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Improvement of SNR in Lidar signal using Wavelet Thresholding Methods

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Abstract: **-- Lidar is a remote sensing active instrument provides vertical profiles of atmospheric parameters and the range of lidar signal is affected by various noises like background noise in the middle atmosphere . Nowadays, wavelet transform (WT) is widely used in the real time signal denoising. Despite there are several achievement s in denoising through wavelet thresholding methods, these do not disclose an optimal configuration. In this paper, we proposed a comparative performance analysis of several thresholding methods using WT; lidar signals are denoised to obtain performance metrics. The efficiency of particular thresholding methods: rigrsure, sqtwolog and heursure using hard and soft thresholding are compared.**

Keywords: **- Lidar,Photon count,snr,Wavelet.**

I. INTRODUCTION

Lidar is a active remote sensing device senses the atmospheric constituents and properties to which radar was insensitive. Lidar acronym stands for light detection and ranging and the block diagram of lidar is shown in Figure 1.There are two types of lidars situated in NARL,Gadanki. They are Rayleigh and Mie lidar operated at 532nm wavelength .Mie lidar is used to obtain aerosol concentration in vertical profiles of the atmosphere using backscatter and extinction coefficient from 0 to 20km altitude and Rayleigh lidar is used to obtain the temperature profiles in the middle atmosphere from 40 to 100km altitude[1]. But the lidar signal is effected by background noise, so that the signal gets disturbed and the signal needs to be denoised to obtain accurate temperature profiles.The work mainly concentrates on denoising the signal in middle atmosphere using different thresholding methods. Lidar emits a beam of light into the atmosphere and some portion of light is absorbed by the atmosphere particles and some portion of light is backscattered and it is collected by the receiver telescope and it is shown in figure 1

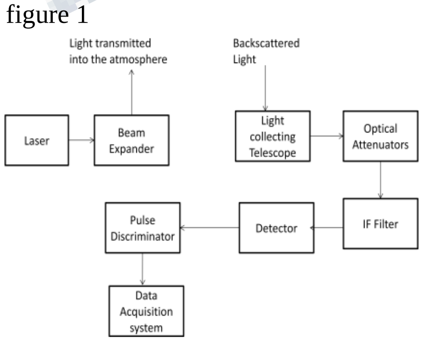

Fig1: Lidar system Descriptio

The backscattered light is in the form of photon count and the signal intensity is measured in the terms of photon count .The raw signal is taken in the form of photon count with respect to time. Time is converted into range using the formula R=cτ/2,where c is the velocity of light and 'τ' is the time[2] .Raw lidar data signal is shown in figure 2 and figure 3 on 05/04/2007

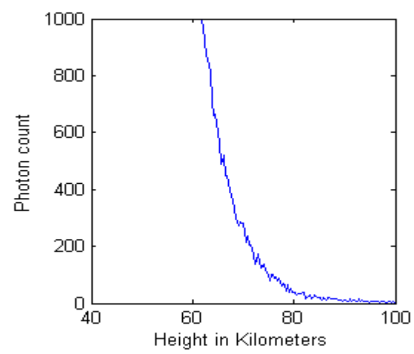

Fig2:Raw lidar signal from 40 to 100km on 05/04/2007

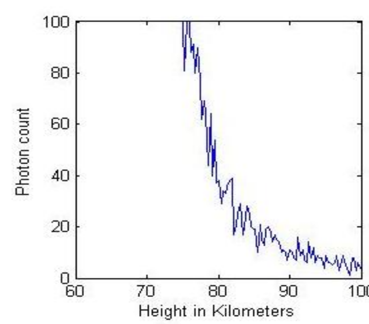

Fig 3:Raw lidar signal from 60 to 100km on 05/04/2007

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II. DENOISING METHODS

Soft and hard thresholding methods are efficient for noise reduction and performance of denoising depends on thresholding estimation

A.Hard Thresholding

Hard Thresholding establishes the values to zero ,the coefficients whose absolute values are less than threshold otherwise coefficient value is not modified is shown in Eq(1)

$$f(H) = \begin{cases} k, \; for|k| \geq T \\ 0, otherwise \end{cases} \quad \ldots\ldots\ldots\ldots\ldots.. (1)$$

where k(n) represents the coefficients and T is the thresholding value

B. Soft Thresholding

Soft thresholding establishes to a sign function which multiplies the subtraction value between a coefficient and threshold value,the coefficients whose absolute values are greater than threshold,and establishes zero coefficients whose absolute values are less than threshold is given in Eq(2)

$$f(H) = \begin{cases} Sign(k).(|k| - T), |k| \geq T \\ 0, |k| < T \end{cases} \quad \ldots\ldots\ldots.(2)$$

III. THRESHOLDING TECHNIQUES

Threshold selection rules consist of mathematical calculations that provide noise thresholding methods like rigrsure, sqtwolog and heursure considered for this study[3]

A. Sqtwolog

Threshold values are calculated using the square root method given in Eq(3)

$$th_i = \sigma_i \sqrt{2\log(N_i)} \quad \ldots\ldots\ldots\ldots\ldots.. (3)$$

Where σ_i is the mean absolute deviation and N_i is the length of the noisy signal and expression for σ_i is given in Eq(4)

$$\sigma_i = \frac{meanabsolutedeviation}{0.6745} = \frac{median(|w|)}{0.6745} \quad (4)$$

Where 'w' represents wavelet coefficients to scale'i'

B. Rigrsure

Threshold selection in rigrsure method is given by Eq(5)

$$th_i = \sigma_i \sqrt{w_c} \quad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where W_c is the c^{th} coefficient wavelet square chosen from the vector $W=[w_1.w_2,---w_n]$,where $w_1.w_2,---w_n$ represents wavelet coefficient squares from small to large.[4]

C.Heursure

Threshold selection is a combination odf sqtwolog and rigrsure methods and sqtwolog gives better threshold estimation[5]

IV PERFORMANCE MEASURE

The performance of three thresholdin methods is evaluated using mathematical calculations like signal to noise ratio(SNR) and root mean square error(RMSE).

A.SNR

Signal to noise ratio is defined as the ratio of signal intensity to the variance from 100 to 300 km. signal intensity means photon count value at the respective altitude.

V. RESULTS

`Signal to noise ratio in decibels at 40km altitude using soft thresholding method is given in Table 1

Table 1: SNR at an altitude of 40km using soft thresholding

Level	Rigrsure	Sqtwolog	Heursure
1	41.14	41.53	41.14
2	44.07	45.02	44.01
3	46.22	48.40	46.22
4	47.65	51.82	47.65
5	48.45	55.50	48.45

It is observed that by increasing the decomposition levels, signal to noise ratio has improved more in sqtwolog thresholding compared to rigrsure and heursure thresholding methods. Signal to noise ratio at an altitude of 40 km using hard thresholding methods shown in Table 2.

Table 2: SNR at an altitude of 40km using hard thresholding

Level	Rigrsure	Sqtwolog	Heursure
1	39.58	41.53	39.58
2	40.47	45.02	40.47
3	40.84	48.40	40.84
4	40.98	51.82	40.98
5	41.04	55.50	41.04

Signal to noise ratio at 80 km using soft and hard thresholding methods is shown in Table 3 and Table 4.

Table 3: SNR at an altitude of 80km using soft thresholding

Level	Rigrsure	Sqtwolog	Heursure
1	11.17	11.56	11.17
2	14.04	15.05	14.04
3	16.24	18.43	16.24
4	17.68	21.85	17.68
5	18.48	25.53	18.48

Table 4: SNR at an altitude of 80km using hard thresholding

Level	Rigrsure	Sqtwolog	Heursure
1	9.61	11.56	9.61
2	10.50	15.05	10.50
3	10.87	18.43	10.87
4	11.01	21.85	11.01
5	11.07	25.53	11.07

By comparing signal to noise ratio at different altitudes from 40 to 80 km , Sqtwolog threshold has more snr compared to rigrsure and heursure thresholding methods. At altitude of 80 km ,more background noise present in lidar signal ,so that snr has limited to 25dB.The signal to noise ratio at different levels from 60 to 100 km and 40 to 100 km is shown in figures 4 and 5.The significant range of the lidar signal has increased from 40 to 80 km using different thresholding methods and the denoised signal at level 5 using sqtwolog and rigrsure thresholds is shown in figures 4 and 5

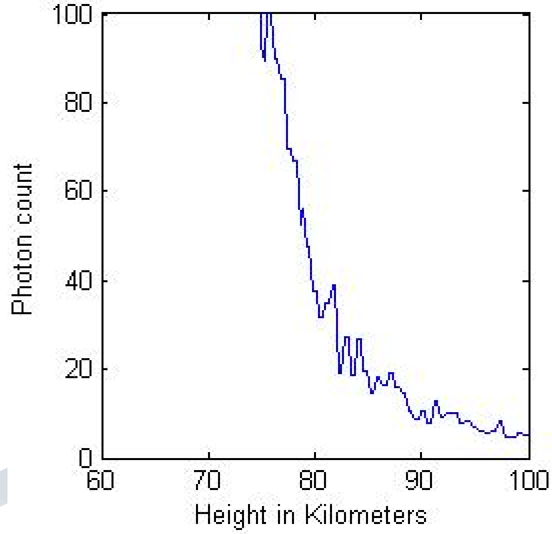

Fig4: Denoised lidar signal at level 3 sqtwolog threshold

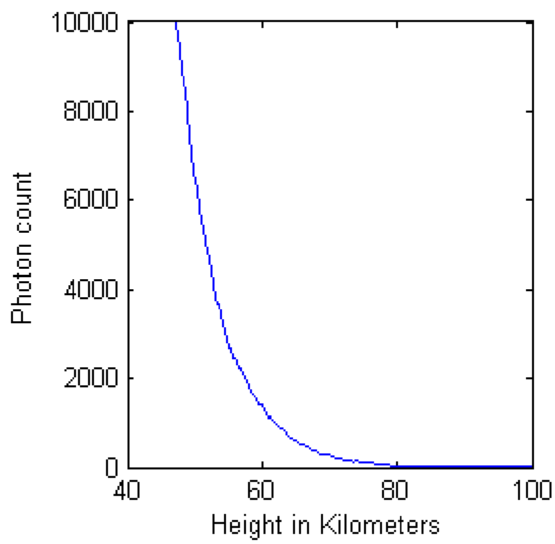

Fig5:Denoised lidar signal at level 5 sqtwolog threshold

VI. CONCLUSION

In this paper, the performance of well-known standard thresholding methods like rigrsure, sqtwolog and heursure presented for denoising lidar signals in the middle atmosphere from 40 to 80 km corrupted by

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background light .Simulations were performed in MATLAB environment. Results are evaluated by calculating signal to noise ratio. The consequence of decomposition levels is examined on the denoising performance of several thresholding evaluation methods. The results indicate that at fourth and fifth decomposition level on hard and soft thresholding, better values of signal to noise ratio is achieved. Overall from the results using Haar Wavelet, sqtwolog on soft thresholding gives the best snr compared with others thresholding methods for denoising lidar signals, still, it is possible to indicate that soft thresholding gives better performance concerning noise reduction than hard thresholding. The significant range of lidar signal is limited to lower altitudes due to less signal to noise ratio and the range is increased from 40 to 80km using wavelet thresholding methods like rigrsure, sqtwolog and heursure .

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