
Use of the Lomb Periodogram to Analyze
SuperDARN Backscatter Spectrum
(adapted from poster presentation)

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Introduction

- The Lomb periodogram [Lomb, *Airophys. and Space Sci.*, v. 39, p. 447, 1975] is a technique for spectral analysis of non-uniformly sampled time series data. This technique is an extension of Fourier spectral analysis that is equivalent to least-squares fitting of sine and cosine functions to the unevenly sampled time series. This technique is particularly suited to the analysis of radar backscatter in the presence of multiple targets (i.e. mixed scatter).
 - In this study, we investigate the utility of the Lomb periodogram method for the analysis of SuperDARN data. Our goal is to develop a tool to reliably estimate the spectral content of the radar backscatter on a pulse sequence-by-pulse sequence basis.
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Method

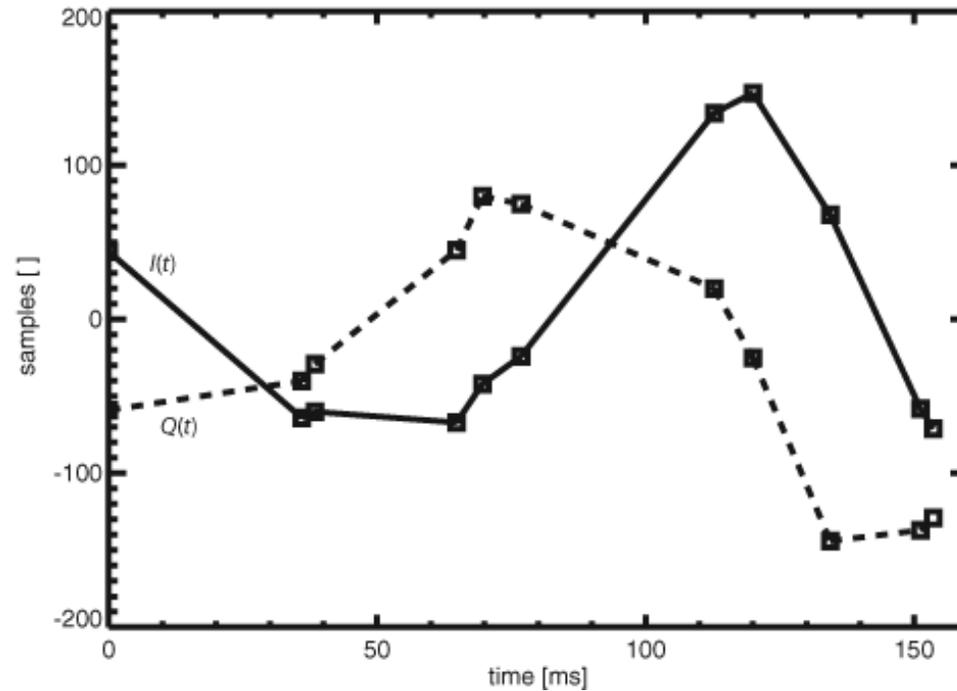
- We use the Lomb periodogram method as generalized to complex-valued time sequences [Koh and Sarkar, *Trans. IEEE*, p. 141, 2000]. The normalized power at a given Doppler frequency is given by

$$P(f) = \frac{1}{\sigma_s^2} \left(\left| \frac{\sum_{k=1}^N (s(t_k) - \mu_s) \cos[2\pi f(t_k - \tau(f))]}{\sqrt{\sum_{k=1}^N \cos^2[2\pi f(t_k - \tau(f))]}} \right|^2 + \left| \frac{\sum_{k=1}^N (s(t_k) - \mu_s) \sin[2\pi f(t_k - \tau(f))]}{\sqrt{\sum_{k=1}^N \sin^2[2\pi f(t_k - \tau(f))]}} \right|^2 \right)$$

where

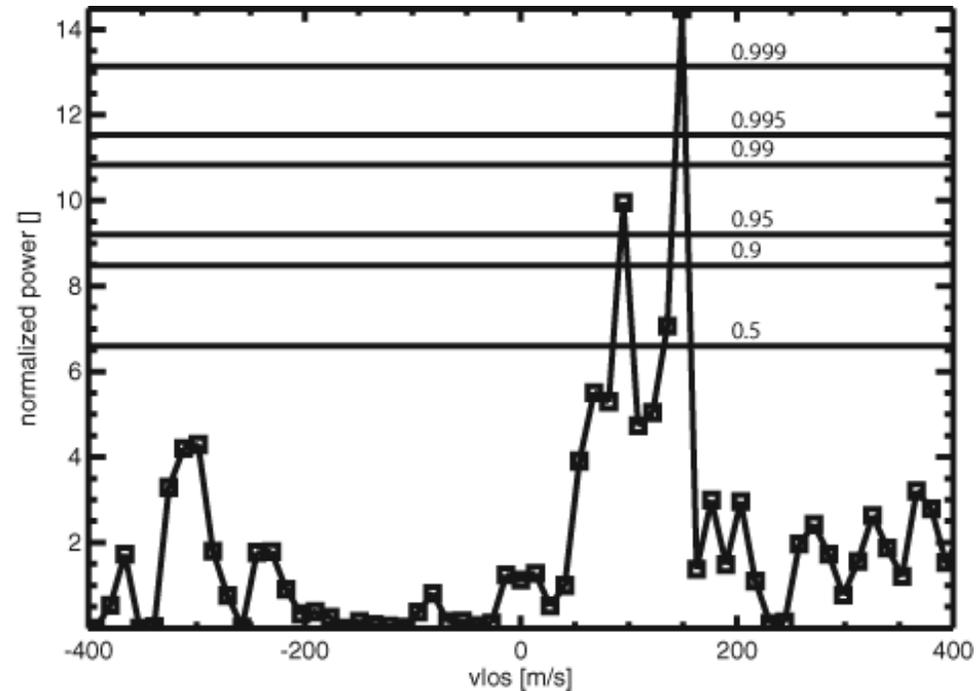
$$\tau(f) = \frac{1}{4\pi f} \arctan \left(\frac{\sum_{k=1}^N \sin(4\pi f t_k)}{\sum_{k=1}^N \cos(4\pi f t_k)} \right)$$

Figure 1



- Figure 1 and Figure 2 present a sample of raw data and Lomb periodogram estimate of the spectral content of this data sample.

Figure 2



- The significance of each spectral component is given by

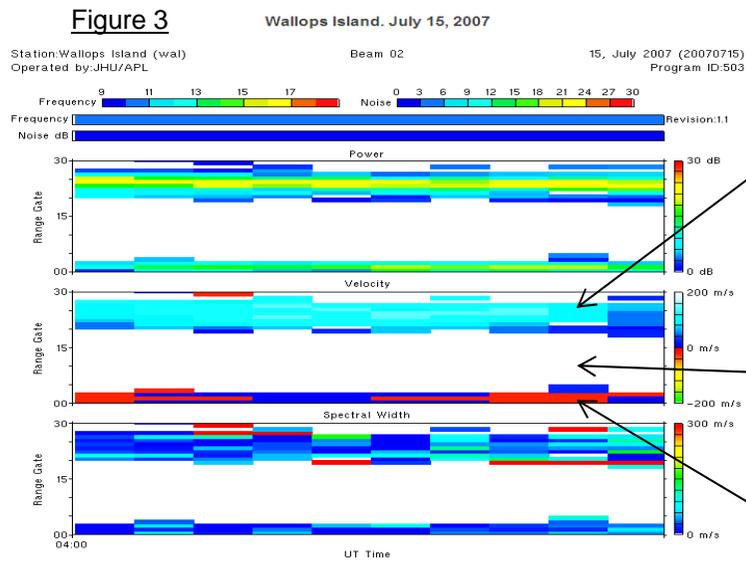
$$1 - \alpha = (1 - e^{-P})^M$$

- Significance levels are shown in Figure 3. Since the Lomb periodogram is greatly underdetermined by the data series, most components are not statistically significant.

Analysis

- We apply the Lomb periodogram method to a selection of data from the Wallops Island HF radar (2008 July 15, 0400-0410 UT, Beam 2). The radar transmits 17 pulse sequences per 1-minute integration period. The FITACF analysis of the backscatter is shown in Figure 3.
 - The Lomb periodogram analysis of the backscatter is shown in Figure 4 for three selected ranges. The spectral content of the backscatter from each individual pulse sequence is shown. Spectral components with significance greater than 0.99 are color coded.
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Figures 3 and 4 overview



range = 30

range = 10

range = 2

Figure 4

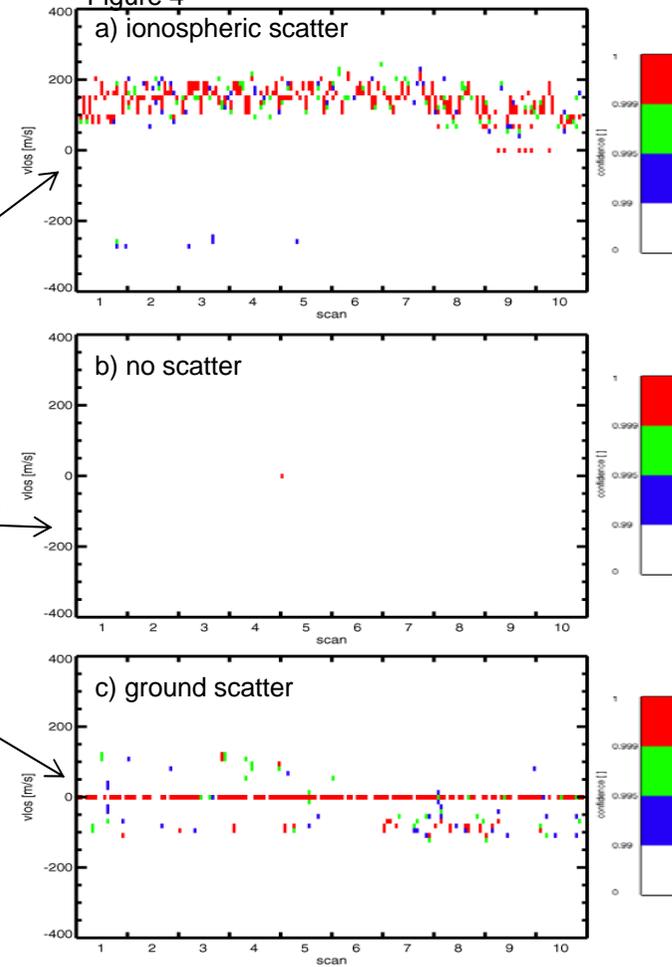


Figure 3

Wallops Island. July 15, 2007

Station: Wallops Island (wal)
Operated by: JHU/APL

Beam 02

15, July 2007 (20070715)
Program ID: 503

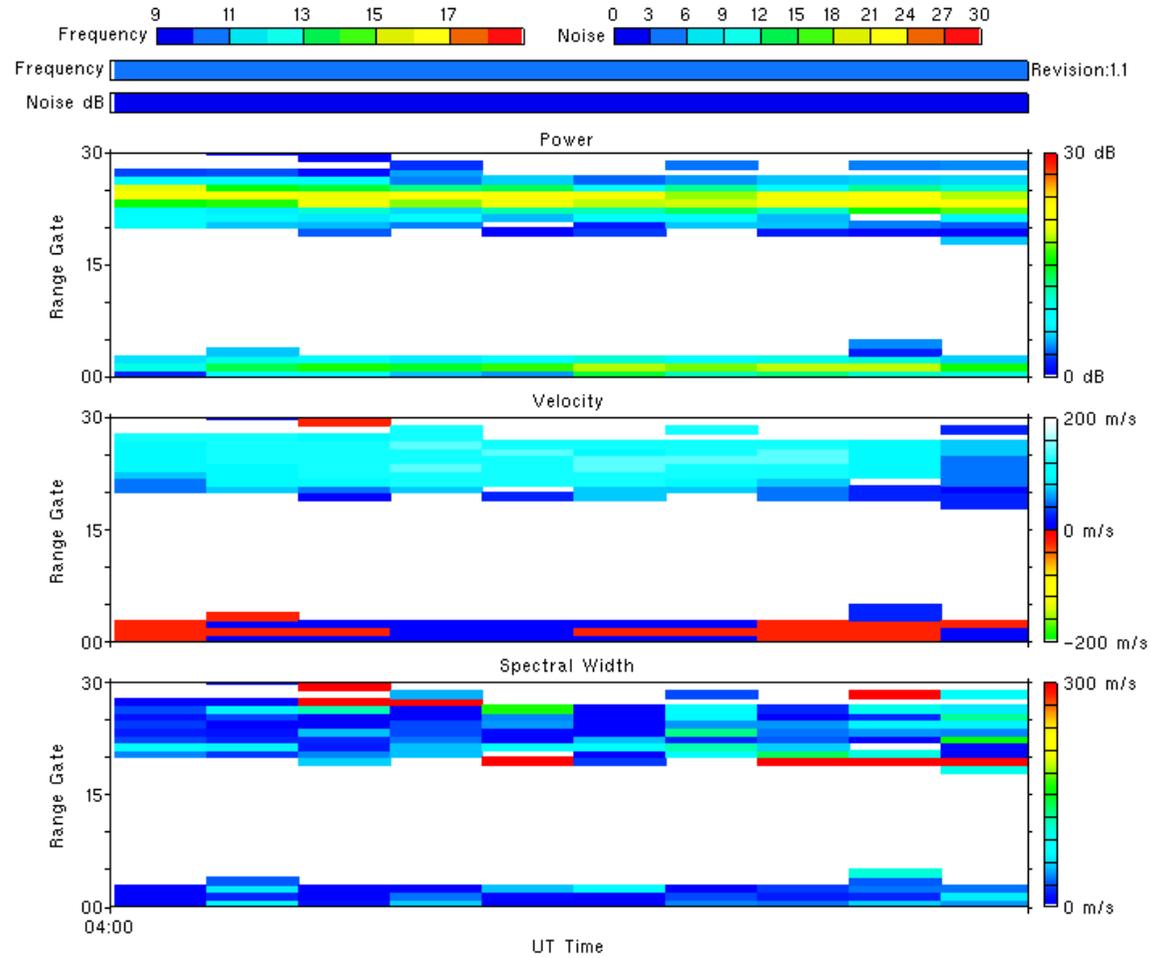


Figure 4a) ionospheric scatter

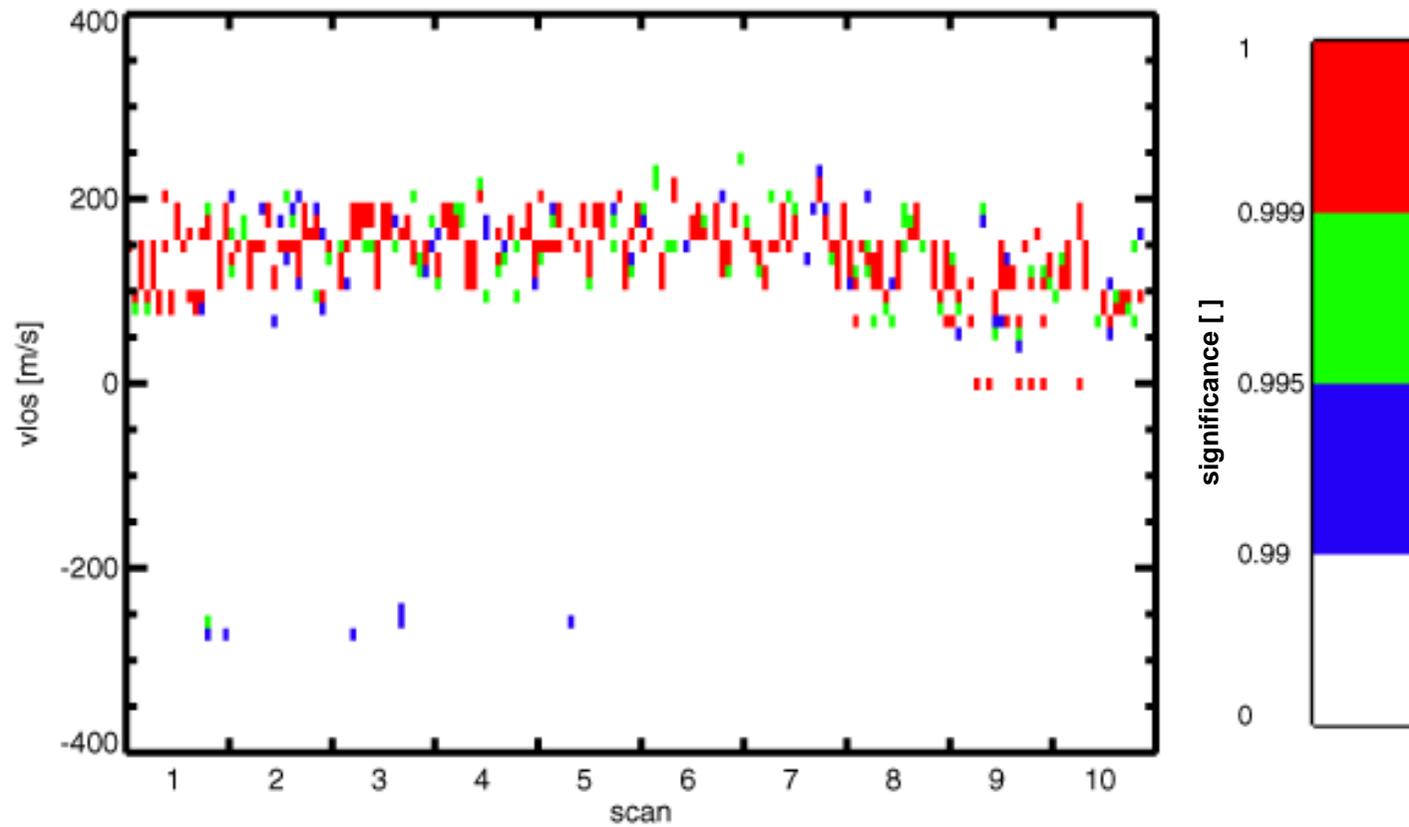


Figure 4b) no scatter

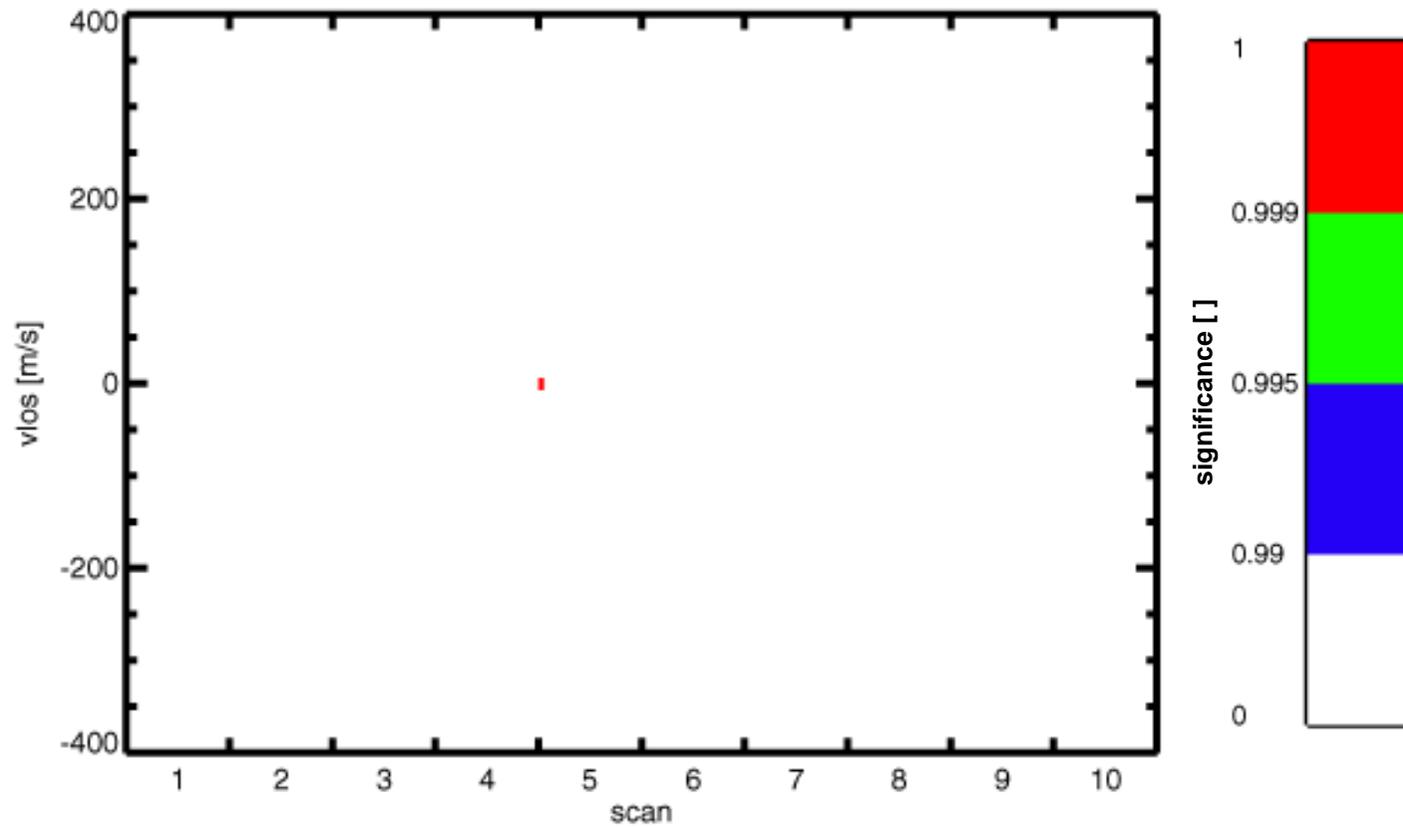


Figure 4c) ground scatter

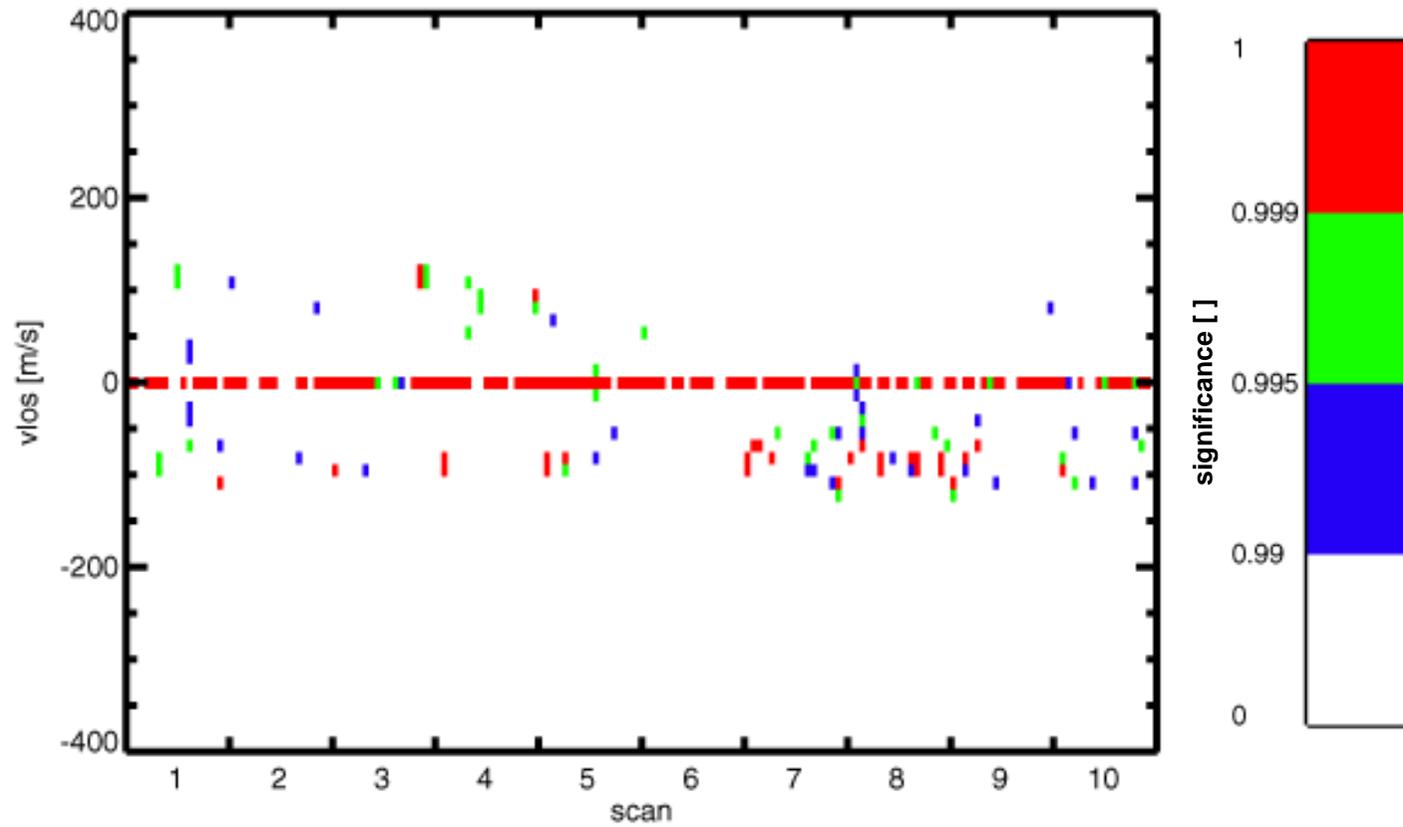
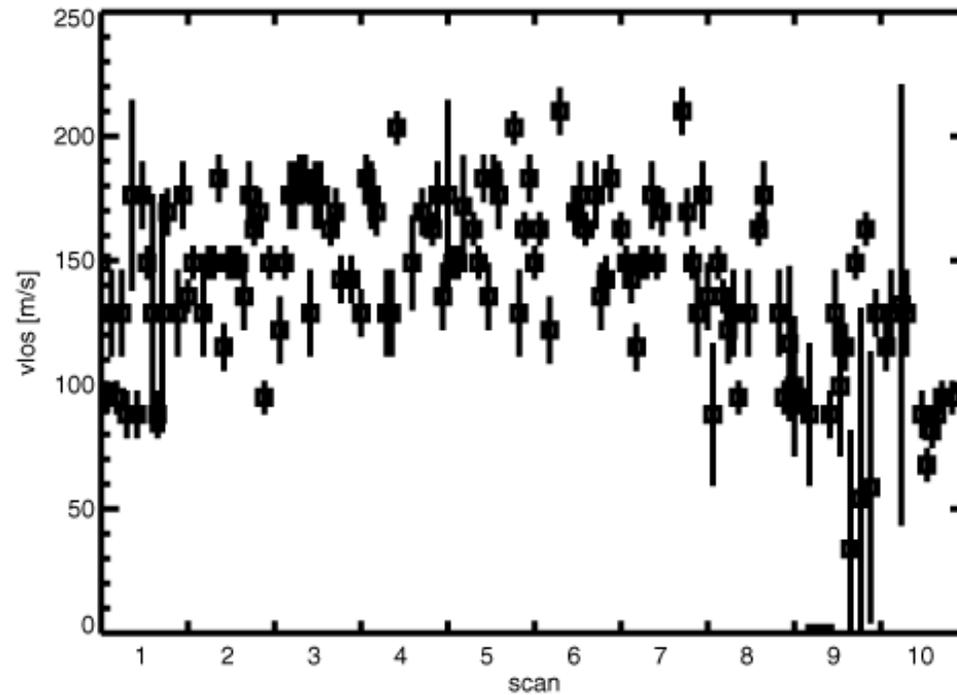
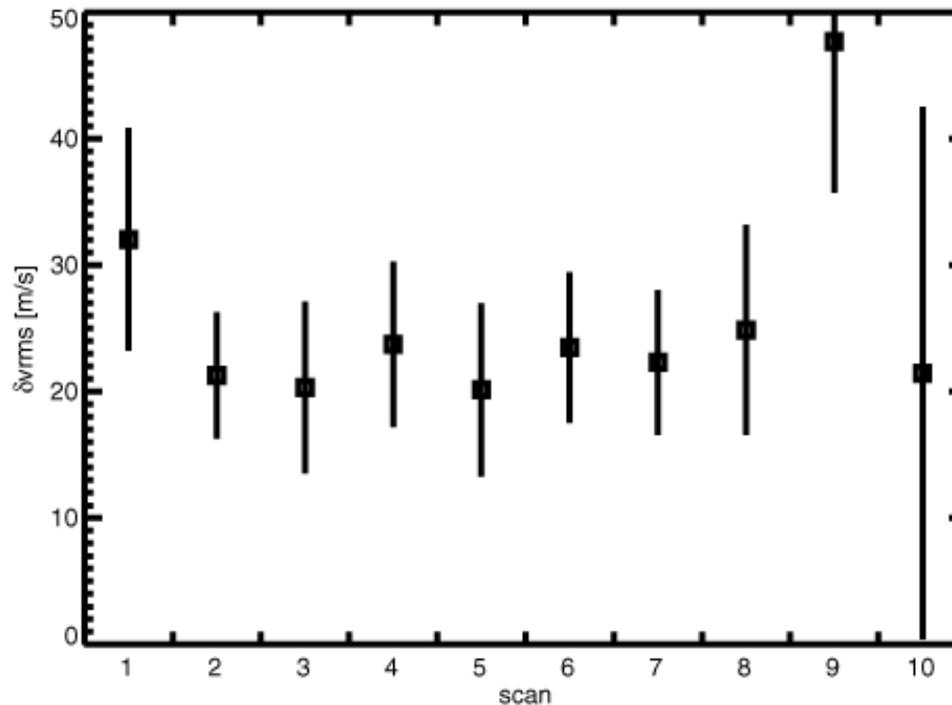


Figure 5



- Figure 5 shows the mean and standard deviation of the backscatter Doppler velocity for each pulse sequence in Figure 4a (ionospheric scatter). The Doppler velocity changes significantly from pulse sequence to pulse sequence.

Figure 6



- The r.m.s. fluctuation of the Doppler velocity within each integration period is shown in Figure 6. This quantity is consistent with the FITACF spectral width.

Conclusions

- Lomb periodogram analysis reproduced the FITACF analysis of a small data selection.
 - Lomb periodogram analysis also provides sub-integration period information on the backscatter.
 - Verification under various scatter conditions is necessary.
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Acknowledgment

- This study was supported by National Science Foundation grant ATM-0535377.
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