An Adaptive Moments Estimation Technique Applied to MST Radar Echoes

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ABSTRACT

An adaptive spectral moments estimation technique has been developed for analyzing the Doppler spectra of the mesosphere–stratosphere–troposphere (MST) radar signals. The technique, implemented with the MST radar at Gadanki (13.5°N, 79°E), is based on certain criteria, set up for the Doppler window, signal-to-noise ratio (SNR), and wind shear parameters, which are used to adaptively track the signal in the range–Doppler spectral frame. Two cases of radar data, one for low and the other for high SNR conditions, have been analyzed and the results are compared with those from the conventional method based on the strongest peak detection in each range gate. The results clearly demonstrate that by using the adaptive method the height coverage can be considerably enhanced compared to the conventional method. For the low SNR case, the height coverage for the adaptive and conventional methods is about 22 and 11 km, respectively; the corresponding heights for the high SNR case are 24 and 13 km. To validate the results obtained through the adaptive method, the velocity profile is compared with global positioning system balloon sounding (GPS sonde) observations. The results of the adaptive method show excellent agreement with the GPS sonde measured wind speeds and directions throughout the height profile. To check the robustness and reliability of the adaptive algorithm, data taken over a diurnal cycle at 1-h intervals were analyzed. The results demonstrate the reliability of the algorithm in extracting wind profiles that are self-consistent in time. The adaptive method is thus found to be of considerable advantage over the conventional method in extracting information from the MST radar signal spectrum, particularly under low SNR conditions that are free from interference and ground clutter.

1. Introduction

The method adopted for identifying the signal and computing the three low-order spectral moments is central to the problem of extracting information from the Doppler spectrum of the mesosphere–stratosphere–troposphere (MST) radar signal. The conventional method of analyzing the MST radar spectral data is based on identifying the most prominent peak of the Doppler spectrum for each range gate and computing the three low order spectral moments and signal-to-noise ratio (SNR) using the expressions given by Woodman (1985). SNR is defined as the ratio of total signal power to the noise power in the coherent filter bandwidth. This simple method, however, has severe limitation in terms of height coverage because the MST

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radar signals are characterized by rapidly falling SNR. For the Gadanki MST radar with a peak power-aperture product of 3 x 10^{10} W m^{-2}, we found that the conventional method limits reliable Doppler profiling up to heights of typically 12–14 km.

To improve the performance of the peak detection algorithm, one might apply a consensus average or a median estimator, rather than a simple average, to the spectra before computing the spectral moments (Fischler and Boltes 1981; May and Strauch 1989; Wilfong et al. 1993). The main motivation for the consensus algorithm was to extend the reliable averages to low SNR. The problem with both the median and consensus methods, however, is that they depend upon the number of samples of desired data, around one-third of the total samples, and this could be lower if there are more samples are used for the average. Merritt (1995) developed a more effective method that makes use of the signal statistics to selectively average the data and that is not restricted by the number of contaminated samples. The method assumes only that the radar dwells on a particular volume of atmosphere long enough for the atmosphere to be observed uncorrupted part of the time. Approaches to filtering the time series data prior to spectral processing and modifications to the spectral processing were considered by May and Strauch (1998) and Jordan and Lataitis (1997) to address clutter issues. All of these statistical averaging techniques and filtering techniques are intended mainly to deal with spectral data contaminated with signals from nonatmospheric sources such as ground clutter, aircraft, birds, insects, etc.

For identifying signals from regions of low SNR, which would improve the reliability and height coverage of Doppler profiles, some kind of an adaptive method needs to be used. An adaptive method based on constructing chains of profiles by maximizing an energy function and using a neural network approach for detecting the most likely profile has been developed by Clothiaux et al. (1994). The performance of the method has been successfully demonstrated with 404-MHz wind profiler spectral data taken in low-altitude mode that showed extensive periods when either the SNR was poor or the atmospheric signal power was significantly less than that of the ground clutter. More recently, a wind confidence algorithm [National Center for Atmospheric Research (NCAR) Improved Moments Algorithm (NIMA)] and an automatic moments estimation technique [NCAR Wind and Confidence Algorithm (NWCA)] were developed and implemented for wind profilers (Morse et al. 2002; Goodrich et al. 2002). The NIMA method implements combinational mathematical analysis, fuzzy logic synthesis, and global image processing algorithms.

We present here another method of adaptive data processing that has been found to perform consistently well under a wide range of SNR conditions of atmospheric signals that are free from interference and ground clutter. The method is based on adaptively tracking the signal in the range–Doppler spectral frame making use of certain criteria for adaptively setting the parameters of the SNR threshold for the Doppler spectral frame, the velocity span for the Doppler velocity window, and the wind shear threshold for each of the range windows, which are blocks of range gates in the range–Doppler spectral frame. The method has been applied to the Gadanki MST radar spectral data and the results are presented for low and high SNR conditions. A stepwise description of the algorithm applied to data from the MST radar is given in section 2. The results and discussion are in section 3 and the important conclusions are in section 4.

2. An algorithm for adaptive moments estimation

An algorithm based on an adaptive method has been developed that aims at tracking the signal adaptively in a range–Doppler spectral frame with background noise. The algorithm works around a set of parameters that get updated constantly so as to optimize the tracking performance of the adaptive method. The implementation of the method for adaptive tracking of the Doppler signal and estimating moments involves a sequence of steps as detailed below. The flowchart of the algorithm is given in the appendix.

a. Step 1: Noise removal

The raw Doppler power spectra recorded online are subjected to low-pass filtering (that is, smoothing) to reduce the level of noise fluctuations that appear particularly prominent in the low SNR regions. The low pass filtering is implemented with a three-point running average of the Doppler spectrum. Then, the mean noise level is estimated for each range gate using an objective method based on Gaussian statistics (Hildebrand and Sekhon 1974). The mean noise level for each range gate is subtracted from the corresponding power spectrum.

b. Adaptive signal profiling

The parameters used for adaptive signal tracking in a range-Doppler frame are the Doppler velocity window, wind shear threshold, and signal-to-noise ratio (SNR). The range-Doppler frame is divided into a number of range windows with a maximum of 50 range windows per profile and each range window containing two or more range gates. For each range window minimum and maximum velocities and maximum wind shear per range gate are identified, with allowed margins, and are called the Doppler velocity window and wind shear threshold, respectively. For the first Doppler frame, as there is no prior information available, the Doppler velocity window and wind shear threshold parameters are set from range gate to range gate based upon certain realistic criteria. For subsequent range–Doppler frames, information from the previous frames is used to set the range window, Doppler velocity window, and wind shear threshold parameters.

In the case of SNR, a threshold value is specified that applies for the entire range–Doppler frame. In the SNR computation, the noise power is computed over the full bandwidth of the power spectrum as determined by the coherent integration time. At the upper end of the height range, where the signal falls below the detectability level, the SNR refers to the most prominent noise peak and it falls generally in the range of -15 to –20 dB. The SNR threshold is set at 10 dB above the mean noise level estimated for the noise region at the upper end of the height range.

c. Step 2: Setting up of Doppler window and wind shear threshold parameters

For the first range–Doppler frame, the Doppler velocity window is set adaptively from range gate to range gate. The window setting is initiated by identifying the most prominent spectral peak in the first range gate for which the SNR is invariably quite high (>7 dB). The Doppler velocity window limits are then set at $\pm 20\%$ of the coherent integration filter bandwidth on either side of the mean Doppler velocity associated with the prominent spectral peak. The Doppler velocity window set for the first range gate is used to identify the most prominent peak in the second range gate since the signal is not expected to change by more than 20% of the coherent filter bandwidth from one range gate to the next. New Doppler velocity window limits are set for the second range gate based on the position of the mean Doppler velocity at its most prominent spectral peak within the Doppler velocity window. The procedure is repeated sequentially for all range gates, thereby fixing a height-varying Doppler velocity window for the entire frame. For the first frame, the wind shear threshold is also set from range gate to range gate and it is expressed in terms of the deviation permissible in the equivalent mean Doppler velocity. The wind shear threshold limit is set by adding 20% of the full width of the Doppler velocity signal to the locally computed wind shear using moving pairs of range gates.

From the second frame onward the total range is divided into a specified number of range windows, up to a maximum set of 50 per profile with each range window having two or more range gates. Doppler velocity window and wind shear threshold are set from range window to range window. Using the information from the previous Doppler frame, for each range window the minimum and maximum mean Doppler velocities are noted and the Doppler velocity window is set to the minimum and maximum mean Doppler velocity with the velocity full width as margin on either side. Similarly, for each range window the maximum wind shear is computed and the wind shear threshold is set to the maximum wind shear with a margin equal to 20% of the velocity full width.

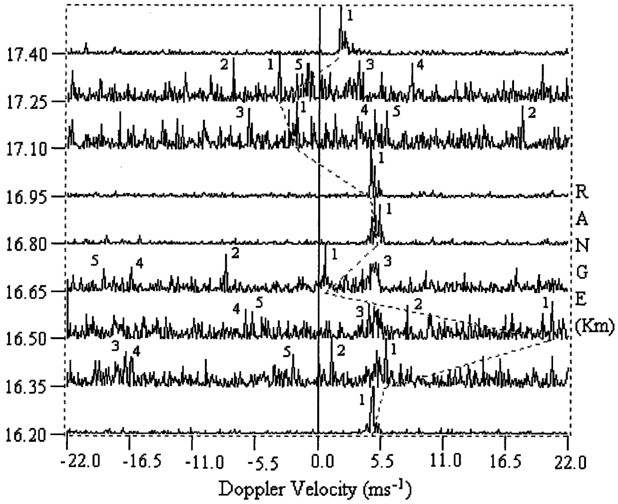


FIG. 1. Sample Doppler spectra for a few range gates showing five candidate peaks per range gate that form the basis for the adaptive technique of signal detection.

d. Step 3: Selecting five candidate signals and estimating their moments

The five most prominent spectral peaks are selected as candidate signals within the specified Doppler velocity window for each range gate. For example, Fig. 1 shows the spectral peaks in descending order of power level for nine range gates covering the height range of 16.20–17.40 km for the radar data taken on 5 May 2002. The radar parameters used for the observations are given in Table 1. The spectrum for 16.5 km with the most prominent peak at 20.6 m s^{-1} clearly shows the limitation of the conventional single peak detection method in identifying the signal and illustrates the need to apply an adaptive method to deal with the situation. For the five candidate signals in each range gate, the three low-order spectral moments are computed following Woodman (1985). The zeroth, first, and second moments, representing total signal power, weighted mean Doppler velocity and velocity width, respectively, are denoted by $M_m^s(n)$, where s varies from 1 to 5 and represents the spectral peak number, m varies from 0 to 2 in the order of the spectral moments, and n is the number of the range gate. The moments for each range gate are stored in descending order of power level for the five selected candidate signals.

e. Step 4: Selecting the most probable candidate signal using SNR and wind shear criteria

The task performed in this step of the algorithm involves adaptive profiling of the Doppler signal through an iterative process. In the first iteration, moments values of the five most prominent candidate signals are selected [i.e., $M_m^1(n)$] and stored in the select list if their SNRs are more than the specified SNR threshold value. In this way the first-cut signal trace is obtained for the

TABLE 1. Radar parameters used for the experiments.

Parameter	Value
Interpulse period	1000 μs
Pulse width	16 μs (complementary code with 1-μs baud)
No. of beam positions	6 (10°E, W, N, S, and 0° Z_x, Z_y)
No. of coherent integrations	64
No. of FFT points	512
Nyquist velocity	± 22 m s^{-1}
Velocity resolution	0.085 m s^{-1}
Observation window	24–174 μs (3.6–25.95 km)
No. of range gates	150
No. of incoherent integrations	1
Data type	Doppler power spectrum

entire height range. The range gates that remain unattended in the first iteration based on the SNR criterion are subsequently dealt with in the following three iterations that make use of the wind shear criterion.

To determine the most probable candidate signal for the unattended *n*th range gate, the trend of the mean Doppler velocity is checked using the first moment values from the select list, where $M_1(n - 2)$ to $M_1(n + 2)$ represent the mean Doppler velocities from two range gates below to two range gates above the *n*th range gate in the select list. If the first moment values are available, we can estimate the trend of the signal in the present range gate, which most likely falls within the allowed deviation of the shear threshold relative to the neighboring range gates. Then, the candidate signal with the highest SNR that best fits the trend and satisfies the shear criterion is taken as the most probable signal in the current range gate and its moments are stored into the select list. This iteration is repeated by considering one range gate above and one range gate below the *n*th range gate and the select list is updated with the moments of most probable signal in the current range gate if the shear threshold criterion is met. Following this iteration, there may still remain some range gates unrepresented.

Now, for the next iteration the condition for establishing the shear trend is further relaxed by considering the case where the moments data are available for a range gate either above or below an unattended range gate. In this iteration, too, the signal that satisfies the shear criterion is taken as the most probable signal to represent the range gate under consideration. After this iteration the few range gates that may still be unrepresented. Generally these range bins have signals that fall below the detectability level where the most prominent peak represents noise itself. These range bins are now assigned a mean Doppler velocity through linear interpolation of spectral moments from the neighboring range gates.

Finally, from the second Doppler frame onward the consistency of the adaptive method is checked by comparing the current mean Doppler (MD) velocity profile with the previous Doppler velocity profile. A threshold is set for checking the validity of the retrieved velocities using the relation

$$\left|\frac{\mathrm{DV}_{\mathrm{diff}}}{\mathrm{MD}}\right| < 0.2,$$

where $\mathrm{DV}_{\mathrm{diff}}$ is the difference in mean Doppler velocities for the same range gate between the two consecutive frames and MD is the mean of the mean Doppler velocities in the previous and current frames. The threshold value of 0.2 is found to be the most acceptable after checking a number of profiles in different conditions. If the computed value of $|\mathrm{DV}_{\mathrm{diff}}/\mathrm{MD}|$ at any range gate exceeds the threshold of 0.2, then its moments are replaced with those of a more agreeable candidate signal, if available. Otherwise, the original values are retained, as they have passed the criteria set for the adaptive profiling. In the above, validity checking when the mean Doppler velocities become zero is a trivial case and in that case checking is inhibited.

As evident from the complexity of the adaptive algorithm, involving five sets of the moments estimation and five iterations for the final moments extraction, the computational load is considerably more than that of the conventional peak detection method. For this reason, we recently implemented it with our system for offline data processing. But, considering the pace of advancement in the speed and memory of modern computers, implementation of the adaptive algorithm for online processing of MST radar data with dedicated digital signal processing (DSP) hardware will soon be possible. In the case of operational wind profilers, data collection is not normally continuous, which should make real-time implementation easier.

The adaptive algorithm was tested with long datasets and was found to yield consistent profiles of spectral moments under varying conditions of SNR. The algorithm, however, has certain limitations in its application, which are associated mainly with severe weather conditions. Under such conditions, the possible presence of multiple echoes may cause the algorithm to be ineffective for adaptive tracking and moments estimation of the clear-air echoes.

3. Results and discussion

The adaptive method was applied to a variety of atmospheric signal conditions. Here, we present the results for two cases: one for low SNR and the other for high SNR conditions. The spectral data considered here were collected using the radar parameters given in Table 1. Spectral averaging improves the detectability and thereby identifying the echoes. The cases presented here are without spectral averaging to highlight the performance of the algorithm. However, it is possible in the algorithm, as a user option, to do spectral averaging

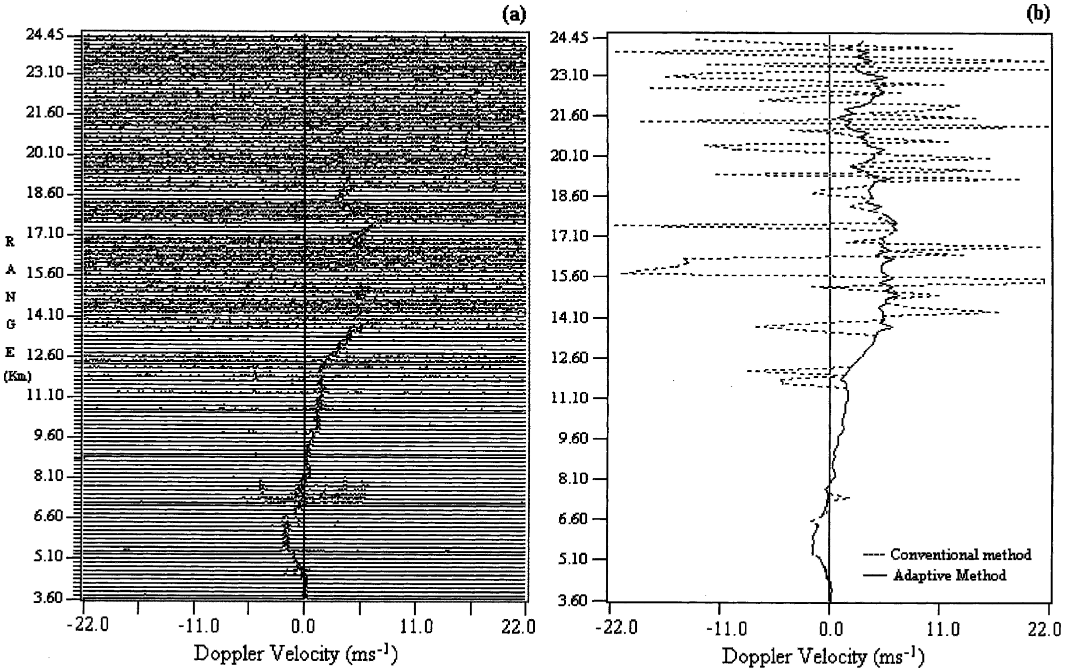


FIG. 2. (a) Height profiles of Doppler power spectra observed on 10 Jul 2002 using the 10° east radar beam when the SNR is low. (b) Mean Doppler velocity–height profile extracted from the spectra shown in (a) using the conventional peak detection method (dotted line) and the adaptive moments extraction technique (solid line).

within the required time resolution. Figure 2a shows Doppler power spectra for the 10° east radar beam observed on 10 July 2002, representing the low SNR case. The atmospheric signal is visible up to a height of about 21 km, although the signal is quite weak above about 14 km. Figure 2b shows the mean Doppler velocity profile retrieved using both the conventional peak detection method (dotted line) and the adaptive method (solid line). The conventional method clearly fails above about 11 km with noise peaks representing the atmospheric signal in a fairly large number of range gates. The advantage of the adaptive method is evident with

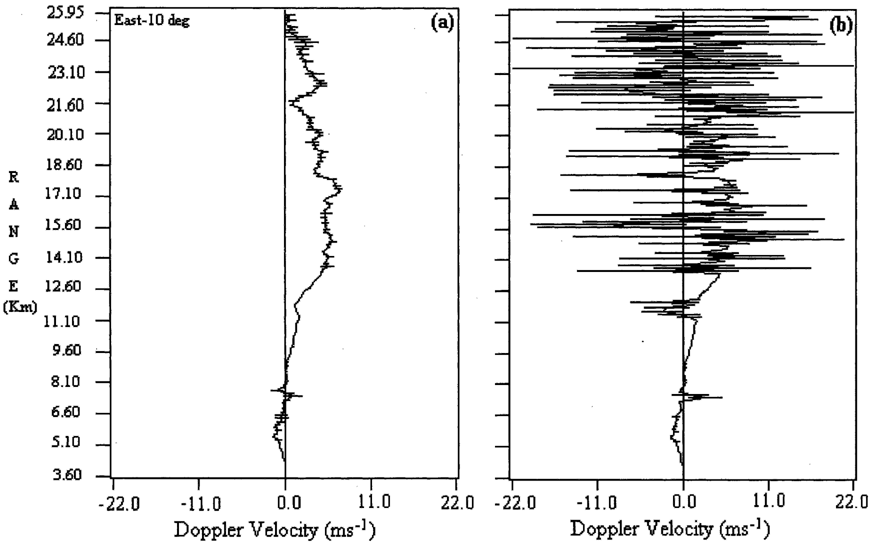


FIG. 3. Eight-profile average mean Doppler velocity–height profiles and corresponding standard deviations observed on 10 Jul 2002 when the SNR is low for (a) the 10° east radar beam using adaptive moments estimation technique and (b) the 10° east radar beam using conventional peak detection method.

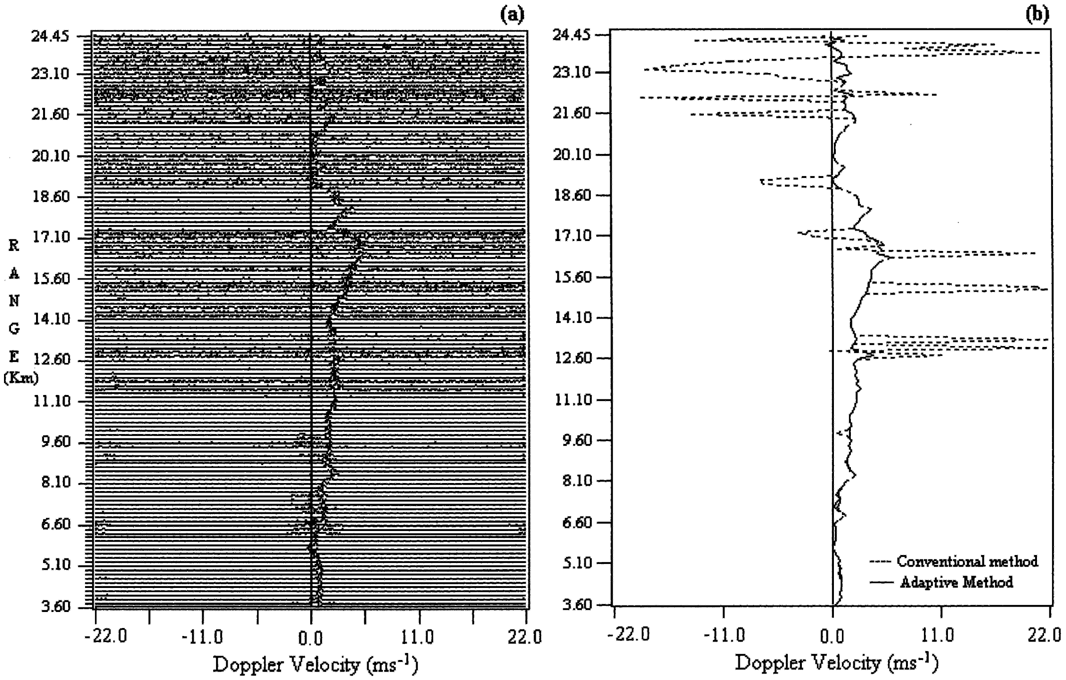


FIG. 4. (a) Height profiles of Doppler power spectra observed 10 May 2002 using the 10° east radar beam when the SNR is high. (b) Mean Doppler–height profile extracted from the spectra shown in (a) using the conventional peak detection method (dotted line) and the adaptive moments extraction technique (solid line).

the mean Doppler velocity values traced to a height of about 22 km. Figure 3a shows a plot of the average mean Doppler velocity profile with standard deviations retrieved by the adaptive method using eight consecutive scans from the east beam position, which is tilted 10° from vertical. The eight scans are covered in an observation time of about 30 min. Figure 3b shows a plot of the corresponding height profiles for the average mean Doppler velocity profile with standard deviations estimated using the conventional peak detection

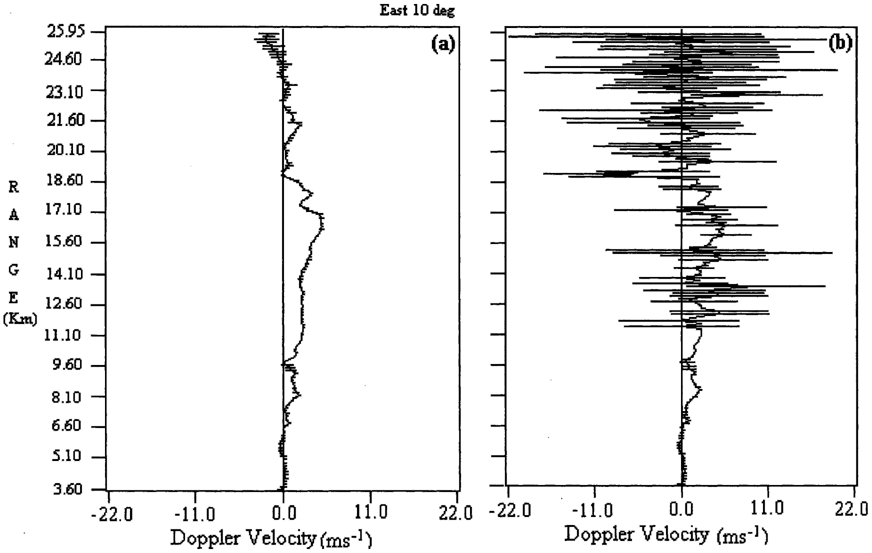


FIG. 5. Eight-profile average mean Doppler velocity–height profiles and corresponding standard deviations observed on 10 May 2002 for (a) the 10° east radar beam using the adaptive moments extraction technique and (b) the 10° east radar beam using the conventional peak detection method.

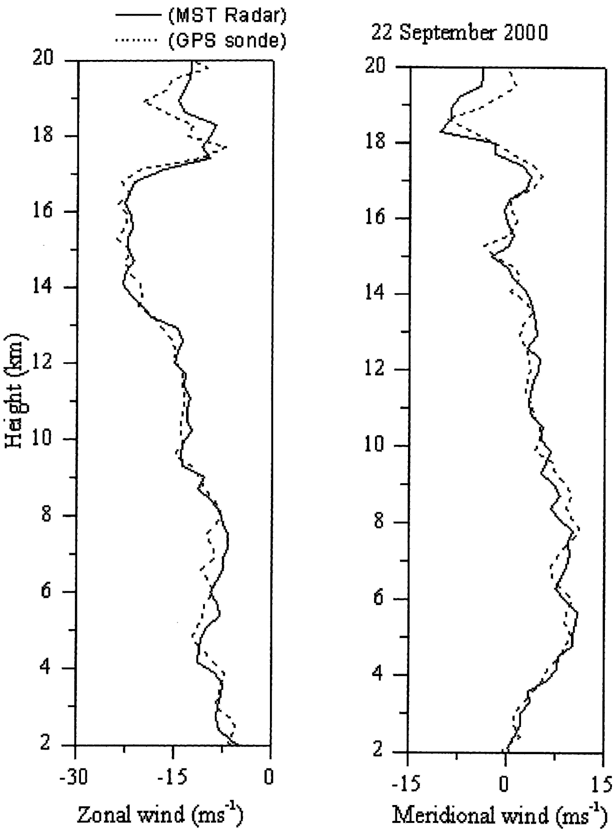


FIG. 6. Zonal and meridional wind velocity comparison using GPS sonde and radar observations. Mean velocity profiles are extracted from the radar observations using the adaptive technique.

method. The standard deviation is found to increase rapidly above about 10 km with values often reaching beyond 11 m s^{-1} and as high as the maximum Doppler velocity bandwidth itself. The adaptive method yields consistent Doppler profiles with erroneous fluctuations greatly reduced. The standard deviation is most often less than 0.6 m s^{-1} up to a height of about 21 km. Thus, the height coverage of the mean Doppler velocity profile can be considerably enhanced for the case of low SNR by using the adaptive method.

Figure 4a shows an example of the Doppler spectrum for the 10° east radar beam for the case of high SNR observed on 10 May 2002. The corresponding mean Doppler velocity profiles obtained by the conventional peak detection (dotted line) and adaptive methods (solid line) are shown in Fig. 4b. In this case even the conventional method provides a reliable mean Doppler velocity profile up to a height of about 12 km with a fairly low number of erroneous fluctuations. However, the adaptive method extends the profile to a height of about 24 km. Figure 5a shows a plot of the average mean Doppler velocity profiles with corresponding standard deviations retrieved by the adaptive method using eight consecutive scans for the east beam position. Figure 5b shows a plot of the corresponding height profile for the average mean Doppler velocity and its associated standard deviations estimated using the conventional peak detection method. For the conventional method the mean Doppler velocity is traced reliably only up to about 12 km, above which the standard deviation becomes quite high. In the case of the adaptive method the profile is found to be consistent with standard deviations mostly less than 0.6 m s^{-1} up to a height of about 24 km. Thus, even for the case of high SNR, application of the adaptive method would result in a significant gain in the height coverage and it is less affected by variations in signal intensity.

To determine the ground truth of the mean Doppler velocity profile estimated by the adaptive method, independent observations were obtained using GPS sondes launched from Gadanki on four days during

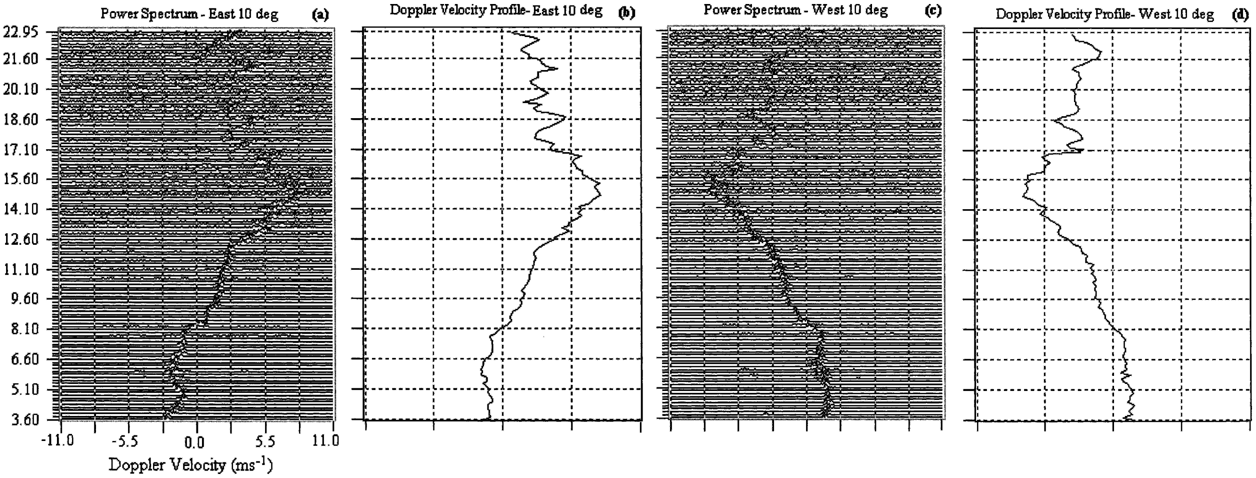


FIG. 7. Sample power spectra from the (a) east and (c) west beams and corresponding mean Doppler velocity profiles for the (b) east and (d) west beams for observations on 24 Jul 2002 showing that the conjugate beams yield Doppler profiles of the same magnitudes but of opposite signs.

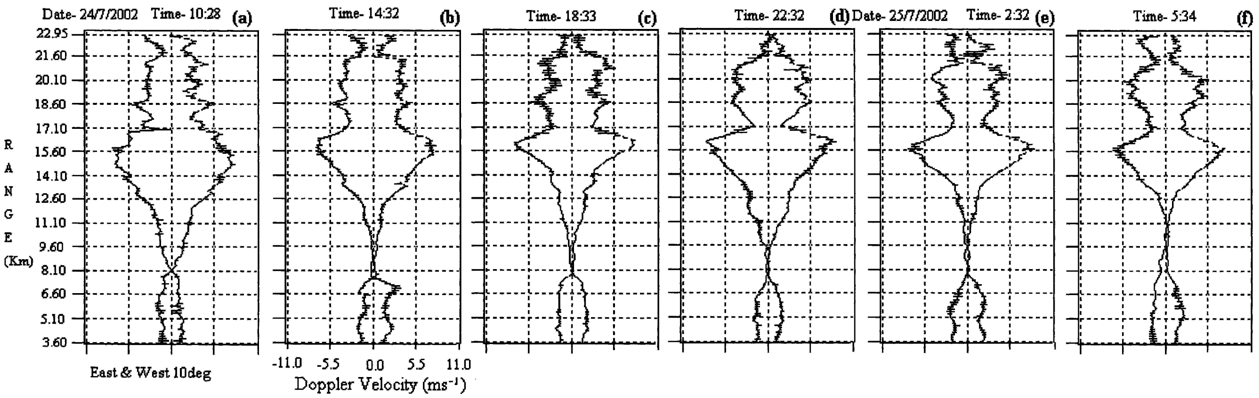


FIG. 8. Average of mean Doppler velocity–height profiles corresponding to the 10°E and W radar beams from the diurnal observations on 24–25 Jul 2002. Plots show the velocity profiles at (local time) (a) 1028, (b) 1432, (c) 1833, (d) 2232, (e) 0232, and (f) 0534.

September 2000. Figure 6 shows a sample plot of the comparisons of the zonal and meridonal velocity of the two independent observations. In Fig. 6 the velocity profile from the radar is extracted using the adaptive moments estimation technique. The results show excellent agreement between the GPS sonde and MST radar velocity profiles. This clearly demonstrates the effectiveness of the algorithm in detecting the correct echoes in the power spectra.

To check the reliability and robustness of the adaptive method, the algorithm was used to extract profiles from the MST radar data obtained during a diurnal experiment conducted on 24 July 2002. The observations were taken every hour for 15 minutes in four beams at 10° off zenith toward the east, west, north, and south. Figures 7a and 7c show sample power spectra for the east and west beams, while Figs. 7b and 7d show the corresponding mean Doppler velocity profiles. For a uniform wind over the spatial extent of the radar scan, if the radar beam formation is correct, the conjugate beams for east and west should yield Doppler profiles of the same magnitude but of opposite sign and similarly for the north and south beams. This criterion is used to check the robustness and reliability of the algorithm in estimating the mean Doppler velocity profile on a continuous basis. Figures 8a–f present mean Doppler velocity profiles with standard deviations for the 10° conjugate east and west beams. In all cases the signal detection is found to be valid with consistency in the mean Doppler velocity profiles from conjugate beams up to about 22 km. Wind velocity estimated from the conjugate beams will be identical if the winds are horizontally homogeneous, the vertical velocity is zero, and there are no radar measurement errors (Strauch et al. 1987). The difference in horizontal velocities estimated after applying the vertical velocity correction in the north–south ($V_N - V_S$) and east–west ($U_E - U_W$) beams for the diurnal set of observations is shown as a scatter diagram in Fig. 9. The standard deviation of the difference in the horizontal wind components was 1.31 m s^{-1}. These results clearly demonstrate that the algorithm is reliable and robust under varying signal conditions.

4. Conclusions

An adaptive moments estimation method has been developed for analyzing MST radar spectral data. An algorithm based on the method has been implemented at the National MST Radar Facility (NMRF), Gadanki, India. The method is found to be of significant advantage in terms of height coverage compared to the conventional peak detection method, particularly under low SNR conditions. The radar wind profiles derived from the adaptive method are found to be quite consistent with GPS sonde measured wind profiles. Each profile retrieved by the adaptive moments estimation

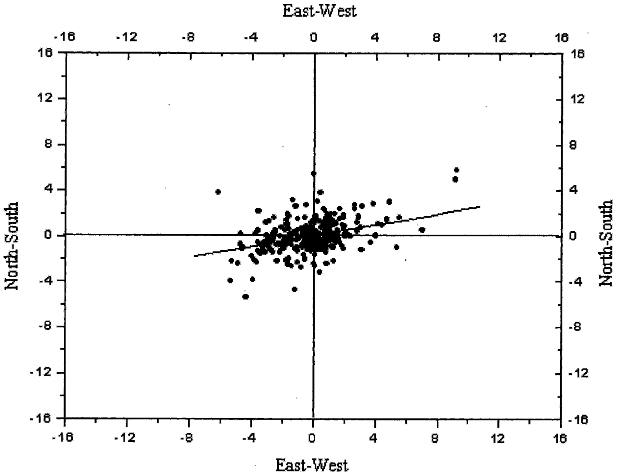


FIG. 9. Scatter diagram of differences in the horizontal velocities ($V_N - V_S$) vs ($U_E - U_W$), measured by the conjugate beams of N–S and E–W during the diurnal observations on 24–25 Jul 2002. Data, with averaging of four mean Doppler velocity profiles, taken at each hour were used.

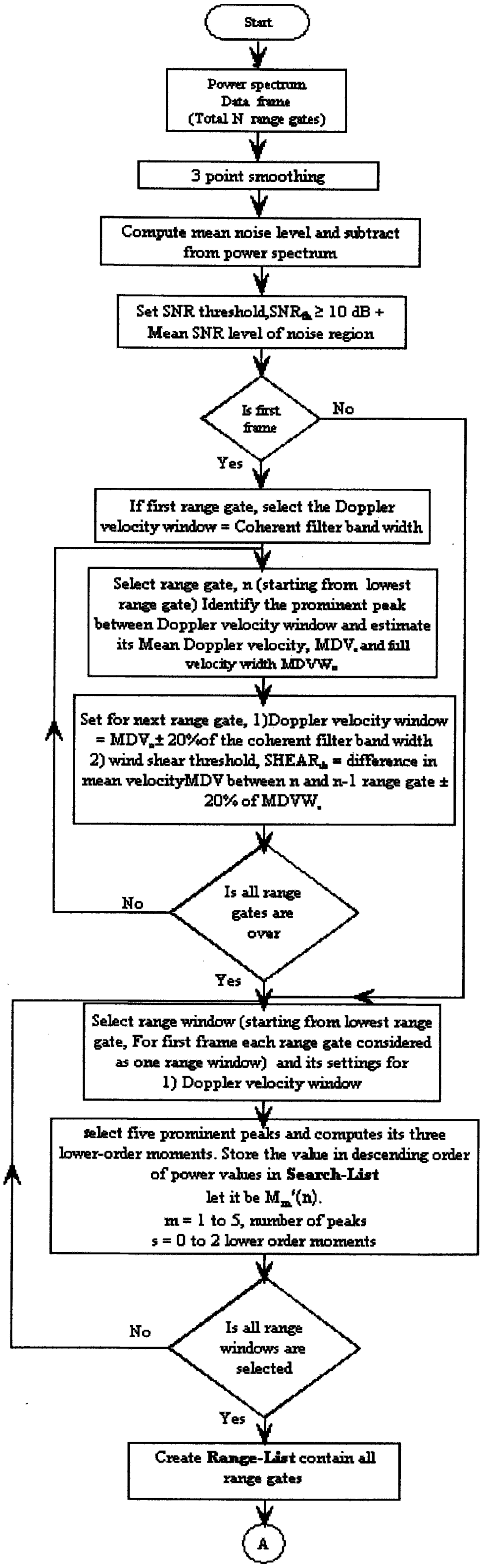
method is relatively free of erroneous moments, thereby providing better temporal resolution compared to statistical averaging. Since adaptive tracking is performed on Doppler power spectra after identifying the most probable signal, this method not only helps to track the mean Doppler velocity profile but also produces accurate estimates of the other moments as well.

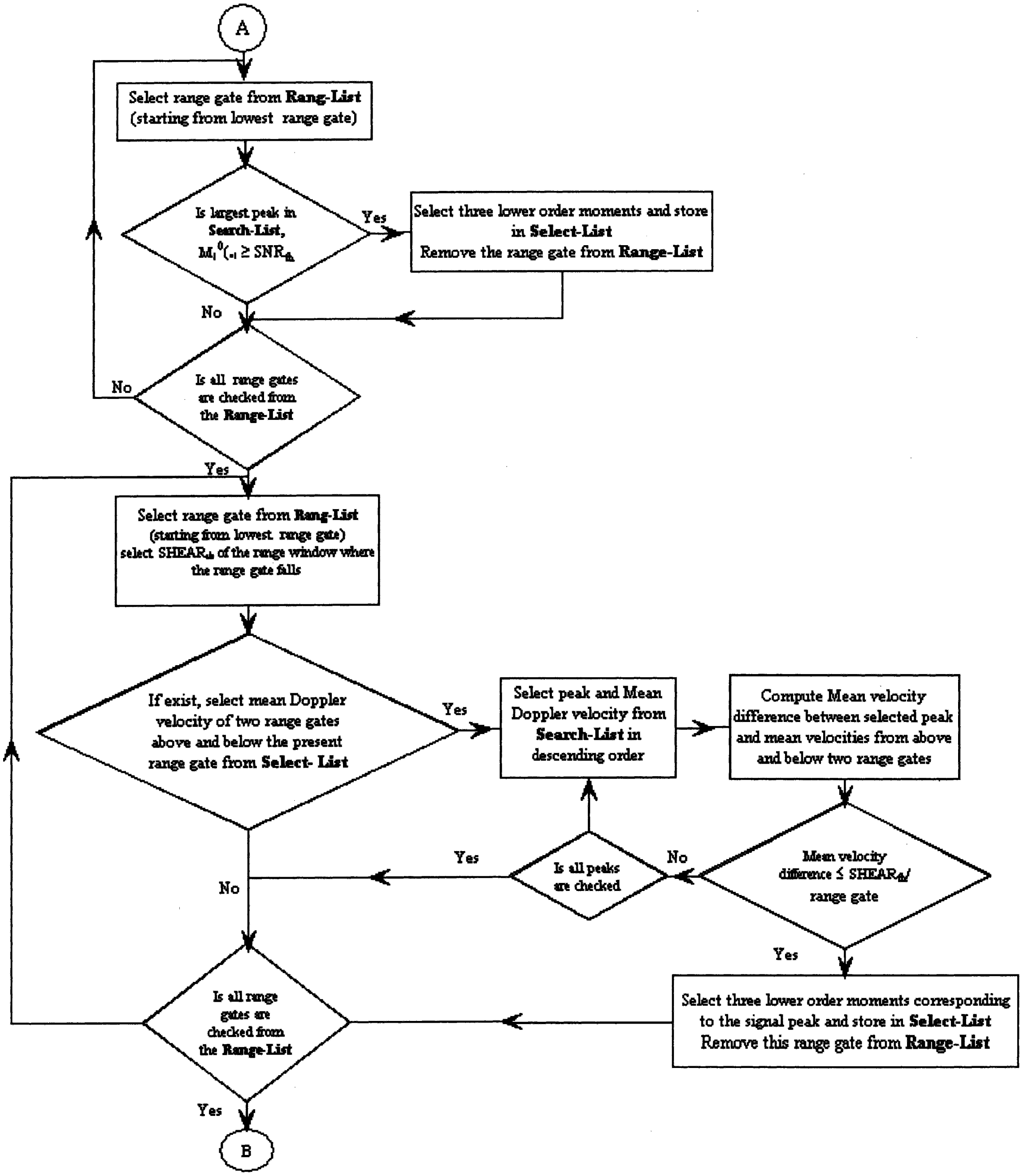
The algorithm is currently used in offline data processing at NMRF in a fully automatic mode. It can, however, be adapted easily for online application with the operational wind profilers, taking advantage of modern-day computers. The method has certain limitations in its application under severe weather conditions such as convection, precipitation, etc., which are due mainly to the difficulties arising from multiple echoes and choosing reliable parameter settings.

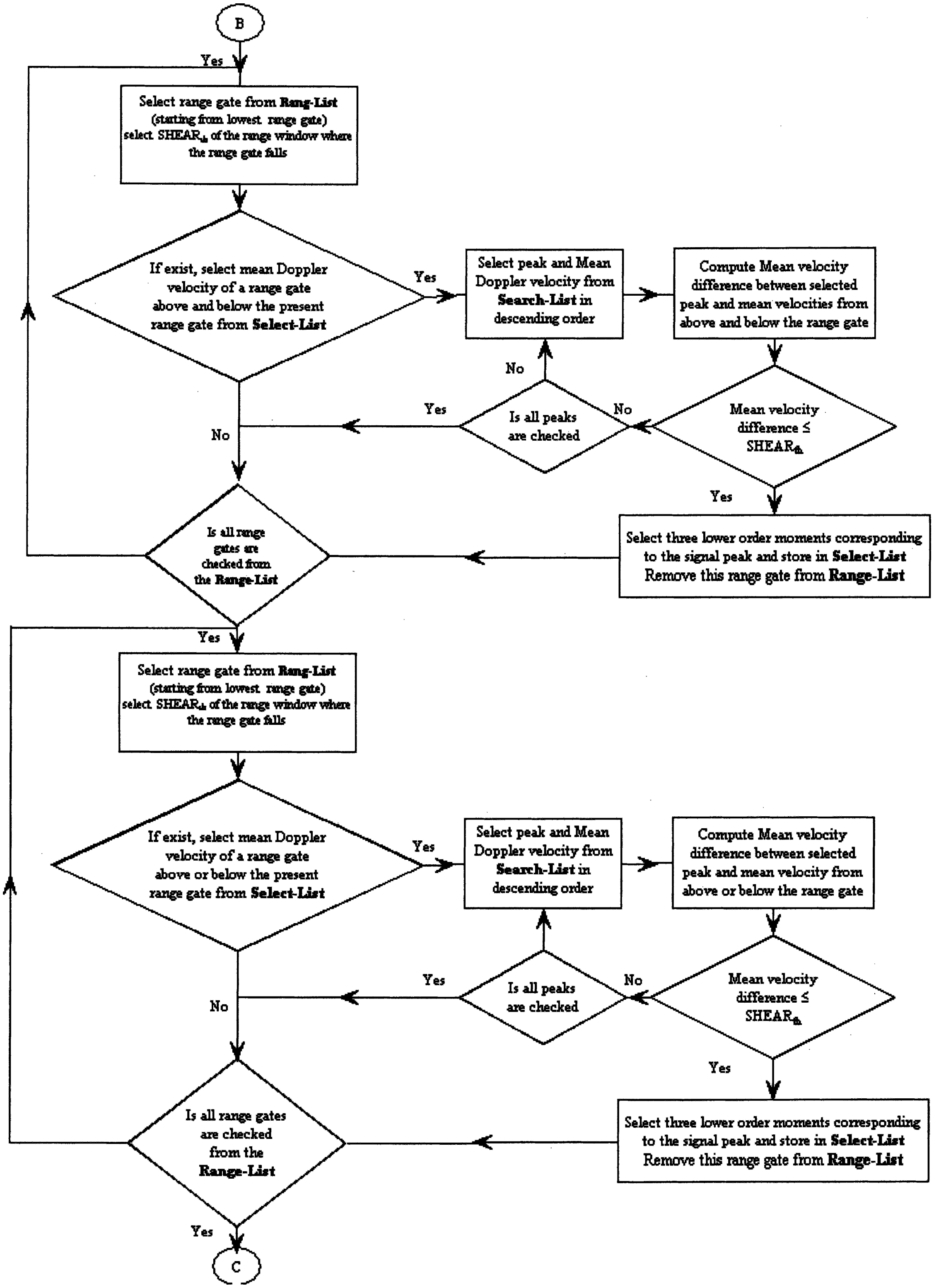
Acknowledgments. The National MST Radar Facility (NMRF) is operated as an autonomous facility under the Department of Space (DOS). Successful operation of the radar for the observations reported here was made possible due to the dedicated efforts of several scientists and engineers associated with it. This paper is partially supported by the National Science Council of the Republic of China, through Grant NSC 91-2811-M-008-025.

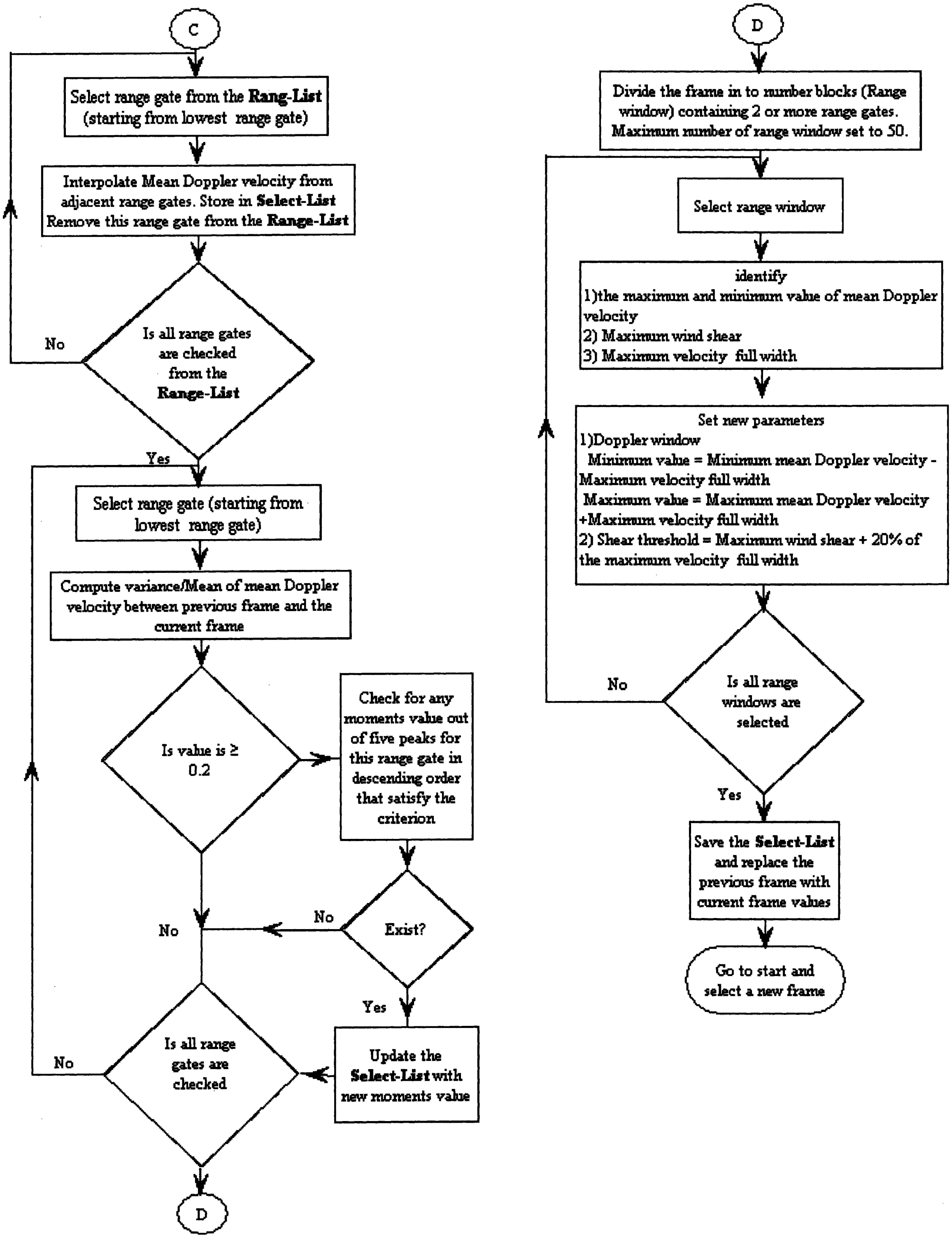
APPENDIX

Algorithm Flowchart




A
Select range gate from Rang-List (starting from lowest range gate)
Is largest peak in Search-List, M_i^0(... ≥ SNR_th
Yes
Select three lower order moments and store in Select-List
Remove the range gate from Range-List
No
Is all range gates are checked from the Range-List
No
Yes
Select range gate from Rang-List (starting from lowest range gate) select SHEAR_th of the range window where the range gate falls
If exist, select mean Doppler velocity of two range gates above and below the present range gate from Select- List
Yes
Select peak and Mean Doppler velocity from Search-List in descending order
Compute Mean velocity difference between selected peak and mean velocities from above and below two range gates
Mean velocity difference ≤ SHEAR_th/ range gate
No
Is all peaks are checked
Yes
No
Yes
Select three lower order moments corresponding to the signal peak and store in Select-List
Remove this range gate from Range-List
Is all range gates are checked from the Range-List
Yes
B


B
Yes
Select range gate from Rang-List (starting from lowest range gate) select SHEAR$_{th}$ of the range window where the range gate falls
If exist, select mean Doppler velocity of a range gate above and below the present range gate from Select-List
Yes
Select peak and Mean Doppler velocity from Search-List in descending order
Compute Mean velocity difference between selected peak and mean velocities from above and below the range gate
No
Yes
Is all peaks are checked
No
Mean velocity difference ≤ SHEAR$_{th}$
No
Yes
Is all range gates are checked from the Range-List
Select three lower order moments corresponding to the signal peak and store in Select-List Remove this range gate from Range-List
Yes
Select range gate from Rang-List (starting from lowest range gate) select SHEAR$_{th}$ of the range window where the range gate falls
If exist, select mean Doppler velocity of a range gate above or below the present range gate from Select-List
Yes
Select peak and Mean Doppler velocity from Search-List in descending order
Compute Mean velocity difference between selected peak and mean velocity from above or below the range gate
Yes
Is all peaks are checked
No
Mean velocity difference ≤ SHEAR$_{th}$
No
Yes
Is all range gates are checked from the Range-List
Select three lower order moments corresponding to the signal peak and store in Select-List Remove this range gate from Range-List
Yes
C


C
Select range gate from the **Rang-List** (starting from lowest range gate)
Interpolate Mean Doppler velocity from adjacent range gates. Store in **Select-List** Remove this range gate from the **Range-List**
Is all range gates are checked from the **Range-List**
No
Yes
Select range gate (starting from lowest range gate)
Compute variance/Mean of mean Doppler velocity between previous frame and the current frame
Is value is ≥ 0.2
Check for any moments value out of five peaks for this range gate in descending order that satisfy the criterion
Exist?
No
Yes
No
Update the **Select-List** with new moments value
Is all range gates are checked
No
D
D
Divide the frame in to number blocks (Range window) containing 2 or more range gates. Maximum number of range window set to 50.
Select range window
identify
1)the maximum and minimum value of mean Doppler velocity
2) Maximum wind shear
3) Maximum velocity full width
Set new parameters
1)Doppler window
Minimum value = Minimum mean Doppler velocity - Maximum velocity full width
Maximum value = Maximum mean Doppler velocity +Maximum velocity full width
2) Shear threshold = Maximum wind shear + 20% of the maximum velocity full width
Is all range windows are selected
No
Yes
Save the **Select-List** and replace the previous frame with current frame values
Go to start and select a new frame

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