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8.4.2 AN EXAMPLE OF SCALING MST DOPPLER SPECTRA USING MEDIAN SPECTRA, SPECTRAL SMOOTHING, AND VELOCITY TRACING

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INTRODUCTION

Although automatic, computer scaling methods appeared at the start of the MST radar technique, there is a continuing need for scaling algorithms that perform editing functions and, if possible, increase the sensitivity of radar by post processing. The scaling method presented here is an adaptation of the method of scaling MST Doppler spectra presented by RASTOGI (1984), to the particular problems encountered at the Sunset radar. It also uses elements from ZRNIC (1979), CLARK and CARTER (1980), CARTER et al. (1980), and WOODMAN (1983).

A brief overview of this method is as follows: a median spectrum is calculated from several sequential spectra; the median noise value is subtracted from this derived spectrum; the median spectrum is smoothed; the detection/nondetection decision is made by comparing the smoothed spectrum to the variance of the smoothed noise; and if a signal is detected, then the half-power points of the smoothed echo spectrum are used to place limits on the evaluation of the first two moments of the unsmoothed median spectrum. In all of the above steps, the algorithm is guided by tracing the expected velocity range upward from the lowest range as far as is possible.

There is evidence that the radar echo power from the troposphere and stratosphere is log-normally distributed (NASTROM, 1985). This means that the use of a point-by-point median of several Doppler spectra is more appropriate than the point-by-point arithmetic mean employed by a number of ST and MST radar groups. The median technique has the added advantage of rejecting transient interference.

To accurately obtain the integral of the echo spectrum for the determination of echo power, the noise must be subtracted from the echo spectrum. This has been a problem to the author, and perhaps others, because if a mean value of the noise is calculated, frequently a large spectral component from noise or interference can cause an unacceptable error. This problem can be reduced, if not practically eliminated by using instead, the median value of the noise.

Smoothing the Doppler spectra in frequency (or radial velocity) increases the signal-to-noise ratio of the radar echo and thus enhances the detectability of weak echo. However, the selection of the smoothing function and its width is important since the detectability is maximum when the smoothing function "matches" the echo spectrum.

The increases sensitivity provided by smoothing the Doppler spectrum before detection also increases the probability of detecting a noise peak not associated with the radar echo. The probability of false detection can be reduced by tracing the velocity from the lowest ranges upwards. At each successive altitude a search for a radar echo can be conducted over a spectral range based on "a reasonable shear" (RASTOGI, 1984).

IMPLEMENTATION OF SCALING ALGORITHM

Figure 1 is an example of this adapted scaling method. The top three panels are Doppler spectra at a particular altitude and antenna beam position from three sequential records. These three spectra are transformed into the median spectrum in the bottom panel by finding the median of each corresponding spectral point. Note that the strong echo from an aircraft on the right side of the 3rd panel has been eliminated from the median spectrum. Also, the median value of the noise has been subtracted from each point of the median spectrum.

Referring again to Figure 1, the spectrum in the 4th panel was obtained by smoothing the median spectrum in the 5th panel with an 11-point Gaussian function. This function and its width were selected empirically as being an approximation of a typical ST radar echo spectrum. The echo spectrum has been obviously enhanced by the smoothing. The algorithm searched for this echo spectrum over a Doppler range centered on the velocity detected at the next lowest range. Limits, L_1 and L_2, were then located at the half-power points of the envelope of the yet untested smoothed signal spectrum. In this case, the smoothed echo was determined to be valid because it was located within the search range, and because its integral from L_1 to L_2 exceeded the integral of the variance of the smoothed spectrum over the same interval by a factor T. T is an arbitrary threshold, discussed below.

Finally, the integral, center and width of the signal spectrum was obtained from the median spectrum in the bottom panel of Figure 3, by the methods used in CLARK and CARTER (1980), but using L_1 and L_2 as limits to the required integrations. The signal integral, center and width can obviously be transformed into the echo power, radial velocity and velocity width. It is suspected, but not yet proven, that the use of the unsmoothed median spectrum in the evaluation of these moments results in greater accuracy.

DISCUSSION

About 1200 individual Doppler spectra from the Sunset radar have been studied using the technique described here. It has been found that the variance of the spectral noise tends to decrease with the square root of the number of spectra used in computing the median spectrum, as expected for an arithmetic average. Because of the large array storage now available in small computers, it is practical to calculate median spectra as a means of on-line compaction of data at a radar site.

As mentioned, the smoothing function and its width should be selected to match the radar echo. At the Sunset radar the Doppler width of echoes varies over a factor of 50:1. The development of an adaptive function is required for the maximum enhancement of weak signal detection.

The selection of the detection threshold requires some consideration. In Figure 2, the two curves, P_t and P_f explore the consequences of the hypothesis that the probability of detecting an actual echo varies as $(S/N)^{1/2}$ and the probability of detecting a false echo as $(S/N)^{-1/2}$. The point at which the two curves intersect represents an equal probability of true and false detection. There are obviously costs associated with setting T too high or too low. One approach is to choose T so that $P_f/P_t < 1/2$ and then employing some further method of automatic editing such as a random sample consensus (STRAUCH, 1983) or the comparison of velocity measurements with redundant antenna positions (CLARK et al., 1983).

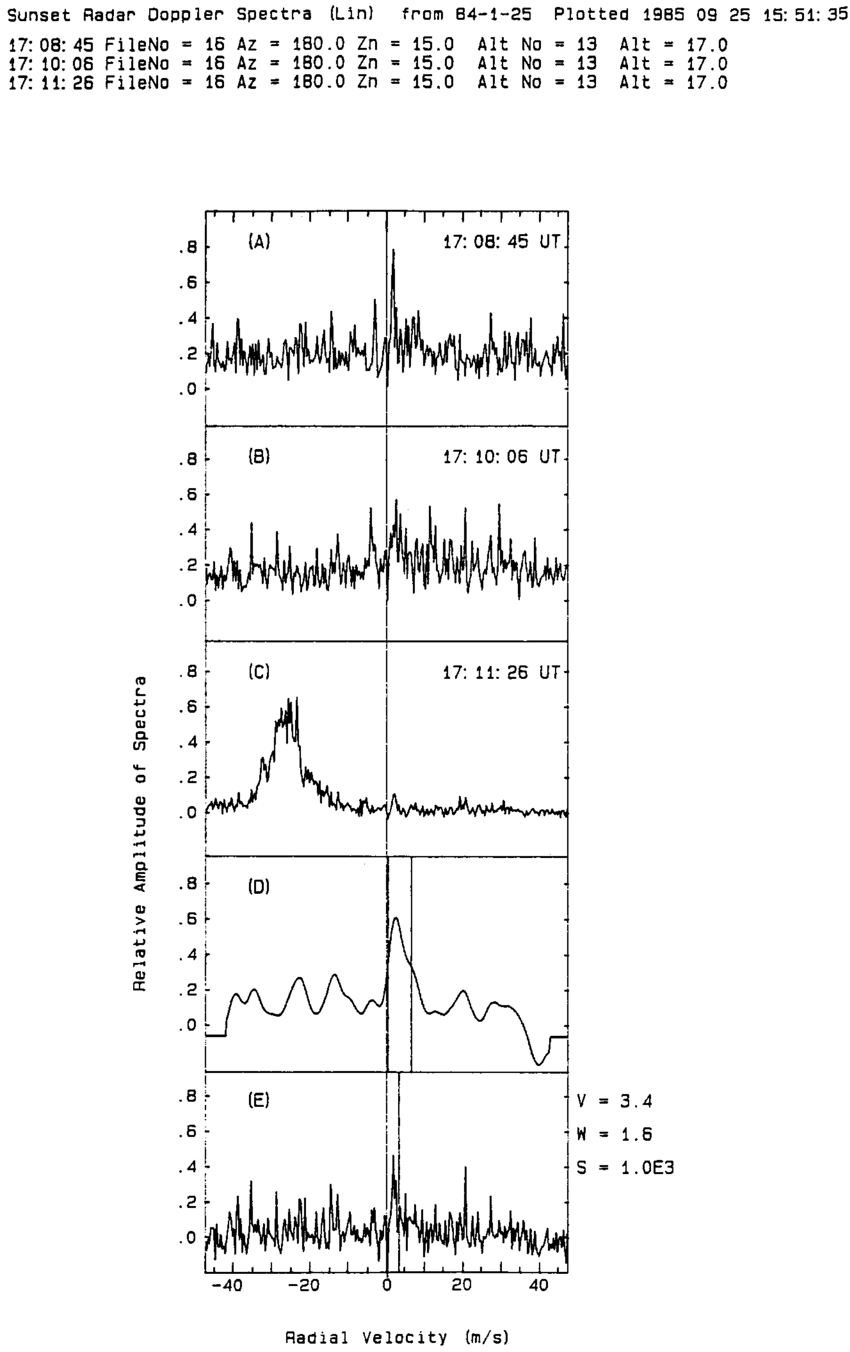

Figure 1. Example of scaling method showing intermediate steps.

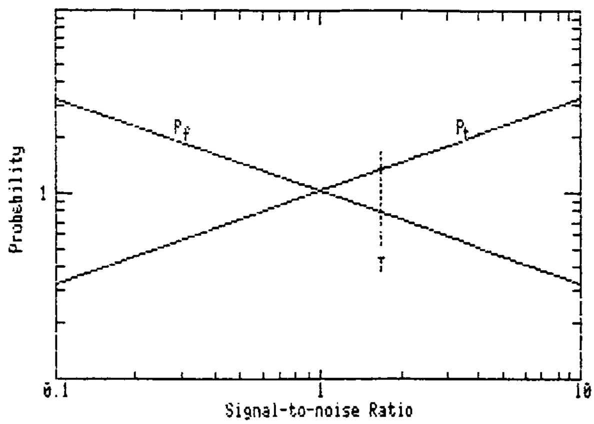

Figure 2. Hypothetical probability of true detection P_t and false detection, P_f. T is an arbitrary threshold.

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