Unclassified

AD-A199 683

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1b. RESTRICTIVE MARKINGS	
2a. SECURITY CLASSIFICATION AUTHORITY	
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE	
3. DISTRIBUTION / AVAILABILITY OF REPORT	Approved for public release; Distribution unlimited
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	
5. MONITORING ORGANIZATION REPORT NUMBER(S)	AFGL-TR-88-0232
6a. NAME OF PERFORMING ORGANIZATION	Photometrics, Inc
6b. OFFICE SYMBOL	
6c. ADDRESS (City, State, and ZIP Code)	4 Arrow Drive Woburn, MA 01801
7a. NAME OF MONITORING ORGANIZATION	Air Force Geophysics Laboratory
7b. ADDRESS (City, State, and ZIP Code)	Hanscom AFB Massachusetts 01731-5000
8a. NAME OF FUNDING / SPONSORING ORGANIZATION	
8b. OFFICE SYMBOL (If applicable)	
8c. ADDRESS (City, State, and ZIP Code)	
9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER	F19628-87-C-0252

DTIC ELECTE SEP 27 1988 S D

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
62101F	4643	14	AH

11. TITLE (Include Security Classification)

RAMAN AUGMENTATION FOR RAYLEIGH LIDAR (U)

12. PERSONAL AUTHOR(S)

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13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
REPRINT	FROM ______ TO ______	1988 September 21	

16. SUPPLEMENTARY NOTATION

Paper presented at International Laser Radar Conference Innichen, San Candida, Italy, June 20-24, 1988

17. COSATI CODES

FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)

LIDAR, RAMAN LIDAR. (mgm/RH)

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Raman detection has recently been added to the Air Force Geophysics Laboratory's ground-based lidar system (GLEAM) to augment that system's Rayleigh lidar measurements. In this paper we examine the possibilities of using the Raman measurements to self-normalize, and downwardly extend, our measurements of stratosphere and lower mesosphere molecular density.

By combining inelastic (Raman) and elastic (Rayleigh plus Mie) scatter measurements, one can isolate the Mie component of the scattering using the techniques of Cooney and correct the data to eliminate the effects of atmospheric attenuation.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT	☐ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS
21. ABSTRACT SECURITY CLASSIFICATION	Unclassified
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22c. OFFICE SYMBOL	AFGL/LID

DD Form 1473, JUN 86 Previous editions are obsolete. SECURITY CLASSIFICATION OF THIS PAGE

AFGL-TR-88-0232

Raman Augmentation for Rayleigh Lidar

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Raman Augmentation for Rayleigh Lidar

Extend lidar atmospheric density measurements downward to a convenient range for normalization.

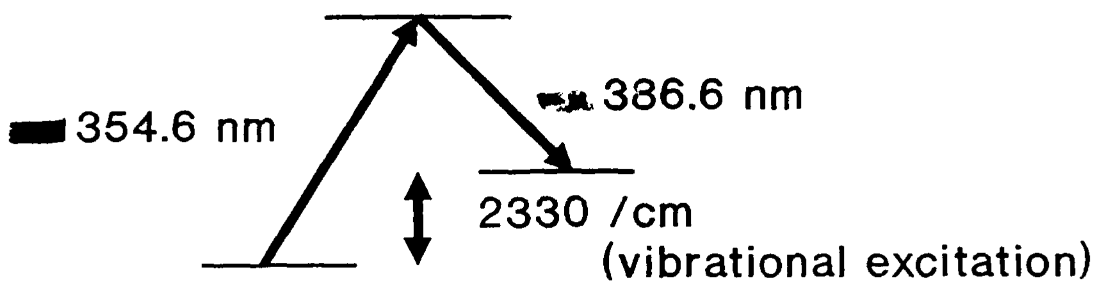
- Below 15 km, Mie scattering from non-gaseous particles contributes strongly to lidar backscatter.
- In the same region, extinction of the laser cannot be ignored if 5 - 10% measurements are needed.

Current Status:

- High altitude Rayleigh density measurements are being made to 85 km.
- The lower bound of the measurements is between 20 and 40 km.
- Rawinsondes provide normalization.

Raman Lidar:

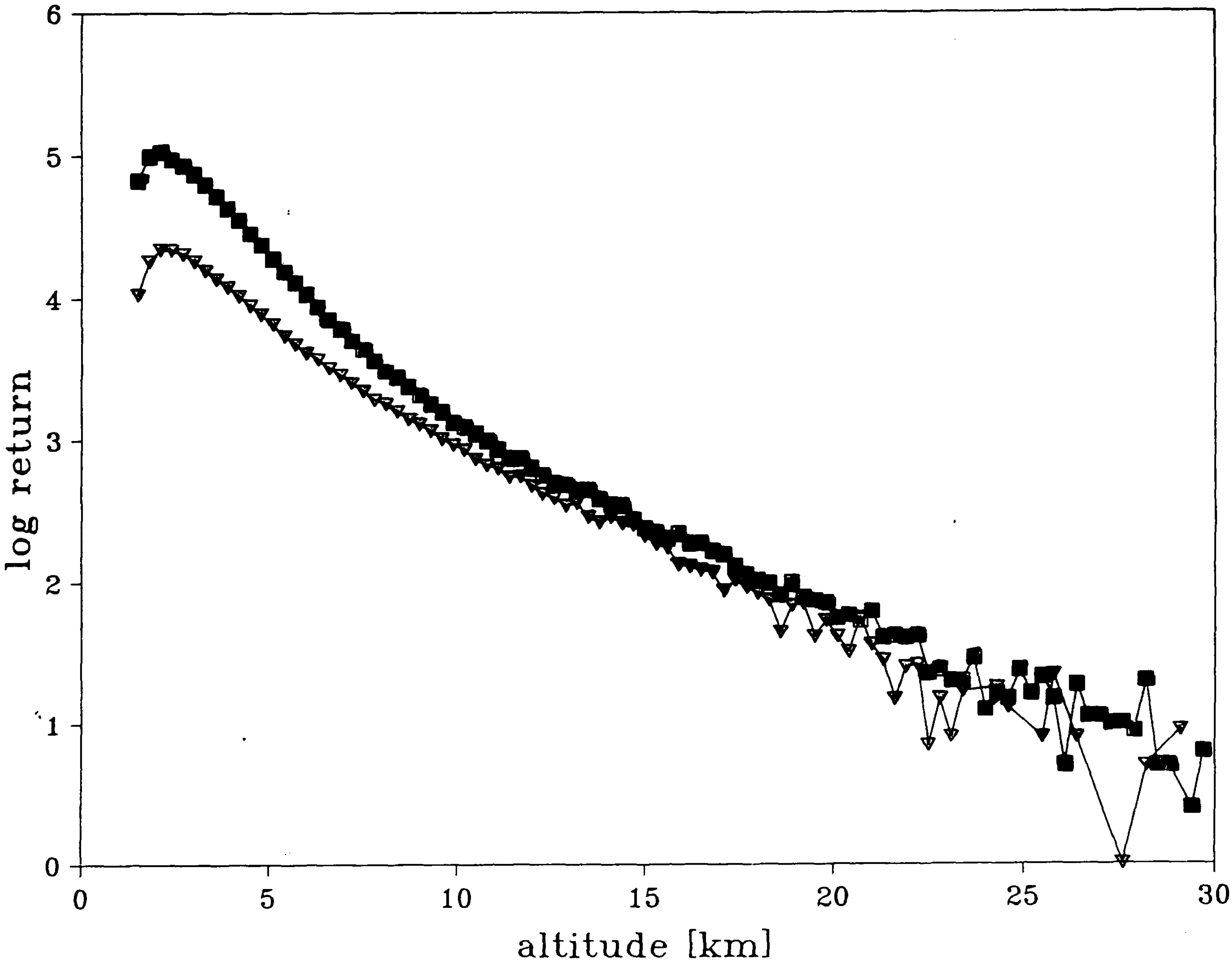
- Sensitive only to nitrogen backscatter.

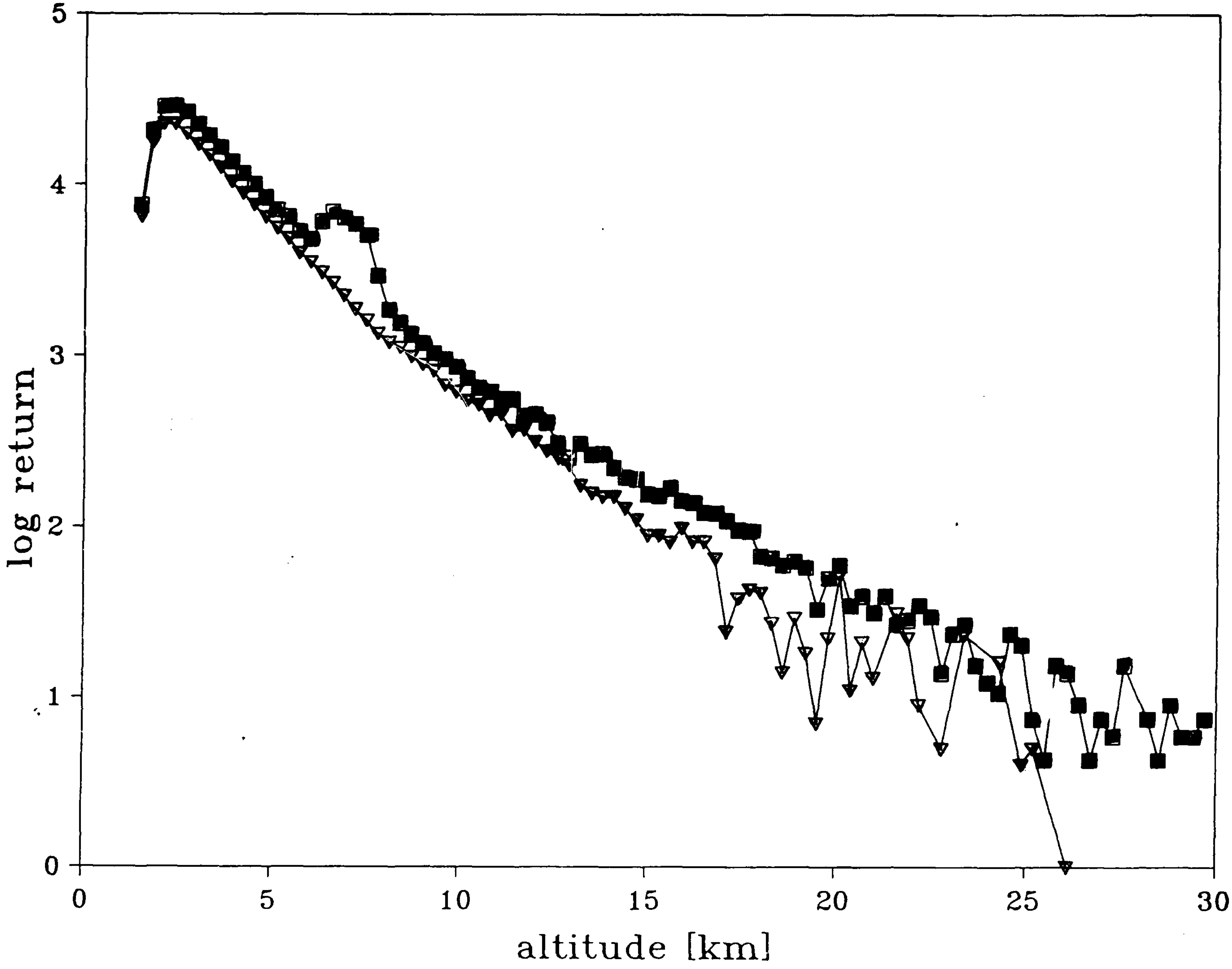


- Vibrational Raman cross section is small - 0.1% of Rayleigh cross section.
- Use simultaneous Rayleigh and Raman lidar - each in its useful regime.

Extinction is present in both Raman (inelastic) and Rayleigh + Mie (elastic) channels.

- Assume extinction is equal for both despite difference in returned wavelengths.
- Use inversion of lidar equation to derive extinction from elastic return.


log return
altitude [km]
0
1
2
3
4
5
6
0
5
10
15
20
25
30



log return
0
1
2
3
4
5
altitude [km]
0
5
10
15
20
25
30

The two-way atmospheric transmission is given by:

$$T(z) = 1 - \frac{2\kappa(z_0)}{z_0^2 S(z_0)} \int_{z_0}^{z} z^2 S(z)\,dz$$

where $S(z)$ is the lidar signal, and $\kappa(z)$ is the extinction.
Alternatively, if $T(z_f)$ is known:

$$T(z) = 1 - \frac{[1 - T(z_f)] \int_{z_0}^{z} z^2 S(z)\,dz}{\int_{z_0}^{z_f} z^2 S(z)\,dz}$$

- Calibration required.
- Proper correction for overlap of laser and receiver field-of-view.
- Wide dynamic range.

Conclusion:

Self-normalized lidar density measurements are possible using a combination of Raman and Rayleigh techniques.