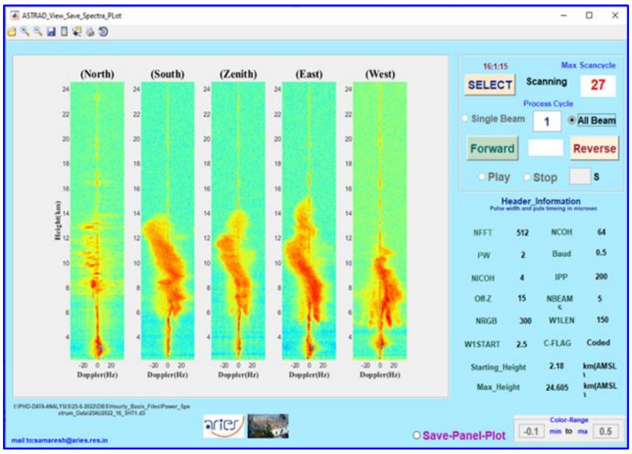


Figure 8. The sub-panel for view and save Doppler spectrum before processing.

7. Conclusion

The development of a ASTRAD Data Processing tool (ADPT) for the ARIES ST Radar is described. This tool features user-friendly, customized techniques for extracting scientific information from the radar data under both neutral air and precipitation conditions. The tool's development aims to facilitate the work on the scientific objectives using the radar data more efficiently.

8. Acknowledgements

We are thankful to Director, ARIES for his motivation and support throughout work.

9. References

1. Bhattacharjee, S., Naja, M., Jaiswal, A., Rawat, K. S., Sagar,R. & Ananthakrishnan, S. (2022), ARIES ST Radar: The first Central Himalayan wind profiler, Journal of Astronomical Instrumentation, Vol. 11, No. 4 (2022) 2240005 (19 pages),World Scientific Publishing Company, DOI: 10.1142/S2251171722400050.