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BACKSCAT LIDAR SIMULATION VERSION 4.0: TECHNICAL DOCUMENTATION AND USERS GUIDE

David R. Longtin
Michael G. Cheifetz
James R. Jones
John R. Hummel

SPARTA, Inc.
24 Hartwell Avenue
Lexington, MA 02173

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PHILLIPS LABORATORY
Directorate of Geophysics
AIR FORCE MATERIEL COMMAND
HANSCOM AIR FORCE BASE, MA 01731-3010

"This technical report has been reviewed and is approved for publication."

Mark A. Cloutier

(Signature)
CAPT MARK A. CLOUTIER
Contract Manager

(Signature)
DONALD E. BEDO
Chief
Measurements Branch

(Signature)
ROGER A. VAN TASSEL
Director
Optical Environment Division

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David R. Longtin, Michael G. Cheifetz, James R. Jones, and John R. Hummel

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Lexington MA 02173

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SPARTA's BACKSCAT software package simulates the performance of lidars for remote sensing and other atmospheric applications. The package accommodates a wide range of lidar systems, viewing scenarios, and atmospheric conditions, plus it contains a user-friendly menu interface system for specifying input parameters. This report gives technical documentation and a Users Guide for BACKSCAT Version 4.0.

In this effort, comprehensive and versatile signal-to-noise (SNR) performance models have been introduced into BACKSCAT. The SNR models give performance and range accuracy estimates for direct detection and coherent Doppler lidar systems, plus estimates of the wind speed accuracy for coherent Doppler systems. The models contain all important noise sources inherent in the detection process and allow the user to select from built-in detectors, as well as define their own detector specifications. In response to the user community, five water clouds have been added to BACKSCAT and they can be "clicked-on" automatically as built-in cloud models. BACKSCAT Version 4.0 also contains an auxiliary software package, "MABS", that estimates the molecular absorption profile for a lidar wavelength. "MABS" generates output that can be used in a simulation. Because "MABS" performs a broadband calculation, it is not intended to be a complete treatment of the molecular absorption problem. Finally, methods of handling the increased size of the BACKSCAT package have been developed.

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Table of Contents

List of Figures

List of Tables

BACKSCAT Lidar Simulation Version 4.0:
Technical Documentation and Users Guide

1 INTRODUCTION

The Electro-Optics Measurements Branch of the Optical Environment Division in the Geophysics Directorate of the Phillips Laboratory (PL/GPOA) uses many lidar systems to probe the atmosphere. These lidar systems typically measure the backscattered return as a way of studying aerosol profiles. Some of the lidar systems have the additional capability of measuring the Doppler return from aerosols for use in determining wind profiles. Other lidar systems have been designed to detect the Raman scattering phenomenon as a way of studying the distributions of molecular species.

In order to interpret the data from lidar systems and to design future lidar systems, it is useful to simulate the operation of lidar systems with computer codes. Since 1988, SPARTA, Inc. has been actively developing a lidar simulation package for the IBM PC environment called BACKSCAT. The code is based on the atmospheric particulate models developed at PL/GPOS and can be used to simulate the backscatter return from lidar systems of different designs, viewing geometries, and atmospheric conditions.

1.1 History of BACKSCAT

SPARTA's BACKSCAT lidar simulation package has undergone considerable growth over the years. For reference, the evolutionary nature of BACKSCAT is shown in Figure 1. Version 1.0[1] was a completely FORTRAN-based package that incorporated a limited menu

[1] Guivens, Jr., N.R., Rafuse, S.E., Hummel, J.R. and Cheifetz, M.G., (1988) "BACKSCAT Lidar Backscatter Simulation User's Manual for Version 1.0," Air Force Geophysics Laboratory, Hanscom AFB, MA, AFGL-TR-88-0331, ADA 219487.

interface system. Version 1.0 permitted users to simulate the backscattered lidar return from model atmospheres and aerosols that have been developed by the Geophysics Directorate.[2] Version 2.0 of BACKSCAT[3] contained a completely redesigned C-based menu interface system. Additionally, Version 2.0 permitted users to simulate the backscattered lidar return from desert aerosols and cirrus clouds, plus the capability to simulate the molecular contribution using radiosonde data. Version 3.0 of BACKSCAT[4] included two features that provided users with more flexible lidar simulation capabilities. The first feature allowed users to define the properties of an aerosol layer by means of size distribution and-index of refraction data. The second feature allowed users to simulate the backscattered lidar return from a Raman scattering lidar system which expanded BACKSCAT from just a backscattering lidar simulation package to a more general purpose lidar simulation package. The purpose of this report is provide technical documentation and a Users Guide for the latest version, BACKSCAT Version 4.0.

1990 Version 1.0
FORTRAN Based System With
AFGL Aerosol Models as
Built-in Defaults

1991 Version 2.0
- New C-Based Menu System
- Cirrus Clouds and Desert
Aerosols Added

1992 Version 3.0
- Surface Reflections Added
- User-Defined Aerosols
- System Efficiency Considered
- Raman Lidars Simulated

1994 Version 4.0
- Signal-to-Noise Added
- Library of Detectors Included
- Coherent Doppler Lidar Simulated
- Water Clouds Included
- Estimates of Molecular Absorption Available

Figure 1. Schematic Representation of the Growth of SPARTA's BACKSCAT Lidar Simulation Package

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[2] Fenn, R.W., Clough, S.A., Gallery, W.O., Good., R.E., Kneizys, F.X., Mill, J.D., Rothman, L.S., Shettle, E.P., Volz, F.E. (1985) "Optical and Infrared Properties of the Atmosphere." Chap. 18 in *Handbook of Geophysics and the Space Environment*, A.S. Jursa Scientific Editor, Air Force Geophysics Laboratory, Hanscom AFB, MA, AFGL-TR-85-0315, ADA 167000.

[3] Hummel, J.R., Longtin, D.R., Paul, N.L., and Jones, J.R. (1991) "BACKSCAT Lidar Backscatter Simulation: User's Guide for Version 2.0," Phillips Laboratory, Hanscom AFB, Massachusetts, PL-TR-91-2181, 11 July, ADA 243949.

[4] Hummel, J.R., Longtin, D.R., DePiero, N.L., and Grasso, R.J. (1992) "BACKSCAT Lidar Backscatter Simulation Version 3.0: Technical Documentation and Users Guide," Phillips Laboratory, Hanscom AFB, Massachusetts, PL-TR-92-2328, 3 December, ADA 267296.

1.2 Summary of Work Performed for BACKSCAT Version 4.0

BACKSCAT Version 4.0 includes a number of major new technical features. Foremost is the ability to evaluate signal-to-noise performance for direct detection and coherent Doppler lidar systems. The performance models are based on standard signal-to-noise relationships and includes all important noise sources. The models permit any detector type and spectral region to be considered. As an additional feature, signal-to-noise ratios are used to estimate the accuracy of range and wind speed measurements for the chosen lidar configuration.

The signal-to-noise performance models transform BACKSCAT into a more general purpose lidar simulation tool. That is, past enhancements to BACKSCAT focused on better ways to define the state of the atmosphere and how it affected the propagation of the lidar beam. However, a thorough assessment of lidar performance must consider the ability of the lidar to detect the backscattered energy after it passes through the atmosphere. With BACKSCAT Version 4.0, users now have more flexibility in regards to the type of detector and how well it responds to the backscattered energy. Thus, BACKSCAT Version 4.0 better serves as a tool for users who want to design a lidar system that explores specific aspects of the atmosphere.

In response to the user community, the second new feature in BACKSCAT Version 4.0 is the ability to include water clouds in lidar simulations. Although the user-defined aerosol option in BACKSCAT Version 3.0 can be used to represent water clouds, it requires detailed information about the cloud particle size distribution that might not be available to some users. Thus, as an alternate approach, water clouds now can be "clicked on" automatically as a built-in cloud model.

The third new feature in BACKSCAT Version 4.0 is an auxiliary package that estimates the molecular absorption profile for a particular lidar wavelength. Although the framework of BACKSCAT Versions 1.0 through 3.0 provided the means to include molecule absorption in a simulation, BACKSCAT did not provide a tool to calculate the molecular absorption. Thus, the burden of obtaining molecular absorption profiles rested entirely with the user. In BACKSCAT Version 4.0, the molecular absorption package has been named *mabs* and generates output that can be directly used in a lidar simulation. It must be noted that *mabs* performs a broad band calculation, so the package is not intended to be a complete treatment of the molecular absorption problem.

The fourth new feature to BACKSCAT Version 4.0 is a rudimentary installation utility. This installation utility is included on the BACKSCAT Version 4.0 distribution diskettes and reduces the amount of user intervention in the initial BACKSCAT setup.

Another development in BACKSCAT Version 4.0 concerns the computer requirements for the package. Specifically, the addition of new software has caused BACKSCAT to encroach on the 640 Kbytes memory barrier imposed by MS-DOS. To overcome this problem, the "science" portion of the code (*backscat.exe*) and the user-defined aerosol package (*usraer.exe*) are now compiled as protected-mode Microsoft FORTRAN programs. The protected-mode programs are then executed from the menu interface system by means of the Phar Lap 286/DOS-Extender™. From the viewpoint of the user, this solution to the memory problem does not alter the flow of execution of BACKSCAT. However, users who wish to recompile the software must have the Phar Lap 286/DOS-Extender™ Run Time Kit (RTK) and bind it with the protected-mode programs.

1.3 Organization of the Report

This report provides technical documentation and a Users Guide for BACKSCAT Version 4.0. Chapter 2 gives detailed information about the new features in BACKSCAT including signal-to-noise performance relations for direct detection and coherent Doppler lidar systems, descriptions of five built in detectors, scientific background for the water clouds feature, and the treatment of molecular absorption. Sample results for the performance models are given in Chapter 3. The remaining chapters in this report serve as a Users Guide for BACKSCAT Version 4.0. Chapter 4 gives an overview of BACKSCAT Version 4.0, including its computer requirements and instructions to install and start the code. Chapter 5 describes how to use many of the Main Menu options for BACKSCAT Version 4.0. Since some of the features in the BACKSCAT menu interface require extensive documentation, they are described in separate chapters. Chapter 6 describes the Main Menu option used to specify a lidar system, including new parameters for the signal-to-noise performance models. Chapters 7 and 8 describe the Main Menu options used to define the viewing and atmospheric conditions, respectively. Chapter 9 describes how to define a user-defined aerosol layer and Chapter 10 describes how to use the Radiosonde Data Entry Program. Currently, the Radiosonde Data Entry Program can be accessed from BACKSCAT Version 4.0 or used as a standalone program. Note that the options discussed in Chapter 7 and 9 are **unchanged** from BACKSCAT Version 3.0, but documentation is provided for completeness. Finally, Chapter 11 provides a summary and recommendations for future work. Two appendices are also included. Appendix A describes the data files used by the code and Appendix B includes instructions on running the code in batch mode.

2 TECHNICAL DOCUMENTATION FOR NEW FEATURES

This chapter gives technical documentation for the new features in BACKSCAT Version 4.0. Instructions to invoke these features from the menu interface are given in the Users Guide, which begins in Chapter 4. Technical documentation for other BACKSCAT features can be found the manuals for Versions 2.0 and 3.0.[3,4]

2.1 Signal-to-Noise Performance Relations for Direct Detection Systems

The signal-to-noise performance relationships for direct detection lidar systems are developed below. In the framework of BACKSCAT Version 4.0, these relationships apply to aerosol backscatter and Raman lidar systems. As output, a BACKSCAT simulation includes values of signal-to-noise as a function of range and altitude. For the most part, the signal-to-noise relationships are taken from readily available references such as Wolfe and Zissis,[5] Kingston,[6] Jelalian,[7] and Skolnik.[8]

2.1.1 Assumptions

The performance model for direct detection systems assumes that the signal-to-noise ratio (SNR) is relatively large, so the lidars do not operate within the photon counting regime. Also, it is assumed that the detection system uses a matched filter and that the field-of-view of the receiver and transmitter are matched. Presently, only pulsed lidar systems are considered. For reference, Table 1 lists the signal and noise factors that are considered for direct detection systems.

Table 1. Signal and Noise Factors That Are Considered in the Performance Model for Direct Detection Systems. In BACKSCAT Version 4.0, aerosol backscatter and Raman lidar systems are direct detection systems

SIGNAL FACTORS	NOISE FACTORS
Hardware optical efficiencies	Signal photon shot noise
Atmospheric attenuation	Background photon shot noise
Aerosol backscatter	Thermal (Johnson) noise
Detector quantum efficiency	Detector dark current
Aperture size/obscuration	Preamplifier noise
Lidar output power	Spatial/spectral/temporal noise suppression
Lidar beam quality	Hardware optical efficiencies
	Detector quantum efficiency
	Detector noise equivalent power (NEP) and excess noise figure

The performance model in BACKSCAT Version 4.0 does not consider flicker noise and optical turbulence effects. In general, turbulence effects can cause a substantial loss in signal and greatly reduce the effectiveness of any lidar system. These effects on a laser beam, both spatial and temporal, include beam wander, beam spread, spatial coherence loss, beam fading/distortion, and beam break-up.

[5] Wolfe, W.L. and Zissis, G.J. (eds.) (1978) *The Infrared Handbook*, Infrared Information and Analysis Center, ERIM, Washington, D.C.

[6] Kingston, R.H. (1978) *Detection of Optical and Infrared Radiation*, Springer-Verlag, New York.

[7] Jelalian, A.V. (1992) *Laser Radar Systems*, Artech House, Boston.

[8] Skolnik, M.I. (ed.) (1970) *Radar Handbook*, McGraw-Hill, New York.

2.1.2 Governing Equations

The SNR relations consider all the important noise terms inherent to the detection processes for photomultipliers (PMT), avalanche photodiodes (APD) and photovoltaic (PV) long wave infrared (LWIR) detectors. These noise sources include signal shot noise, background shot noise, dark current, Johnson (thermal) noise and other amplifier noise factors.

The voltage signal-to-noise ratio is defined as

$$\mathrm{SNR} = \sqrt{\overline{i_s^2} / \overline{i_n^2}}, \tag{1}$$

where $\overline{i_s^2}$ is the mean square current due to the return signal and $\overline{i_n^2}$ is the overall mean square noise current due to all noise sources. The mean square signal current is

$$\overline{i_s^2} = G^2 \Re^2 P_s^2, \tag{2}$$

where P_s is the received power on the detector due to atmospheric backscatter. $\Re$ is the detector cathode responsivity at the lidar wavelength, λ, and G is the detector gain. The signal current can be recast in terms of the detector's quantum efficiency, η, as

$$i_s = G \frac{\eta e}{h\nu} P_s, \tag{3}$$

where h is the Planck constant, ν is λ/c with c being the speed of light, e is the charge of an electron (1.6×10^{-19}C), and the cathode responsivity equals

$$\Re = \frac{\eta e}{h\nu}. \tag{4}$$

In Eqs. 2 and 3, the received power from a volume of aerosol a distance R away from the lidar is

$$P_s = P_l \tau_T \tau_a^2 \tau_R \frac{\beta c t_p}{2} \frac{\varepsilon A_R}{R^2}, \tag{5}$$

where

P_l is the peak power per lidar pulse;
τ_T is the overall transmitter optical efficiency;
τ_a is the one way atmospheric transmission to the aerosol volume location;
τ_R is the overall receiver optical efficiency which includes any narrowband filter transmission and polarization losses;
β is the backscatter coefficient at the aerosol volume location;
t_p is the lidar pulse length;
A_R is the receiver collector outer aperture area; and
ε is the receiver obscuration efficiency.

In Eq. 5, the obscuration efficiency equals

$$\varepsilon = 1 - \frac{D_{obs}^2}{D_R^2}, \tag{6}$$

and the receiver collector outer aperture equals

$$A_R = \pi D_R^2 / 4 \tag{7}$$

where D_R is the receiver diameter and D_{obs} is the diameter of any obscuration. The effective collection area is equal to εD_R. Also note that Eq. 5 assumes the field-of-view (FOV) of the transmitter and receiver are matched. That is, the laser spot size on target is the same size as the "image" seen on the detector. Thus, the FOV is not required in the lidar SNR equation when there is no atmospheric background radiance.

In Eq. 1, the total detection system noise current is

$$i_n = \sqrt{2eBFG^2\Re(P_s + P_b) + i_{sys}^2}, \tag{8}$$

where F is the detector excess noise figure, B is the matched filter electronic bandwidth ($B=1/2t_p$), and i_{sys} is the total detector system noise current from all other sources. In Eq. 8, the total detector system noise current can be specified in two ways. First it can be related to the system noise equivalent power source term

$$i_{sys} = \Re G B \sqrt{\overline{\mathrm{NEP}}} \tag{9}$$

where $\overline{\mathrm{NEP}}$ is the system noise equivalent power density, or second

$$i_{sys} = \sqrt{i_J^2 + i_{dc}^2 + i_a^2}. \tag{10}$$

where i_{dc} is the rms dark current noise, i_J is the Johnson (thermal) noise, and i_a is other amplifier noise current terms. The rms dark current noise is expressed in terms of the dark current at the anode, I_{dca},

$$i_{dc} = \sqrt{2eFBGI_{dca}}. \tag{11}$$

and the Johnson noise term equals

$$i_J = \sqrt{4kT_L B / R_L}, \tag{12}$$

where R_L is the load resistor, T_L is the effective load temperature, and k is the Boltzmann constant. In Eq. 8, the power, P_b, received at the detector focal plane due to background radiance is

$$P_b = L_b \, \Delta\lambda \, \Omega_R \, \tau_R \, \varepsilon \, A_R, \tag{13}$$

where L_b is the background radiance, $\Delta\lambda$ is the receiver spectral bandpass filter bandwidth, and Ω_R is the total instantaneous solid angle of the receiver FOV. In Eq. 13, Ω_R equals $\pi\theta_R^2/4$ where θ_R is the full angle instantaneous FOV of the receiver (and transmitter). Note that the full angle instantaneous FOV of the receiver must be greater than the diffraction limit of the receiver optics, θ_{dl},

$$\theta_R \geq \theta_{dl} = \frac{4}{\pi}\frac{\lambda}{D_R}. \tag{14}$$

BACKSCAT Version 4.0 issues a warning message in the log file whenever Eq. 14 is not satisfied.

2.2 Signal-to-Noise Performance Relations for Coherent Doppler Systems

This section gives the signal-to-noise performance relationships for coherent Doppler lidar systems. As with direct detection systems, the signal-to-noise relationships are taken from readily available references such as Wolfe and Zissis,[5] Kingston,[6] Jelalian,[7] and Skolnik.[8]

2.2.1 Assumptions

In most operational coherent Doppler systems, the local oscillator power can be made large enough to provide shot-noise limited operation of the receiver. This is assumed to be the case in the signal-to-noise performance model in BACKSCAT Version 4.0. The performance model also assumes unity mixing efficiency of the local oscillator with the atmospheric return. As with direct detection systems, it is assumed that the detection uses a matched filter and that the field-of-view of the receiver and transmitter are matched. Also, turbulence effects are not considered in this version. In coherent Doppler systems, optical turbulence can cause a severe loss in detected signal due to wavefront distortion effects on the mixing efficiency and it can also limit the effective size of the receiver diameter.

2.2.2 Governing Equations

In coherent Doppler systems, a local oscillator operating at a single frequency, ω_{LO}, is used as a reference beam to down-convert the amplitude of the incoming signal and phase at the optical signal frequency, ω_s, into a low frequency. The combined current due to the local oscillator and incoming signal is

$$i(t) = i_{LO} + i_s + 2\sqrt{i_{LO}\, i_s}\cos(\omega_s - \omega_{LO})t, \tag{15}$$

where i_{LO} and i_s are the dc currents due to the local oscillator and signal power, respectively. The intermediate frequency, ω_{if}, which is much smaller than both the local oscillator and optical signal frequencies, equals the difference between the frequency of the two beams

$$\omega_{if} = \omega_s - \omega_{LO}. \tag{16}$$

For coherent Doppler systems, the voltage signal-to-noise is defined as

$$SNR = \sqrt{\overline{i_{SIG}^2} / \overline{i_n^2}} \tag{17}$$

where $\overline{i_{SIG}^2}$ is the mean square intermediate frequency current due to the return signal and $\overline{i_n^2}$ is the overall mean square noise current due to all noise sources. The mean square intermediate frequency current is obtained by time averaging the detector current *i(t)* in Eq. 15

$$\overline{i_{SIG}^2} = (2\sqrt{i_{LO} i_s})^2 / 2 = 2 i_{LO} i_s, \tag{18}$$

where averaging over the cosine-squared term introduces the 1/2 factor. The noise term is the sum of all the possible noise sources

$$\overline{i_n^2} = i_{n_{LO}}^2 + i_{n_s}^2 + i_{n_b}^2 + i_j^2 + i_{dc}^2 + i_a^2, \tag{19}$$

where $i_{n_{LO}}^2$, $i_{n_s}^2$, $i_{n_b}^2$, i_j^2, i_{dc}^2, and i_a^2 are noise currents due to the local oscillator, the signal, background, thermal, dark current, and other amplifier noise factors, respectively. The local oscillator shot-noise is the only new noise term not discussed previously. It equals

$$i_{n_{LO}}^2 = 2eBFG\, i_{LO}. \tag{20}$$

With sufficient local oscillator power, only the Johnson noise term might compete with the local oscillator. Thus,

$$SNR = \sqrt{\overline{i_{SIG}^2} / (\overline{i_{n_{LO}}^2} + \overline{i_j^2})} \tag{21}$$

and after substituting Eqs. 12, 18, and 20

$$SNR = \sqrt{\frac{2 i_{LO} i_s}{2eGFBi_{LO} + (4kT_L B / R_L)}} \tag{22}$$

or

$$SNR = \sqrt{\frac{i_s}{eGFB\left(1 + \frac{2kT_l}{eGFR_l i_{LO}}\right)}} \tag{23}$$

As in Eq. 3, the local oscillator current can be recast in terms of the local oscillator power, P_{LO},

$$i_{LO} = G\frac{\eta e}{h\nu}P_{LO}, \tag{24}$$

and substituting Eqs. 3 and 24 into the SNR relation gives

$$SNR = \sqrt{\frac{\eta P_s}{h\nu FB}\frac{1}{\left(1 + \frac{2kT_l h\nu}{e^2 G^2 FR_l \eta P_{LO}}\right)}} \tag{25}$$

With the assumption that P_{LO} is large, the Johnson noise term becomes negligible and the SNR relation reduces to the shot-noise limit

$$SNR = \sqrt{\frac{\eta P_s}{h\nu FB}} \tag{26}$$

where F equals 1 for CO_2 Doppler systems and

$$P_{LO} >> \frac{2kT_L}{R_L}\frac{1}{eFG^2}\frac{h\nu}{e\eta}. \tag{27}$$

For reference purposes, the quantity in Eq. 27 is always included in BACKSCAT's log file.

2.3 Estimates of Range and Velocity Accuracy

The ability of a lidar to detect an atmospheric return is fundamentally limited by noise. For example, the range of an atmospheric return is determined by when the received signal crosses a threshold noise value in the receiver. For coherent Doppler systems, the determination of a target's velocity is limited by the ability of the Doppler processor to locate the center frequency of the received signal spectrum having a signal-to-noise ratio and finite observation time.

To help users evaluate lidar performance, BACKSCAT Version 4.0 uses the signal-to-noise ratios to estimate the accuracies of range and velocity measurements for the chosen lidar configuration. As output, a BACKSCAT simulation includes range accuracies as a function of range and altitude (velocity accuracies are only included for coherent Doppler systems). In the framework of BACKSCAT, the term "accuracy" only refers to the uncertainty introduced by finite signal-to-noise ratios and, thus, it is confined to a system's inherent measurement capability. (Accuracy should not be confused with the range or velocity resolution of a lidar, which are fixed by the pulse duration and refer to the grid spacing for range and velocity measurements by a lidar.)

2.3.1 Assumptions

Because output from the SNR performance model is used, estimates of range and velocity accuracy are subject to the assumptions discussed in Sections 2.1.1 and 2.2.1. The governing equations currently assume a rectangular pulse of length t_p, although this limitation can be relaxed in future versions of BACKSCAT. The estimations do not consider other factors that may limit measurement accuracy. For example, it is assumed that no wind field structure exists within range bins, either small scale turbulence or large scale wind shear. The lidar is assumed to be stationary and there are no short-term or long-term pointing errors. Finally, for coherent Doppler systems, it is assumed that there is no frequency jitter in the local oscillator.

2.3.2 Governing Equations

The expressions governing range and velocity accuracy are taken from Jelalian[7] and Skolnik.[9] The range accuracy, σ_R, is given as

$$\sigma_R = \frac{\Delta R}{\sqrt{2SNR}} \tag{28}$$

where $\Delta R = c\,t_p/2$. For coherent Doppler systems, the velocity accuracy is derived from the frequency accuracy, σ_f, which equals

$$\sigma_f = \sqrt{\frac{3}{2}}\frac{1}{\pi t_p}\frac{1}{SNR} \tag{29}$$

Using the Doppler relationship

$$f = \frac{2V}{\lambda}\cos\gamma \tag{30}$$

the conversion factor for velocity accuracy equals $\lambda/2$ where γ is the angle between the velocity vector and the line-of-sight of the lidar. Thus, the velocity accuracy, σ_V, is given as

$$\sigma_V = \sqrt{\frac{3}{2}}\frac{\lambda}{2\pi t_p}\frac{1}{SNR} \tag{31}$$

[9] Skolnik, M.J. "Theoretical Accuracy of Radar Measurements," *IRE Transactions on Aeronautical and Navigational Electronics*.

Note that care must be taken when applying the relations for range and velocity accuracy These relations are primarily for hard target returns and not for targets distributed within a range bin (*i.e.*, the aerosol) with variable and/or random motion. For both range and velocity measurements, there will be amplitude and phase modulation of the return signal. The range accuracy of an aerosol medium within a range bin is somewhat misleading and inappropriate. Furthermore, the Doppler spectrum of an aerosol medium can have a very broad spectral envelope so the velocity accuracy can again be misleading.

2.3.3 Comparisons Against Existing Atmospheric Wind Fields

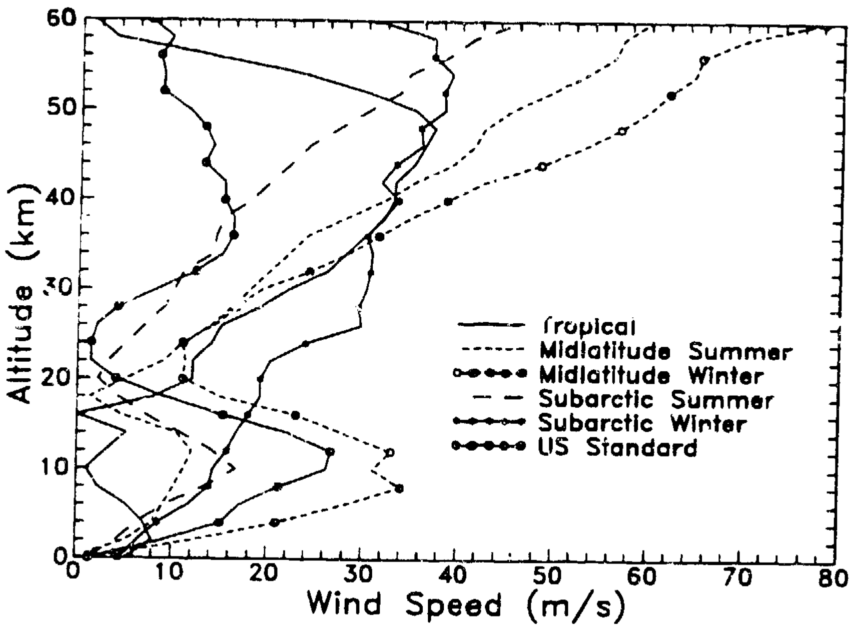
For coherent Doppler simulations, it is useful to compare velocity accuracies for a lidar configuration against existing atmospheric wind fields. These wind fields are neither used in the simulation nor are any wind fields produced by the simulation. Rather, the wind velocity accuracy as "measured" by the simulated lidar can be referenced to these wind fields.

In BACKSCAT Version 4.0, atmospheric wind fields can be specified with radiosonde data or users can select from built-in wind fields that are representative of six model atmospheres. When radiosonde data are used, users can specify an existing radiosonde data file or create one with the Radiosonde Data Entry Program (see Chapter 10). The built-in wind field models come from Kantor and Cole[10] who have tabulated monthly averages of wind fields at various locations around the world. Table 2 lists the wind fields that have been chosen to represent six model atmospheres. For reference, the built-in wind speeds and directions are shown in Figure 2. It is important to note that the monthly averages of the Kantor and Cole data have large variances, so they should only be used for "what if" research studies.

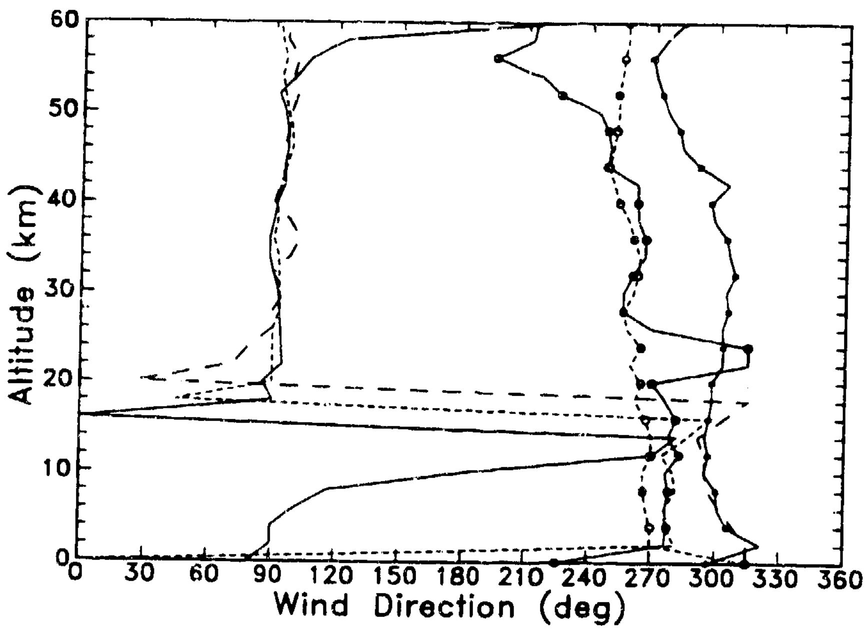
Table 2. Locations and Monthly Averages of Wind Field Data[10] That Have Been Chosen to Represent the Six Model Atmospheres

MODEL ATMOSPHERE	LOCATION USED	MONTH USED
Tropical	Kwajalein (9°N,168°E)	July
Midlatitude Summer	Wallops Island, Virginia (38°N,75°W)	July
Midlatitude Winter	Wallops Island, Virginia (38°N,75°W)	January
Subarctic Summer	Fort Churchill, Manitoba (59°N,94°W)	July
Subarctic Winter	Fort Churchill, Manitoba (59°N,94°W)	January
US Standard	Wallops Island, Virginia (38°N,75°W)	April

[10] Kantor, A.J., and Cole, A.E. (1980) "Wind Distributions and Interlevel Correlations, Surface to 60 km," Air Force Geophysic Laboratory, Hanscom AFB, Massachusetts, AFGL-TR-80-0242, 19 August, ADA 092670.



(a.)



(b.)

Figure 2. Built-In Wind Profiles for Six Model Atmospheres. (a.) Wind Speed. (b.) Wind Direction

During a coherent Doppler lidar simulation, BACKSCAT converts the existing wind field to the radial wind speed, V_r, at range R along the lidar line-of-sight. Assuming the wind field is horizontally uniform and no vertical motion exists, the conversion is

$$V_r(R) = V(R)|\cos\theta|\cos(\varphi - \phi_w(R)) \tag{32}$$

where θ and φ are the lidar elevation and azimuth angles, respectively, and $\phi_w(R)$ and $V(R)$ are the wind direction and wind speed, respectively, at range-R. Any ranges above (or below) the limits of wind field data use the highest (or lowest) values. Note that winds moving towards the lidar are positive.

2.4 Types of Detectors

BACKSCAT Version 4.0 contains five built-in detectors for use with the SNR performance models. The five detectors have their parameters fixed and they cannot be changed. Below, the specifications for the five detectors are given and their wavelength regions of operation are provided. Additionally, users can define their own detector in terms of the parameters given in Section 2.1.2.

2.4.1 Overview

In the visible and UV regions, avalanche photodiodes (APD) and photomultiplier tubes (PMT) are available as built-in detectors. PMT detectors offer high internal gain and low noise performance because Johnson, amplifier, and dark current noise sources are usually negligible when compared to photon shot noise. On the other hand, APD detectors have a much higher quantum efficiency but poorer gain and noise performance than PMT detectors. The lower gain of APD detectors dramatically increases the significance of the Johnson and amplifier noise. However, the higher quantum efficiency of APD detectors ultimately allows photon shot noise to dominate system performance, even when the effects of lower gain and noise performance are considered.

In the LWIR region ($\approx$10 μm), a cooled photovoltaic (PV) HgCdTe detector is available as a built-in detector. This detector can be selected for CO_2 coherent Doppler lidar systems and it offers a relatively high detectivity and quantum efficiency.

2.4.2 APD-Visible Detector

The C30919 APD detector, manufactured by EG&G[11], includes an integral preamplifier and temperature compensation circuit. EG&G specifies an overall system noise equivalent power density which includes all dark current, Johnson noise, and amplifier noise terms. The applicable

[11] EG&G Electro Optics Inc. (1987) Data Sheet for Photodiode-Preamplifier Module C30919E, Canada.

wavelength regime of this detector is approximately 0.45 μm to 1.1 μm. Curve fits for the quantum efficiency and overall system responsivity ($\Re_s$) are given in Figure 3.

The detector gain, responsivity, and spectral NEP of the built-in APD detector are obtained from the system responsivity and quantum efficiency curves using

$$\overline{NEP_\lambda} = \frac{2\times 10^{-14}}{\Re_s(\lambda)}, \tag{33}$$

and

$$\Re_s = 0.8\eta\lambda_\mu \tag{34}$$

where λ_μ is the lidar wavelength in microns. The detector excess noise figure, F, is the only other parameter that is required for the performance of the built-in APD detector. The detector specifications are given in Table 3.

2.4.3 Visible PMT Detector

To give users a choice of detectors at visible wavelengths, BACKSCAT Version 4.0 also offers a visible PMT detector. The detector chosen is the Hamamatsu R636 side-on type photomultiplier tube with a 28 mm diameter.[12] The curve fits of the R636 quantum efficiency and responsivity are shown in Figure 4. Table 4 lists the tube's specifications.

2.4.4 UV PMT Detector

BACKSCAT Version 4.0 also offers a PMT that is better suited for the UV region (*i.e.*, the Raman scattering regime). The UV detector chosen is the Hamamatsu R375 head-on type PMT[12] with a 51 mm base diameter. The curve fits of the R375 quantum efficiency and responsivity are shown in Figure 5. Table 5 lists the tube's specifications.

2.4.5 SWIR Optimized APD Detector

EG&G also makes a version of their visible APD that is optimized to operate in the SWIR ($\approx$1 μm) by "dimpling" the silicon detector's surface.[13] It is assumed that this detector is only used within a very narrow spectral region so all parameters are constant. The specifications for this detector are given in Table 6.

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[12] Hamamatsu, Inc. (1989) Photomultiplier Tubes Catalog, Hamamatsu Photonics K.K., Electron Tube Division.

[13] Polansky, C. (1991) Private Communication, EG&G Electro Optics, Inc.

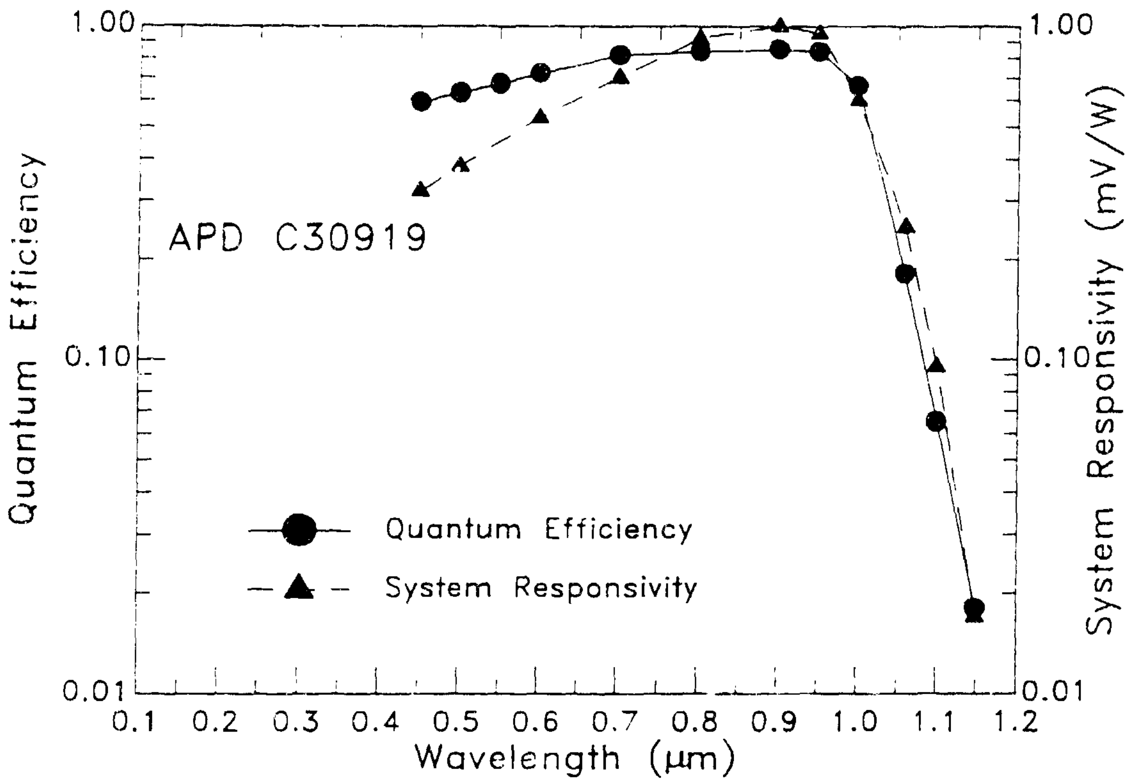

Figure 3. Quantum Efficiency and System Responsivity for the Built-In C30919 APD Detector

Table 3. Specifications for the Built-In C30919 APD Detector

PARAMETER	UNITS	SPECIFICATION
Spectral response range	μm	0.40 - 1.10
Spectral response range (curve fit)	μm	0.45 - 1.10
Quantum efficiency, η	(-)	0.84 @ λ=0.85 μm
Cathode responsivity, $\Re$	A/W	0.58 @ λ=0.85 μm
Total system gain, G	(-)	36000 @ λ=0.85 μm
Total system responsivity, $\Re_s$	MV/W	1.0 @ λ=0.85 μm
System spectral NEP, $\overline{NEP}$	$W/\sqrt{Hz}$	2×10^{-14} @ λ=0.85 μm
Excess noise figure (measured), F	(-)	3.0
Active detector diameter	mm	0.8
Operating temperature range	C	-40 to 70
Output rise time	ns	≤ 10

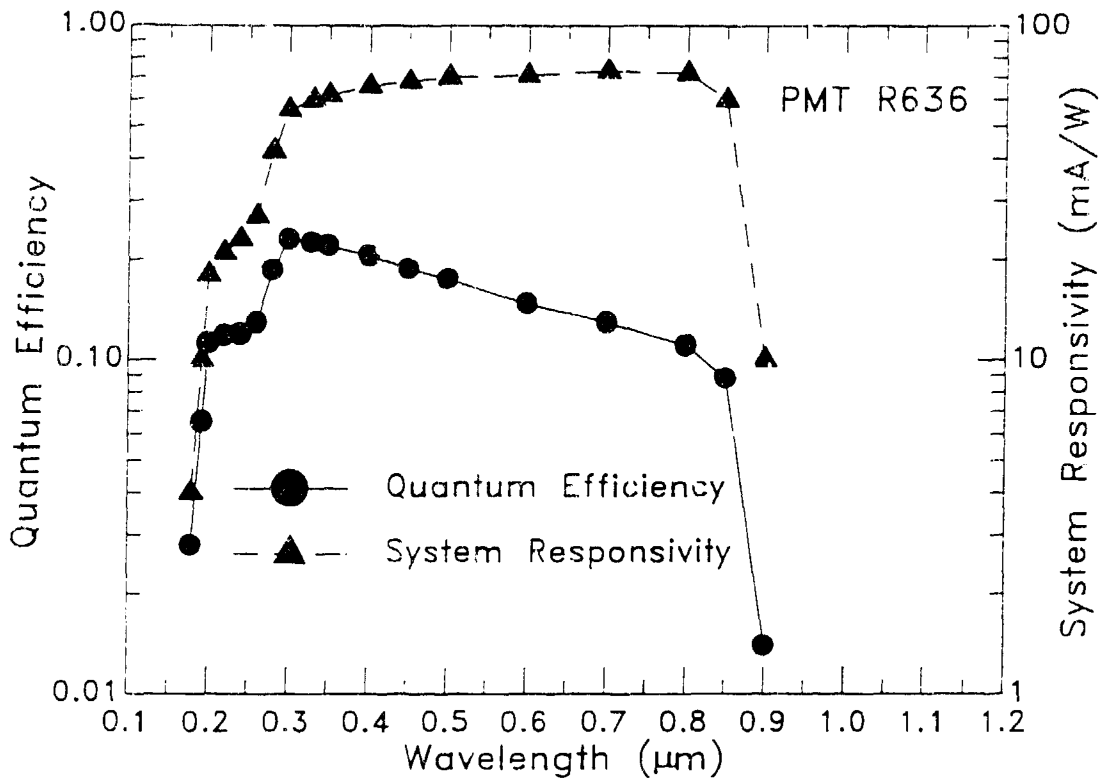

Figure 4. Quantum Efficiency and System Responsivity for the Built-In Visible PMTs (R636) Detector

Table 4. Specifications for the Built-In Visible PMT (R636) Detector

PARAMETER	UNITS	SPECIFICATION
Spectral response range	μm	0.185 - 0.93
Spectral response range (curve fit)	μm	0.185 - 0.90
Quantum efficiency, η	(-)	0.088 @ λ=0.85 μm
Cathode responsivity, $\Re$	mA/W	60.0 @ λ=0.85 μm
Total system gain, G	(-)	1.8×10^5
Anode dark current, I_{dc}	namp	0.10
Excess noise figure, F	(-)	1.20
Load resistor, R_L	ohm	50.0
Effective load temperature, T_L	K	300.0
Other amplifier noise current, i_a	namp	0.0

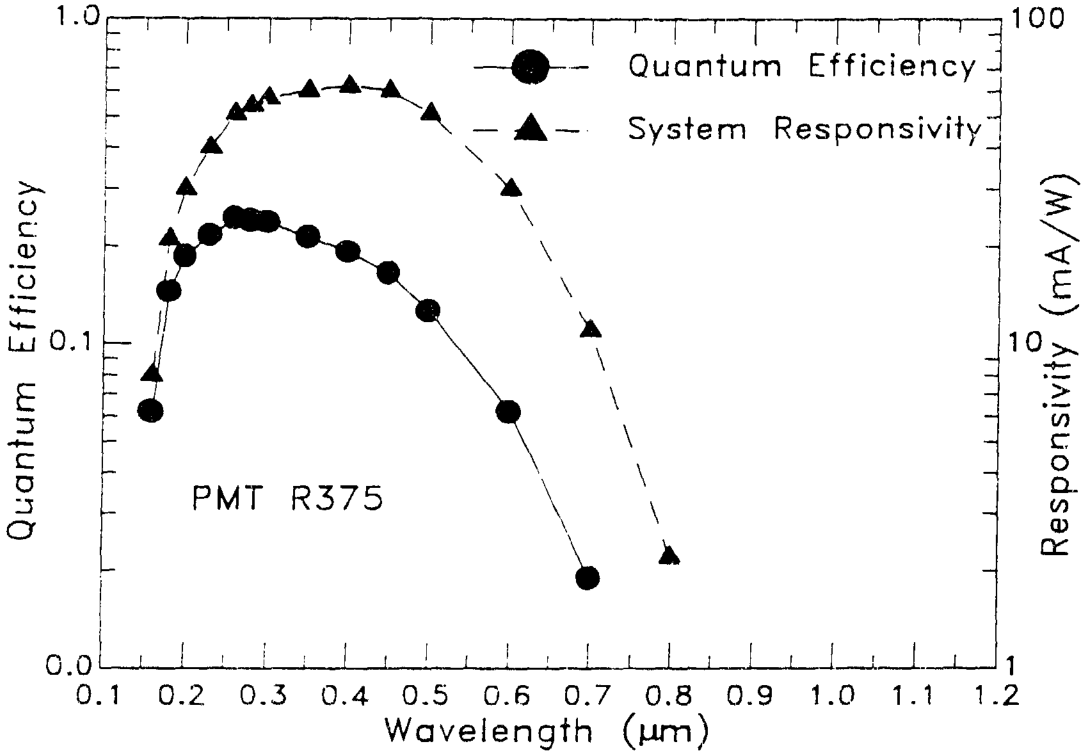

Figure 5. Quantum Efficiency and System Responsivity for the Built-In UV PMT (R375) Detector

Table 5. Specifications for the Built-In UV PMT (R375) Detector

PARAMETER	UNITS	SPECIFICATION
Spectral response range	μm	0.16 - 0.85
Spectral response range (curve fit)	μm	0.16 - 0.70
Quantum efficiency, η	(-)	0.19 @ λ=0.40 μm
Cathode responsivity, $\Re$	mA/W	62 @ λ=0.40 μm
Total system gain, G	(-)	6.7×10^5
Anode dark current, I_{dc}	namp	5.0
Excess noise figure, F	(-)	1.2
Load resistor, R_L	ohm	50.0
Effective load temperature, T_L	K	300.0
Other amplifier noise current, i_a	namp	0.0

Table 6. Specifications for the Built-In "Dimpled" APD Detector

PARAMETER	UNITS	SPECIFICATION
Spectral response range (curve fit)	μm	1.04 - 1.06
Quantum efficiency, η	(-)	0.40
Cathode responsivity, $\Re$	A/W	0.51
Total system gain, G	(-)	30000
Total system responsivity, $\Re_s$	MV/W	0.5
System spectral NEP, $\overline{NEP}$	$W/\sqrt{Hz}$	4×10^{-14}
Excess noise figure, F	(-)	3.0
Active detector diameter	mm	0.8
Operating temperature range	C	-40 to 70
Output rise time	ns	≤ 10

2.4.6 LWIR Detector

For coherent Doppler lidars operating in the LWIR region ($\approx$10 μm) a cooled HgCdTe photovoltaic detector[5] is available as a built-in detector. D^* equals 5×10^{10} cm$\sqrt{Hz}$/W within a 30° FOV at 100K and an assumed size of 0.5 mm. The specifications for this detector are given in Table 7.

Table 7. Specifications for the Built-In LWIR HgCdTe Detector

PARAMETER	UNITS	SPECIFICATION
Spectral response range (curve fit)	μm	9 - 11
Quantum efficiency, η	(-)	0.40
Specific detectivity, D^*	cm$\sqrt{Hz}$/W	5×10^{10}
System spectral NEP, $\overline{NEP}$	$W/\sqrt{Hz}$	10^{-12}
Total system gain, G	(-)	1.0
Excess noise figure, F	(-)	1.0
Active area	mm^2	0.25

2.4.7 Other Detectors

BACKSCAT Version 4.0 is able to accommodate any detector that users wish to supply to the program. Depending on how the detector is described, there are four or seven required inputs. These inputs are essentially the same parameters that are used by the built-in detectors, including the detector quantum efficiency, gain, and excess noise figure. Additionally, users must specify either the spectral NEP or four other noise parameters including the 1) anode dark current, 2) load resistor, 2) effective load temperature, and 4) all other amplifier noise currents.

2.5 Addition of Water Clouds

A new feature in BACKSCAT Version 4.0 is the ability to include water clouds in a lidar simulation. Although the existing user-defined aerosol option can be used to represent a water cloud, this new feature allows users to "click on" a water cloud as a built-in model in the Atmospheric Conditions Submenu. Technical documentation for the water cloud feature is given in the following sections. A description of how to access water clouds in BACKSCAT's menu interface is given in Section 8.4.3.5.

2.5.1 Physical and Optical Properties of Water Clouds in BACKSCAT Version 4.0

The five types of water clouds in BACKSCAT Version 4.0 are cumulus, altostratus, stratus, stratocumulus, and nimbostratus. To describe the properties of the cloud layer, users specify the cloud type, base altitude, cloud thickness, and the extinction coefficient at 0.55 μm. The units and limits for the input parameters are given in Table 8. Table 9 shows default values for each type of water cloud. In Table 9, the cloud bases and thicknesses are consistent with those in LOWTRAN7.[14] The extinction coefficients and corresponding number densities are taken from Shettle.[15]

During a BACKSCAT simulation, the cloud extinction, scattering, and absorption coefficients at the lidar wavelength are obtained by means of wavelength scaling factors from LOWTRAN7 for each water cloud type. For reference, Figure 6 shows cloud extinction coefficients as a function of wavelength for the five water clouds. As required for cloud backscattering coefficients, cloud backscattering phase functions in BACKSCAT were calculated using the Henyey-Greenstein relationship, which is consistent with the approach used by LOWTRAN7. Users should note that the Henyey-Greenstein phase function relationship is an

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[14] Kneizys, F.X., Shettle, E.P., Abreu, L.W., Chetwynd, J.H., Anderson, G.P., Gallery, W.O., Selby, J.E.A. and Clough, S.A. (1988) *Users Guide to LOWTRAN7*, Air Force Geophysics Laboratory, Hanscom AFB, MA, AFGL-TR-88-0177, (ADA206773).

[15] Shettle, E.P. (1989) "Models of Aerosols, Clouds, and Precipitation for Atmospheric Propagation Studies," Proceedings of the AGARD 45th Symposium of the Electromagnetic Wave Propagation Panel on *Atmospheric Propagation in the UV, Visible, IR, and mm-Wave Region and Related Systems Aspects*, Copenhagen, Denmark, 9-13 October 1989.

approximation and it fails to predict unique angular scattering features, such as the glory phenomenon in the backscattering direction.

When a water cloud is used in a BACKSCAT simulation, the altitudes of the cloud base and top are inserted into the height grid that describes the aerosol and molecular profiles. After calculating background aerosol properties for the cloud base and top, BACKSCAT adds the cloud attenuation coefficients to the background aerosol coefficients for every altitude within the cloud layer. Note that BACKSCAT assumes the attenuation and backscattering properties of water clouds to be constant throughout the cloud layer. This modeling approach differs slightly from that used by LOWTRAN7 which adopts "transition zones" at the cloud base and top.

Table 8. Units and Limits of Input Parameters for Water Clouds. BACKSCAT's menu interface issues warning messages when users specify values that are out of bounds

INPUT PARAMETER	UNITS	LIMITS/CHOICES
Cloud Type		Cumulus Altostratus Stratus Stratocumulus Nimbostratus
Base Altitude	km	$0.0 \le z_{base} \le 10.0$ & < Height of Troposphere
Cloud Thickness	km	$0.0 < \Delta z \le 10.0$
Extinction Coefficient at 0.55 μm	km^{-1}	$\beta_{ext} \ge 0.0$

Table 9 Default Properties of Water Clouds in BACKSCAT Version 4.0. Constant cloud extinction is assumed throughout the cloud layer. In BACKSCAT's menu interface, users can override the cloud type, base altitude, cloud thickness, and extinction coefficient at 0.55 μm. The corresponding particle number densities are shown for reference purposes

CLOUD TYPE	BASE ALTITUDE (km)	CLOUD THICKNESS (km)	EXTINCTION AT 0.55 μm (km^{-1})	NUMBER DENSITY (cm^{-3})
Cumulus	0.66	2.34	130.8	250
Altostratus	2.40	0.60	91.04	400
Stratus	0.33	0.67	55.18	250
Stratocumulus	0.66	1.34	35.65	250
Nimbostratus	0.16	0.50	87.08	200

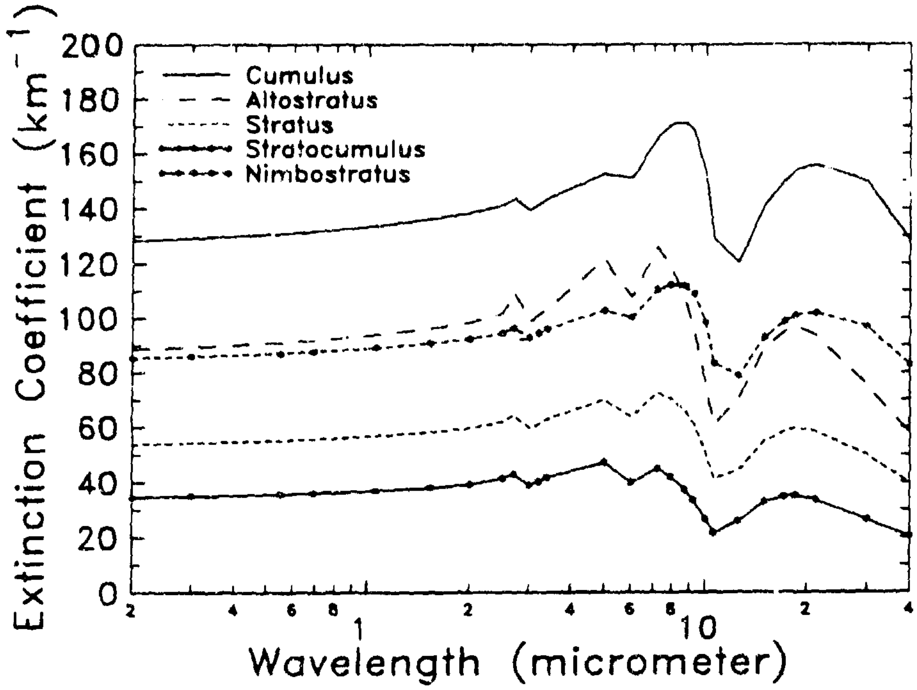

Figure 6. Extinction Coefficient as a Function of Wavelength for Five Water Clouds in BACKSCAT Version 4.0. The curves are normalized according to the default extinction coefficient at 0.55 µm (see Table 9)

2.5.2 Integration Scheme Near the Cloud Boundaries

Users who compare lidar simulations with and without clouds may notice slight differences in the optical depths and lidar returns before the beam encounters the nearest cloud boundary, especially when the cloud top and base do not fall on a height grid point for the aerosol and molecular profiles. These differences are due to the treatment of the background aerosol when lidar returns are evaluated along the lidar integration grid. (Recall that lidar returns are evaluated at range increments defined by the lidar pulse duration, plus they are evaluated at the boundaries of water clouds, cirrus clouds, and user-defined aerosol layers.) To help explain this, Figure 7 shows the general integration scheme for an arbitrary cloud layer. When no cloud is included, the assumed aerosol extinction is calculated by means of linear interpolation on the background aerosol grid (*i.e.*, the "*" points). When a cloud is included, however, linear interpolation is not appropriate between background aerosol grid points and cloud boundaries because the cloud boundaries mark sharp changes in the aerosol extinction. Thus for range bins between a cloud boundary and the next background aerosol grid point (outside the cloud), the assumed aerosol extinction equals the next background aerosol grid point.

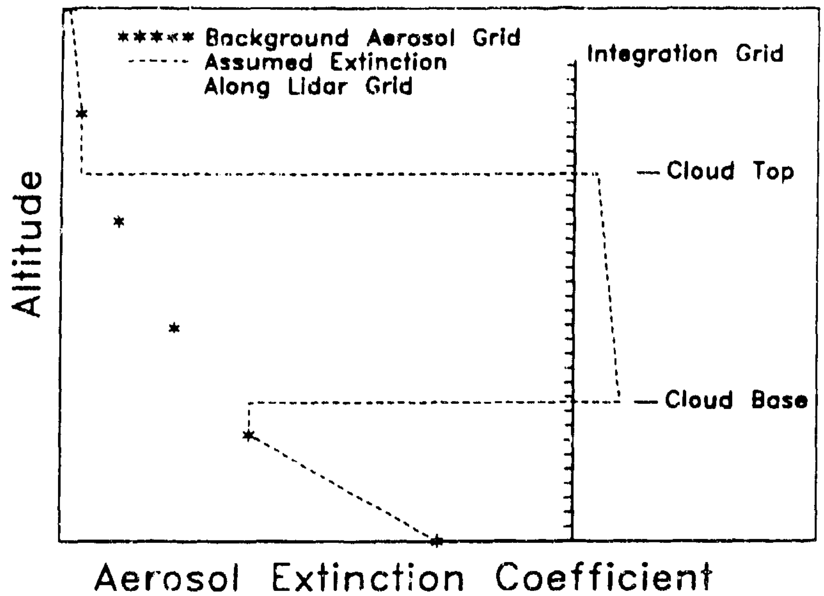

Figure 7. Assumed Aerosol Extinction in BACKSCAT Version 4.0 When an Arbitrary Cloud Layer Is Included in a Lidar Simulation. In this case, a ground-based lidar is looking straightupward. Lidar returns are calculated along the integration grid, plus they are calculated at the cloud base and top. The cloud layer extinction decreases slightly because it equals the (constant) cloud extinction plus the (smaller) background aerosol extinction which decreases slightly with altitude

2.6 Treatment of Molecular Absorption

Most laser lines are affected by molecular absorption to some extent somewhere in the atmosphere. To aid users in their lidar simulation studies, BACKSCAT Version 4.0 contains an auxiliary package named *mabs* that estimates molecular absorption as a function of altitude for a particular wavelength. Users can instruct *mabs* to calculate molecular absorption for a model atmosphere or a user-defined atmosphere. The results from *mabs* are molecular absorption coefficients that correspond to 1 km horizontal (constant pressure) paths at incremental altitudes. The output file from *mabs* is formatted such that it can be directly used in BACKSCAT simulations. Examples of the input and output files for *mabs* are described in Appendix A.

The *mabs* package was derived from LOWTRAN7[14] which has a fixed spectral resolution of 20 cm^{-1}. To be consistent with the finest spectral grid in LOWTRAN7, the output from *mabs* corresponds to the frequency given by the nearest integer multiple of 5 cm^{-1}. Although MODTRAN[16] would have provided more accurate estimates of molecular absorption, it would have demanded higher storage requirements and limited the portability of the full BACKSCAT package. To reduce the executable size, the standard LOWTRAN7 molecular absorption

[16] Berk, A., Bernstein, L.S., and Robertson, D.C. (1989) *MODTRAN: A Moderate Resolution Model for LOWTRAN7*, Air Force Geophysics Laboratory, Hanscom AFB, MA, AFGL-TR-89-0122, (ADA214337).

parameters now reside in an external data file named *molecule.abs* which is included with the *mabs* package.

Since it is based on LOWTRAN7, users must recognize the limitations of *mabs* and interpret its results only as estimates of the true molecular absorption. In many cases, for example, the spectral resolution of *mabs* output will not match the lidar's spectral resolution. To demonstrate this, Figure 8 shows the wavelength resolution that corresponds to a fixed wavenumber resolution of 20 cm^{-1}. The wavelength and wavenumber resolution are related as

$$\Delta\lambda = -\Delta v / v^2 \tag{35}$$

where λ and v are wavelength and wavenumber respectively. Figure 8 indicates that for wavelengths beyond 10 μm, the spectral resolution of *mabs* exceeds that of most lidars. Thus, *mabs* does not account for many absorption lines beyond 10 μm, although it will predict the main absorption features and trends. For more accurate predictions of molecular absorption, users must resort to computer programs that perform line-by-line calculations, such as FASCODE.[17]

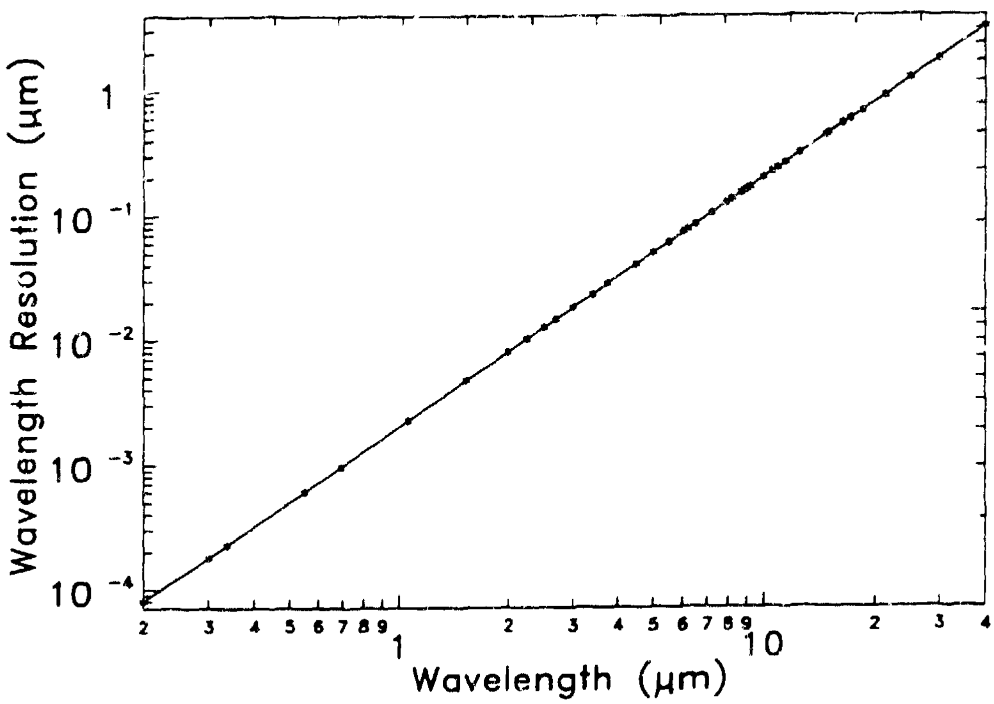

Figure 8. Wavelength Resolution for a Fixed Wavenumber Resolution of 20 cm^{-1}

[17] Clough, S.A., Kneizys, F.X., Shettle, E.P., and Anderson, G.P. (1986) "Atmospheric Radiance and Transmittance: FASCODE 2", *Proc. of the Sixth Conference on Atmospheric Radiation*, Williamsburg, VA, American Meteorological Society, Boston, MA, 141-144.

3 SAMPLE APPLICATIONS OF THE SNR PERFORMANCE MODELS

This chapter gives sample results from the SNR performance models in BACKSCAT Version 4.0. First, the performance of an APD detector is compared against a PMT-VIS (R636) detector using the relations for an aerosol backscatter (*i.e.*, direct detection) system. Second, sample results are given for a CO_2 coherent Doppler system.

3.1 Comparison of APD and PMT-VIS (R636) Detectors

3.1.1 Simulation Conditions

In this scenario for an aerosol backscatter system, the lidar system parameters and viewing conditions are representative of a typical lidar scenario. The lidar is ground-based and directed 30° off the horizon. Nighttime operation is assumed, so the background radiance is set to zero. The transmitter has a 90% optical efficiency and makes use of a 0.85 μm pulsed laser diode having 100 mJ per pulse and a pulse length of 70 ns. The receiver has an optical efficiency of 80% and a field-of-view of 300 μrad. The outer aperture of the transmitter/receiver system has a diameter of 50 cm with no obscuration.

The default atmospheric conditions in BACKSCAT Version 4.0 are used for this study. Specifically, the molecular profile corresponds to the tropical model atmosphere. In the boundary layer, the aerosol type is rural, the surface visibility is 23 km, and the surface relative humidity is 70%. Above the boundary layer, the fall/winter aerosol profiles are used and the background stratospheric aerosol type is adopted. Clear skies are assumed. For reference, the total (aerosol plus molecular) extinction and backscatter coefficients at 0.85 μm are shown in Figure 9.

3.1.2 Results

Signal-to-noise ratios with the APD and PMT-VIS (R636) detectors are shown in Figure 10. Figure 10 indicates that the APD detector is better able to detect the aerosols because its quantum efficiency is an order of magnitude greater than the PMT detector (see Tables 3 and 5) and its amplifier noise sources are relatively small. Thus, the APD detector gives greater detection capability at this wavelength and power. Because signal-to-noise ratios are higher with the APD detector, the ability to locate aerosol features is also better. For the current viewing scenario, Figure 11 indicates that range inaccuracies for the PMT detector are excessively large at ranges beyond 10 km, but they remain acceptable for the APD detector system. Note that the range resolution of the lidar system is about 10.5 m.

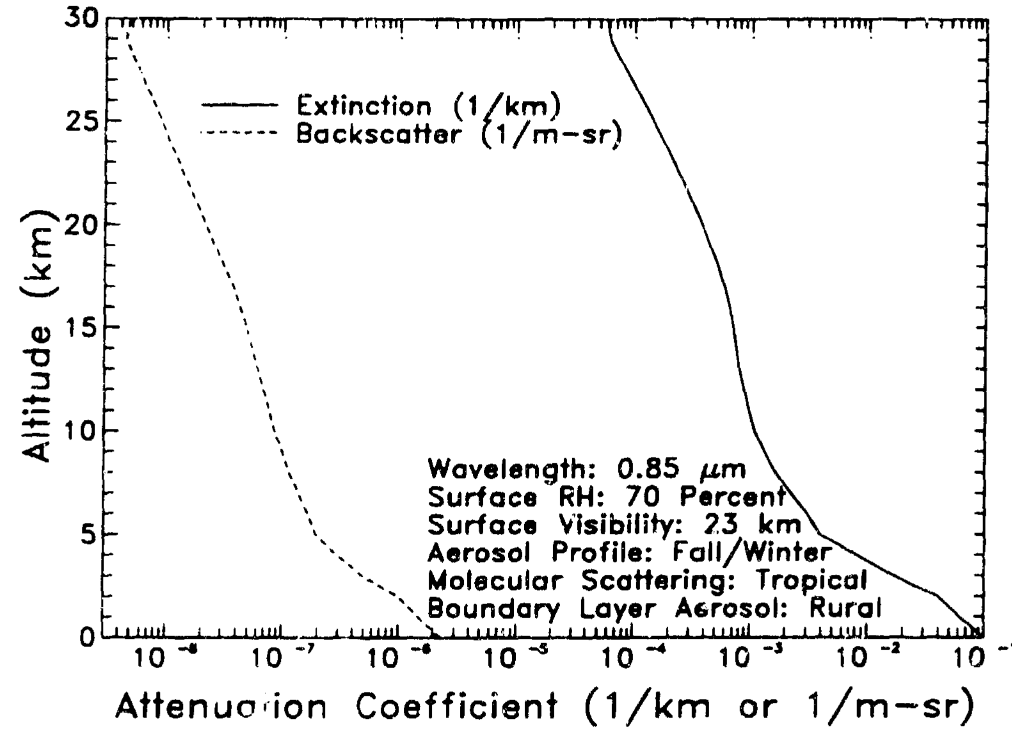

Figure 9. Profiles of the Total (Aerosol Plus Molecular) Extinction and Backscatter Coefficients at 0.85 μm To Be Used in the Comparison of APD and PMT-VIS (R636) Detectors

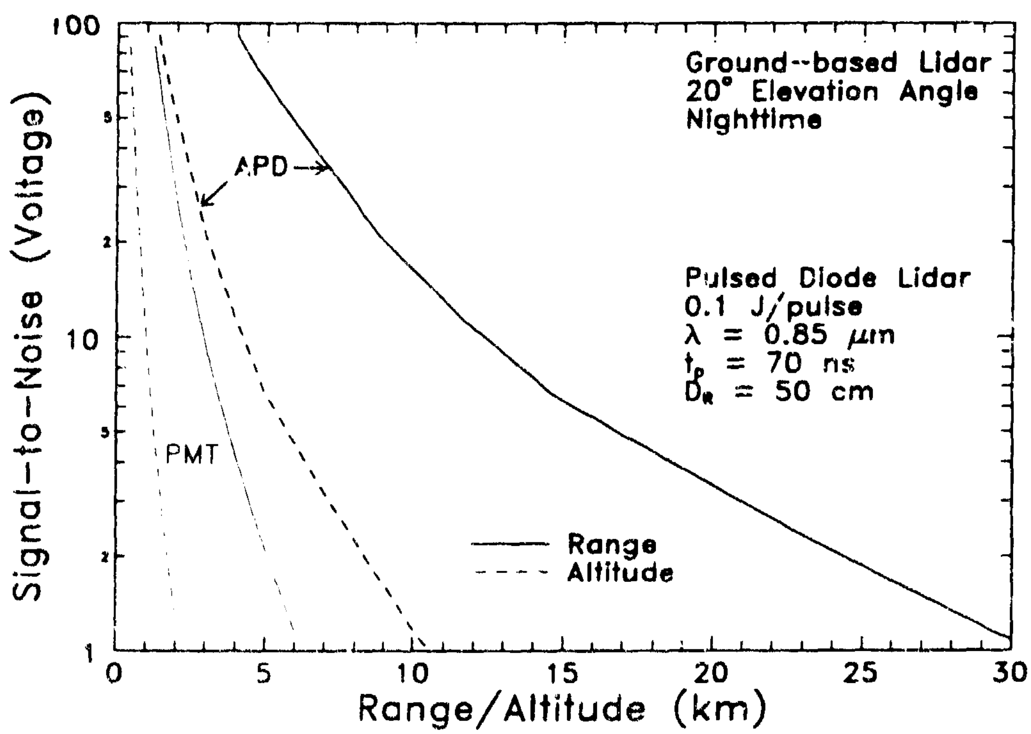

Figure 10. Signal-to-Noise Ratios Versus Range and Altitude for APD and PMT-VIS Detectors

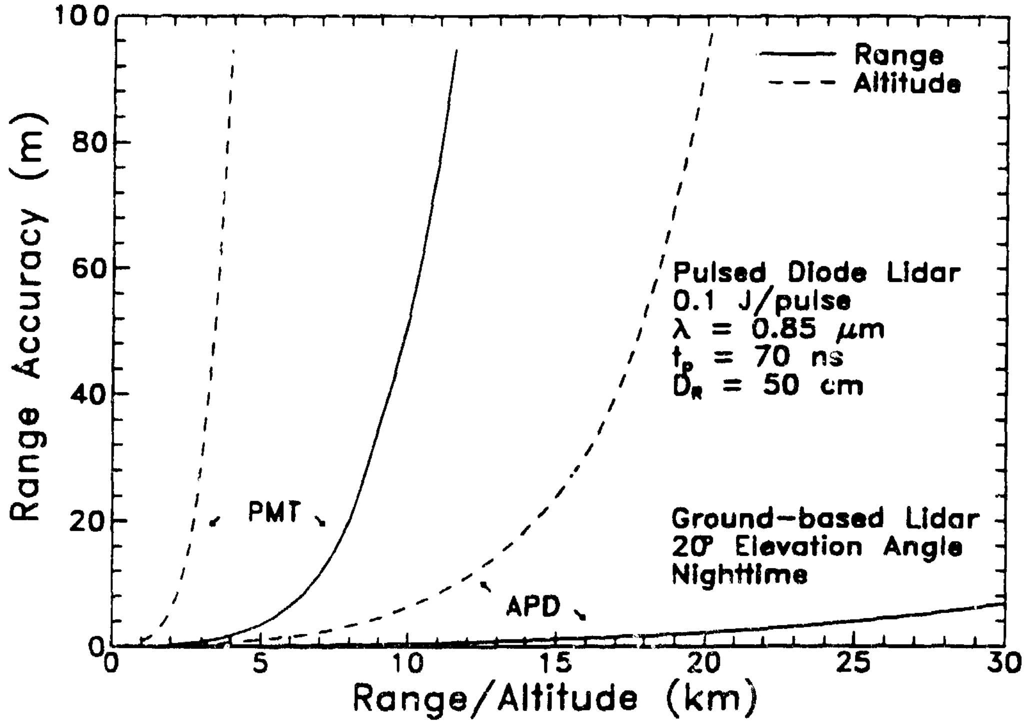

Figure 11. Range Accuracies Versus Range and Altitude for APD and PMT-VIS Detector Systems

3.2 Airborne Coherent Doppler System

3.2.1 Simulation Conditions

In this simulation for a coherent Doppler system, an airborne lidar is situated at 15 km and directed 20° below horizontal. For wind field considerations, the lidar azimuth is 270° (*i.e.*, facing due west). Nighttime operation is assumed, so the background radiance is set to zero. The transmitter has a 90% optical efficiency and makes use of a 10.6 μm CO_2 pulsed laser diode having 1 J per pulse with a pulse length of 70 ns. The receiver has an optical efficiency of 80% and a field-of-view of 300 μrad. The outer aperture of the transmitter/receiver colinear system has a diameter of 50 cm with no obscuration. Finally, the built-in HgCdTe photovoltaic detector is used in the simulation.

In this simulation, the state of the atmosphere is characterized by Subarctic winter conditions. The built-in wind field profile for Subarctic winter conditions provides large radial components for the wind field because the wind is strong and from the west-northwest. Below 15 km, molecular scattering contributions are generally small at 10.6 μm. Other atmospheric parameters are set to the default values.

3.2.2 Results

Signal-to-noise ratios as a function of altitude and range are shown in Figure 12. The signal-to-noise ratios decrease initially, but then increase as the lidar beam encounters more aerosol in the lower atmosphere. Figure 13 shows the range accuracy as a function of range and altitude. The systems's range resolution equals 10.5 m. Figure 14 shows the wind speed accuracy and wind speed along the lidar line-of-sight. Note that the wind speed accuracy has nothing to do with the actual wind field and the wind speed resolution of the system equals 75.7 m/s. For this scenario, Figure 14 indicates that even though winds are stronger in the middle atmosphere, more accurate measurements of wind speeds are nearer the ground where the signal-to-noise is larger.

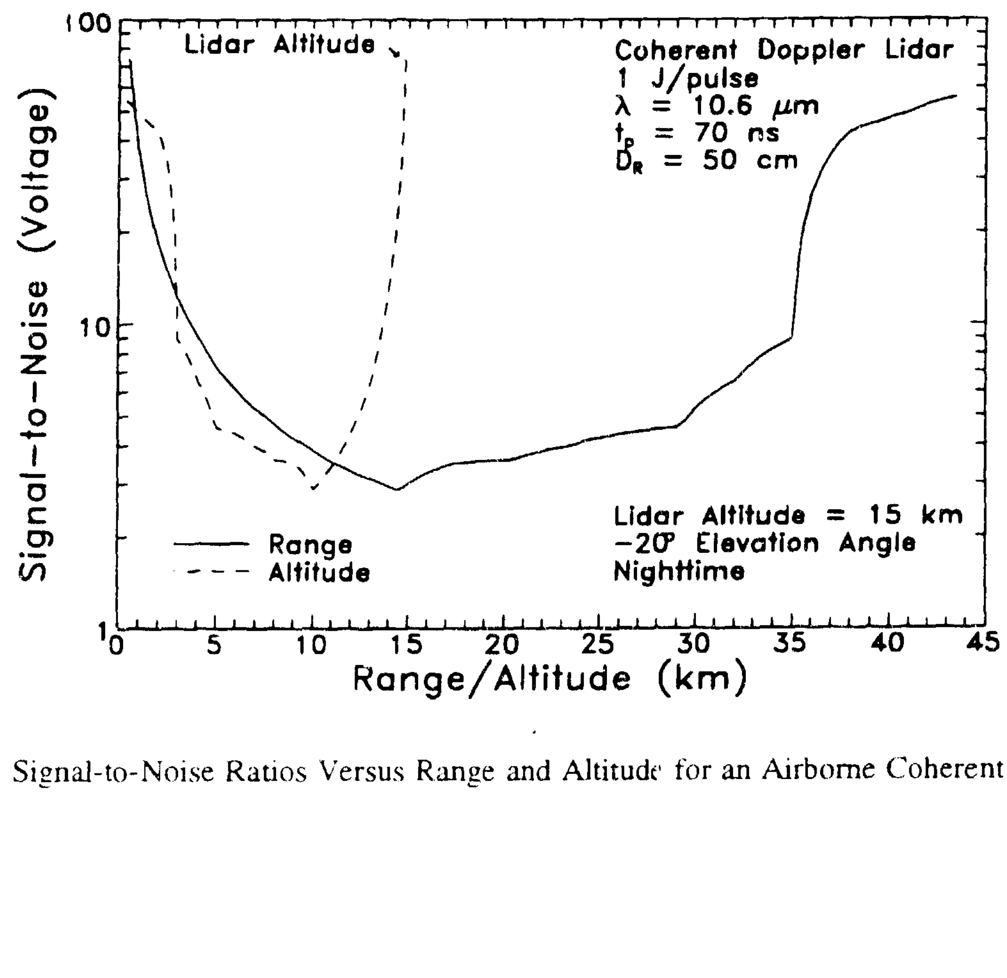

Figure 12. Signal-to-Noise Ratios Versus Range and Altitude for an Airborne Coherent Doppler System

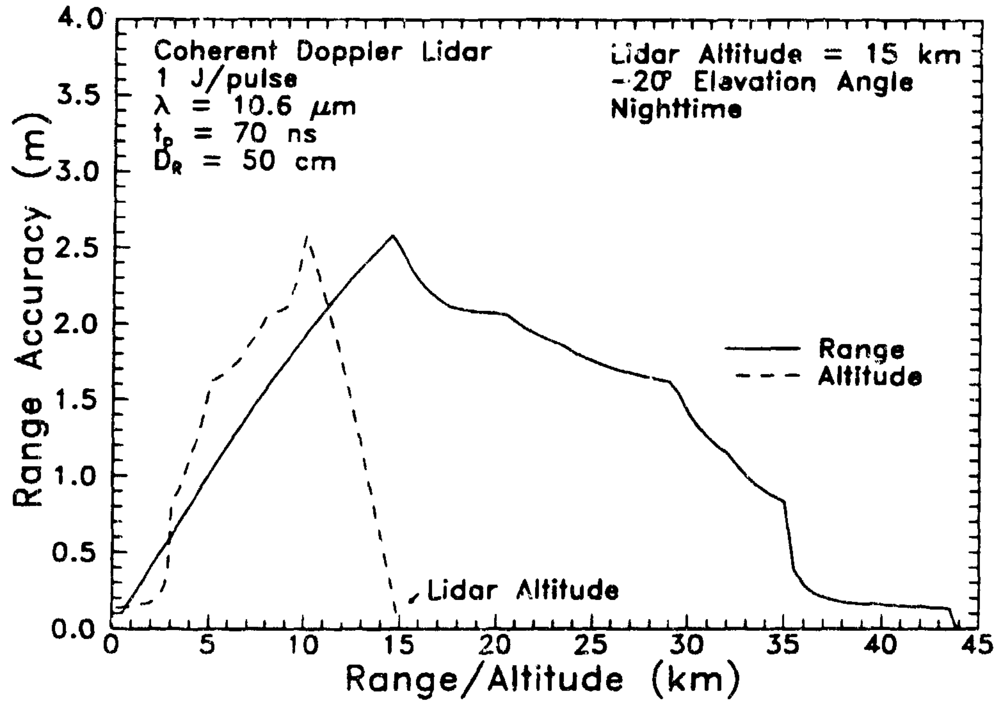

Figure 13. Range Accuracies Versus Range and Altitude for an Airborne Coherent Doppler System

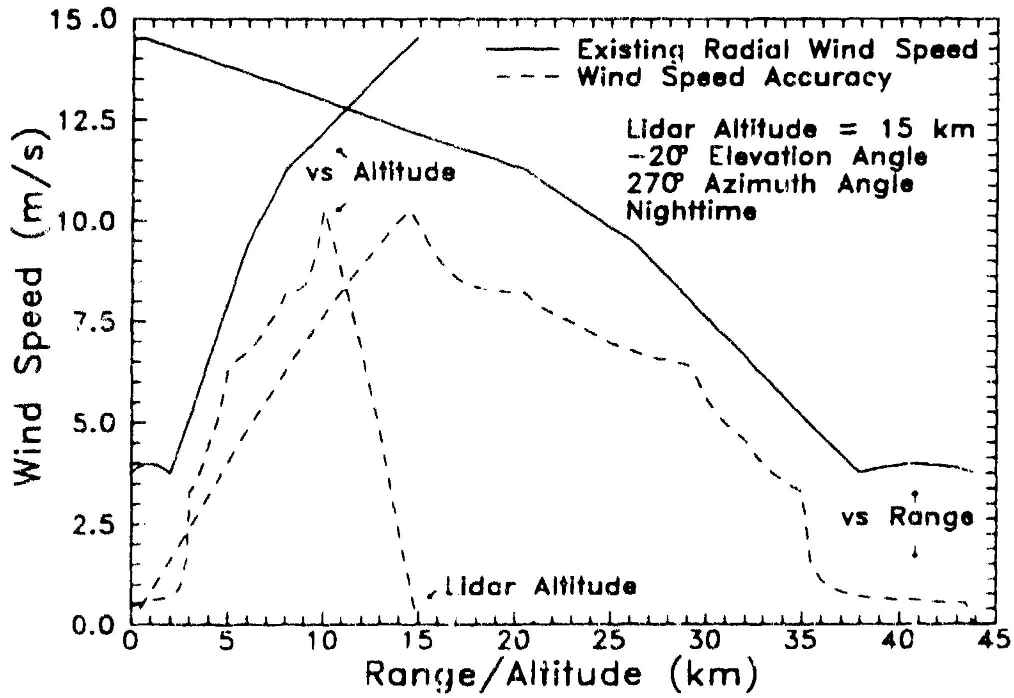

Figure 14. Wind Speed Accuracies and Radial Wind Speed Versus Range and Altitude for an Airborne Coherent Doppler System

4 OVERVIEW OF THE BACKSCAT VERSION 4.0 SOFTWARE

BACKSCAT Version 4.0 is written in C and FORTRAN 77. The menu interface system uses Microsoft™ C Version 6.0 and GreenLeaf™ DataWindows Version 3.0 to create the data entry menus and to view the results of a simulation. The menu interface system can be used with or without a mouse. The "science" portions of the code use Microsoft™ FORTRAN 77 Version 5.1 and are compiled as protected-mode programs because new features have caused BACKSCAT to encroach on the 640 Kbyte memory barrier imposed by MS-DOS. To execute the protected-mode programs from the menu interface system, they have been binded with the Phar Lap 286/DOS-Extender™ Run Time Kit (RTK). From the viewpoint of the user, this solution to the memory problem does not alter the flow of execution of BACKSCAT. However, users who wish to recompile *backscat.exe* or *usraer.exe* must have the Phar Lap 286/DOS-Extender™ Run Time Kit (RTK) and bind it with the protected-mode programs.

Although BACKSCAT Version 4.0 is designed to run on an IBM PC, the scientific portions of the code are not IBM PC-specific. This portion of the code can be run without the menu interface system provided the user inputs the required files. This feature allows the science portion of the code to be run on other computer platforms or in batch mode.

4.1 Computer Requirements

The executable, source, and data files for BACKSCAT Version 4.0 occupy about 2.85 Mbytes. A hard disk is recommended, but the code can be run without one. BACKSCAT can be used with either color or monochrome displays, and on systems with or without a floating point processor.

BACKSCAT Version 4.0 has been tested on both 386 and 486 PCs. In these tests, the available RAM was about 530 Kbytes and 500 Kbytes, respectively, for the 386 and 486 machines. If problems arise, such as the computer "locking up", check the amount of available RAM. Try to remove any memory resident resident programs that are not absolutely needed.

BACKSCAT Version 4.0 should be run **without** entering MS Windows (*i.e.*, boot-up to the DOS prompt and then run BACKSCAT.) The code might run under a MS Windows DOS window with the exception of its graphics routines, but this has not been tested and not recommended. Additionally, the graphics routines may not execute normally if they are used after a MS Windows session. If this problem occurs, it is recommended that the user reboot the computer and try running BACKSCAT again.

4.2 Installing the Program

There are three distribution diskettes for BACKSCAT Version 4.0. The diskettes have three subdirectories, *data*, *exec*, and *source*, which contain the data files required to run the code, the executable files, and the source code, respectively. The first diskette also contains *readme* and *updates* files which describes the contents of the diskettes in more detail.

The simplest way to install BACKSCAT Version 4.0 is to use the three rudimentary installation scripts that accompany the package. The first installation script sets up the

BACKSCAT executable directory and files, while the second sets up the data and source directories and files. The third installation script installs the stand-alone program *mabs*.

To install BACKSCAT in the default directory location (*c:\bscat*), insert distribution disk 1 into a floppy disk drive. Type *b:* (or *a:*) and press RETURN. Then type *install1* and press RETURN. After disk 1 is installed, insert distribution disk 2 into the same floppy disk drive, type *install2*, and press RETURN. After disk 2 is installed, insert distribution disk 3 into the same floppy disk drive, type *install3*, and press RETURN. Each installation script allows the user to quit the installation at the start.

To install BACKSCAT Version 4.0 in a directory location other than the default (for example, *c:\bscatv4_0*), insert distribution disk 1 into a floppy disk drive. Type *b:* (or *a:*) and press RETURN. Then type *install1 c:\bscatv4_0* and press RETURN. After disk 1 is installed, insert distribution disk 2 into the same floppy disk drive, type *install2 c:\bscatv4_0*, and press RETURN. After disk 2 is installed, insert distribution disk 3 into the same floppy disk drive, type *install3 c:\bscatv4_0*, and press RETURN. To account for a non-default directory location, modifications are automatically made to the batch file *back.bat* which runs BACKSCAT's menu interface system. Note that when a root installation location directory is more than one level deep (for example, *c:\level1\level2\bscat*), all the directories in the hierarchy (*c:\level1* and *c:\level1\level2*) must exist before installation.

In addition to starting the menu interface system for BACKSCAT Version 4.0, the batch file *back.bat* sets up environment variables that define the paths to BACKSCAT data files and executable code. An example *back.bat* file is shown in Figure 15. When the rudimentary installation scripts are used to install BACKSCAT, they automatically make the appropriate changes to *back.bat*. However, if the BACKSCAT directories are moved from the installation directory location, *back.bat* must be changed so it defines the appropriate installation paths. Use a standard text editor to set the environment variable "BSCATEXE" to the full path where the executable files reside and to set the environment variable "BSCATDATA" to the full path where the data files reside. Note that both path names must end with a trailing "\". Save the changes to the batch file *back.bat* and place the batch file within the current search path.

```
echo off
set BSCATEXE=C:\BSCAT\EXEC\
set BSCATDATA=C:\BSCAT\DATA\
%BSCATEXE%backmenu
```

Figure 15. Sample Batch File, *back.bat*, Used to Execute BACKSCAT Version 4.0

Table 10 lists the files that are required to run BACKSCAT Version 4.0. Note that the file *modern.fon* **must** be in the user's current directory. The *exec* subdirectory on the distribution diskettes also contains *bscatv4.** files which are a series of data files containing sample input and output data.

Table 10. Files Required to Use BACKSCAT Version 4.0. The code makes use of other files, but they are optional, see Appendix A

FILENAME	DESCRIPTION
	Batch Files
back.bat	Executes BACKSCAT via the menu interface system
	Program Files
backmenu.exe	Menu interface system
quikview.exe	"Quick View" graphics program
radio.exe	Radiosonde data entry program
runfile.exe	Interface between menus and scientific programs
usraer.exe	User-defined aerosol layer program (protected-mode)
backscat.exe	Lidar backscatter solution program (protected-mode)
mabs.exe	Auxiliary program for molecular absorption
mabs.in	Sample input file for the molecular absorption package
	Data files
standard.scl	Built-in aerosol extinction profiles
models.aer	Wavelength scaling factors for built-in aerosols/clouds
models.ram	Built-in constituent profiles for Raman molecules
models.wnd	Built-in wind profiles
indexof.ref	Refractive indices for six built-in aerosols
molecule.abs	Database of molecular absorption parameters
	Miscellaneous Files
modern.fon	Font file required for graphics

4.3 Starting the Program

To start BACKSCAT Version 4.0, users execute the batch file *back.bat* by simply typing *back* at the main command prompt and hitting RETURN. (The batch file *back.bat* must be in the search path or in the current directory.) Figure 16 shows the initial screen that is displayed when entering BACKSCAT Version 4.0. To proceed, hit RETURN. (Note that the terms RETURN and ENTER are used interchangeably throughout this report.)

4.4 Selecting the Type of Lidar Simulation

Figure 17 shows the initial menu to prompt users to select the type of lidar system to be simulated. Users can select an Aerosol Backscatter, Raman, or Coherent Doppler Lidar System. To select a lidar system, use the up and down cursor control keys or a mouse to move the highlighted area to the desired system and press RETURN, or type the highlighted letter for the desired system twice. Once a lidar system is selected, users automatically proceed to the Main Menu of BACKSCAT Version 4.0.

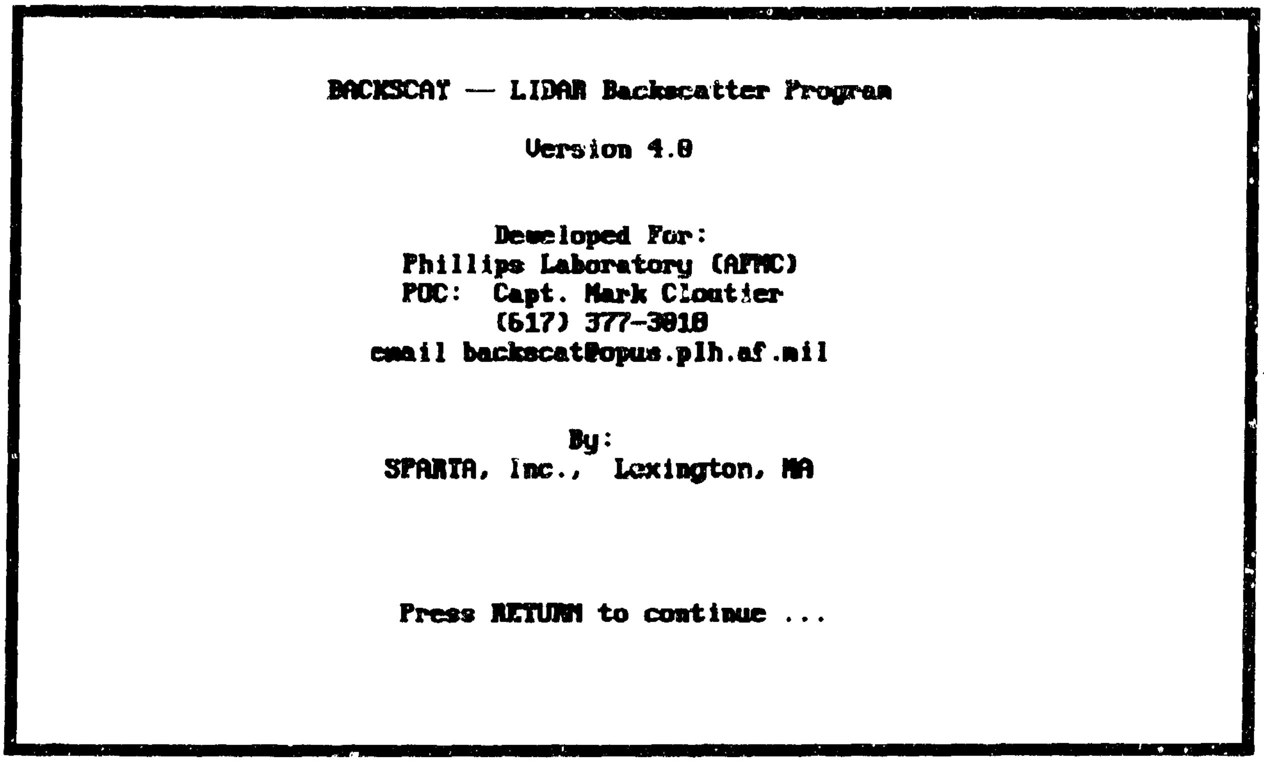

Figure 16. Initial Menu When Entering BACKSCAT Version 4.0

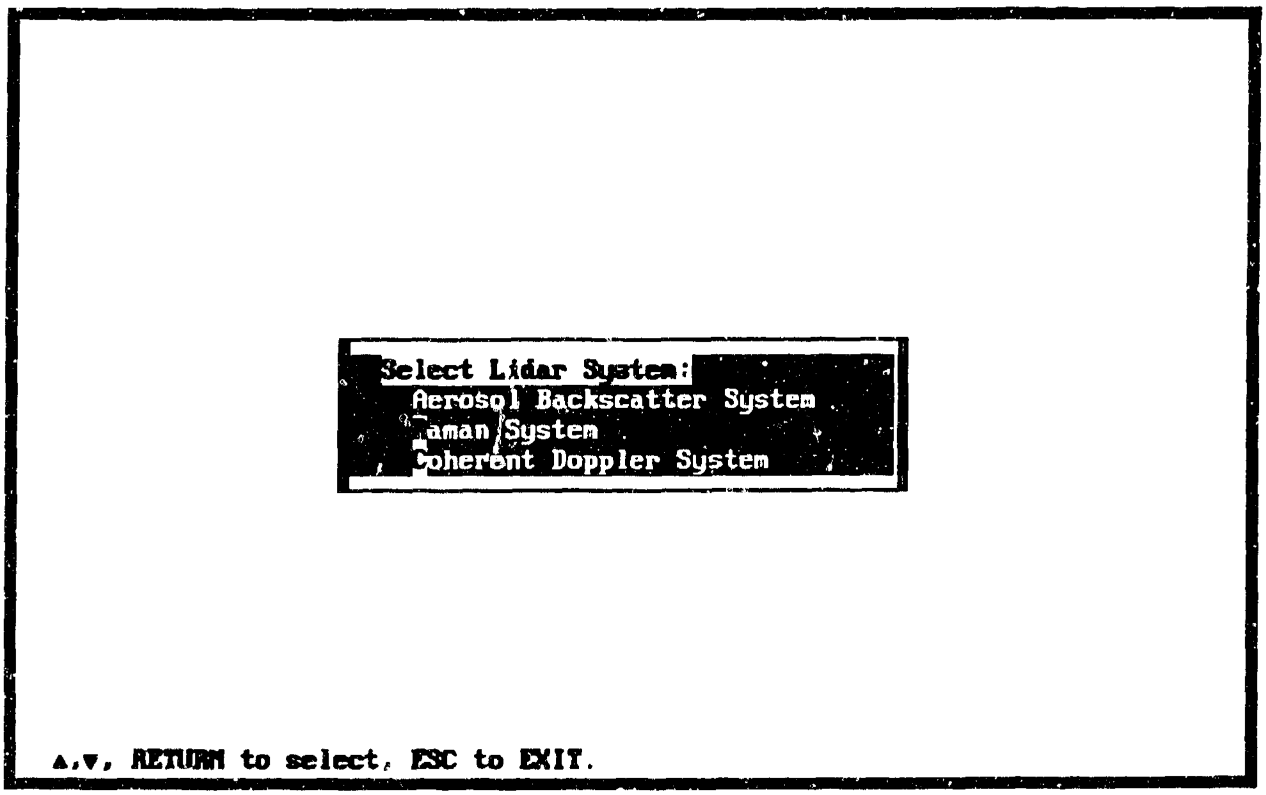

Figure 17. BACKSCAT Menu for Selecting the Type of Lidar Simulation

5 MAIN MENU OF BACKSCAT VERSION 4.0

Figure 18 shows the Main Menu of BACKSCAT Version 4.0. In this case, the Main Menu shows the default conditions for an aerosol backscatter lidar system. The top half of the Main Menu displays general information about the current simulation and the bottom half is a list of options from which the user can perform different BACKSCAT operations. The user cannot move the cursor to the top portion of the Main Menu. Rather, the display automatically changes when the user performs operations in the bottom half of the Main Menu.

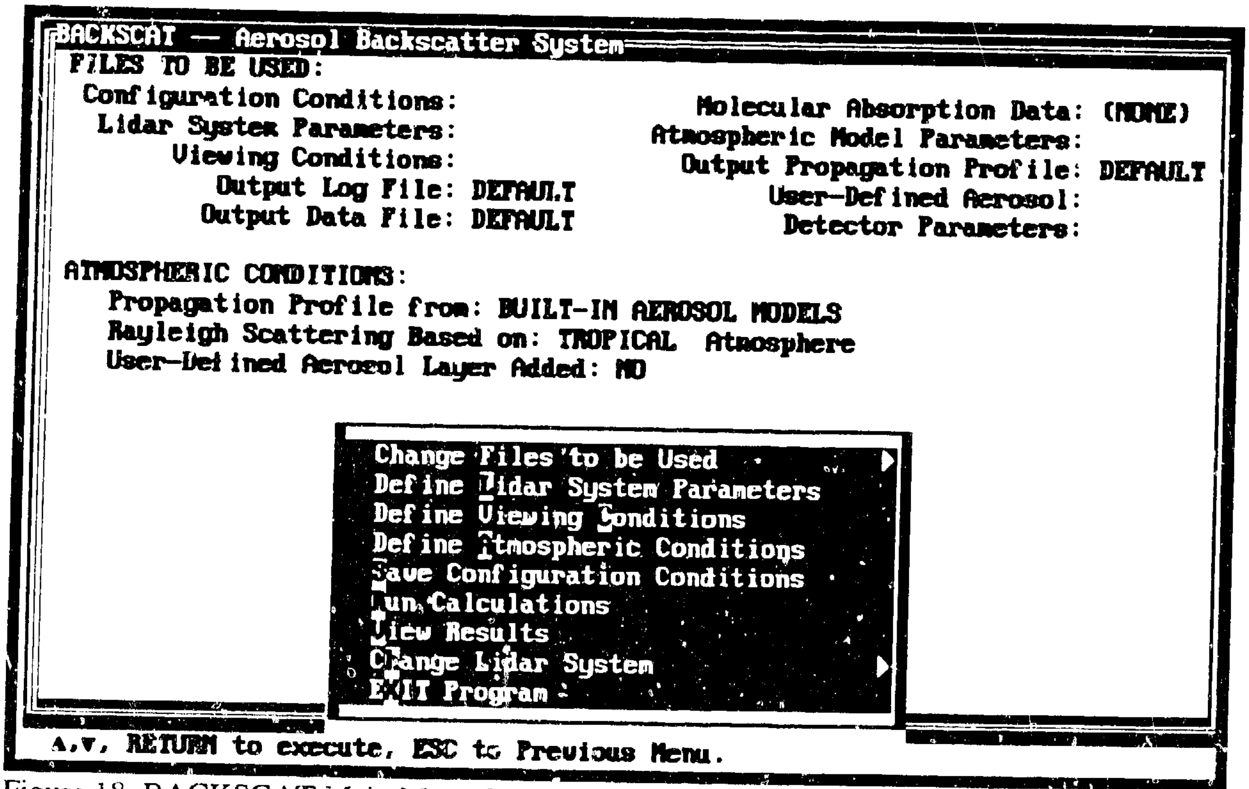

Figure 18. BACKSCAT Main Menu for an Aerosol Backscatter Lidar System

The information in the top portion of the Main Menu can be subdivided into three parts: (1) the type of lidar system, (2) file names to be accessed, and (3) a summary of the atmospheric conditions. The type of lidar system is always shown on the top line of the Main Menu. The file names to be accessed in the current simulation are displayed in two columns. Appendix A gives a detailed description of the file contents. Appendix A also lists the default data files supplied with the code.

The box in the bottom portion of the Main Menu lists the available BACKSCAT options. To select an option, use the up and down cursor control keys or a mouse to move the highlighted area to the desired option and press RETURN, or type the highlighted letter for the desired option twice. Figure 19 outlines the parameters that are specified within each Main Menu option. The remainder of this chapter gives a Users Guide for many of the Main Menu options. Some options are more involved and addressed separately in subsequent chapters.

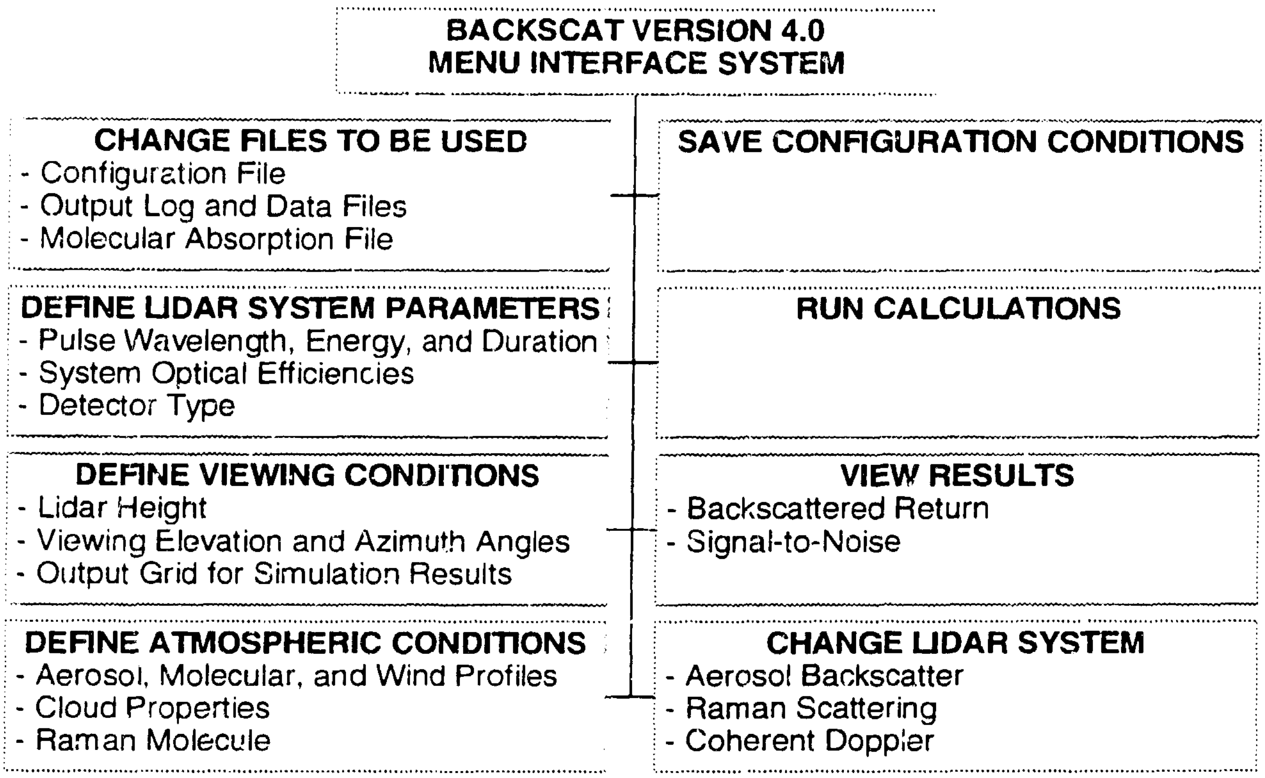

Figure 19. Schematic Representation of the Options in BACKSCAT's Menu Interface System

5.1 Changing the Files to be Used in a Simulation

To select this option, use the up and down cursor control keys or a mouse to move the highlighted area to the line "Change Files to be Used" and press RETURN, or type the letter "F" twice. A "popup" submenu will appear, as shown in Figure 20, which lists the files that can be changed. To change the names of one of the listed files, move the highlighted area to the desired choice and hit RETURN. To exit this option without making a change, hit the ESC key. Note that this submenu does not list the filenames for the lidar system and detector parameters, viewing conditions, atmospheric model parameters, propagation, molecular profile, and user-defined aerosol layer. These files are changed from the Main Menu options "Define Lidar System Parameters", "Define Viewing Conditions" or "Define Atmospheric Conditions".

```
BACKSCAT -- Aerosol Backscatter System
 FILES TO BE USED:
  Configuration Conditions:                 Molecular Absorption Data: (NONE)
   Lidar System Parameters:              Atmospheric Model Parameters:
        Viewing Conditions:                 Output Propagation Profile: DEFAULT
           Output Log File: DEFAULT                User-Defined Aerosol:
          Output Data File: DEFAULT                 Detector Parameters:

 ATMOSPHERIC CONDITIONS:
     Propagation Profile from: BUILT-IN AEROSOL MODELS
     Rayleigh Scattering Based on: TROPICAL Atmosphere
     User-Defined Aerosol Layer Added: NO

                          Change Files to be Used              ►
                          Define Lidar System Parameters
                          De
                          De   Change Configuration File
                          Sa   Change Output Log File
                          Ru   Change Output Data File
                          Vi   Change Molecular Absorption File
                          Se
                          EXIT Program
 ▲,▼, RETURN to execute, ESC to Previous Menu.
```

Figure 20. BACKSCAT Submenu For Changing the File Names in a Simulation

5.1.1 Changing the Configuration File

BACKSCAT allows the user to save all information about a given simulation in a file called the configuration file. The configuration file contains the file names for lidar system and detector parameters, viewing conditions and atmospheric model parameters, plus information that describes the overall simulation conditions including the file names for (optional) molecular absorption data, simulation log output, and tabular form of the output for the simulation data. Configuration files are given the default extension, *.cfg*. A configuration file is not required to run BACKSCAT, but it is useful if the user is performing similar types of simulations very often.

To enter or change a configuration file name from the submenu in Figure 20, move the highlighted area to the "Change Configuration File" line and press RETURN, or type the letter "C" twice. BACKSCAT then displays a "popup" submenu that lists the configuration file names in the current working directory. Figure 21 shows an example of the "popup" submenu for changing the configuration file name. To select a configuration file, move the highlighted area to the desired filename and hit RETURN. To exit the "popup" submenu and not select a new configuration file, hit the ESC key. If no files exist in the current directory with the *.cfg* extension, BACKSCAT alerts the user with a warning message as noted in Figure 22. The user is then returned to the Main Menu.

```
BACKSCAT -- Aerosol Backscatter System
 FILES TO BE USED:
  Configuration Conditions:                     Molecular Absorption Data: (NONE)
   Lidar System Parameters:                  Atmospheric Model Parameters:
        Viewing Conditions:                    Output Propagation Profile: DEFAULT
           Output Log File: DEFAULT                   User-Defined Aerosol:
          Output Data File: DEFAULT                    Detector Parameters:

 ATMOSPHERIC CONDITIONS:
     Propagation Profile from: BUILT-IN AEROSOL MODELS
     Rayleigh Scattering Based on: TROPICAL  Atmosphere
     User-Defined Aero
                       Select File:
                       TEST    .CFG
                       DEFAULT .CFG
                       SNR     .CFG

 ▲,▼, RETURN to select file, ESC to abort.
```

Figure 21. BACKSCAT Submenu for Selecting a Configuration File Name

```
BACKSCAT -- Aerosol Backscatter System
 FILES TO BE USED:
  Configuration Conditions:                     Molecular Absorption Data: (NONE)
   Lidar System Parameters:                  Atmospheric Model Parameters:
        Viewing Conditions:                    Output Propagation Profile: DEFAULT
           Output Log File: DEFAULT                   User-Defined Aerosol:
          Output Data File: DEFAULT                    Detector Parameters:

 ATMOSPHERIC CONDITIONS:
     Propagation Profile from: BUILT-IN AEROSOL MODELS
     Rayleigh Scattering Based on: TROPICAL  Atmosphere
     User-Defined Aerosol Layer Added: NO

No files exist with the extension '.CFG'
         Press ANY KEY to continue ...

 ▲,▼, RETURN to select file, ESC to abort.
```

Figure 22. Warning Message Displayed by BACKSCAT if No Configuration Files Exist in the Current Working Directory

5.1.2 Change Output Log File

BACKSCAT keeps a detailed log of the calculations being made and writes this information to a log file. This file lists all of the input parameters for the simulation, components of the propagation profile, and output from the lidar simulation. The default name of the log file is *default* and the default extension is *.log*. An example of a log file is given in Appendix A.

To change the name of the output log file, move the highlighted area on the submenu in Figure 20 to the "Change Output Log File" line and press RETURN, or type the letter "L" twice. The code provides a "popup" submenu in which the user can enter the output log file name, as shown in Figure 23. Type in a name of eight characters or less and hit RETURN. (The extension in brackets is not typed by the user, but it is supplied internally by the code.) Note that BACKSCAT does not check to see if the name is already in use.

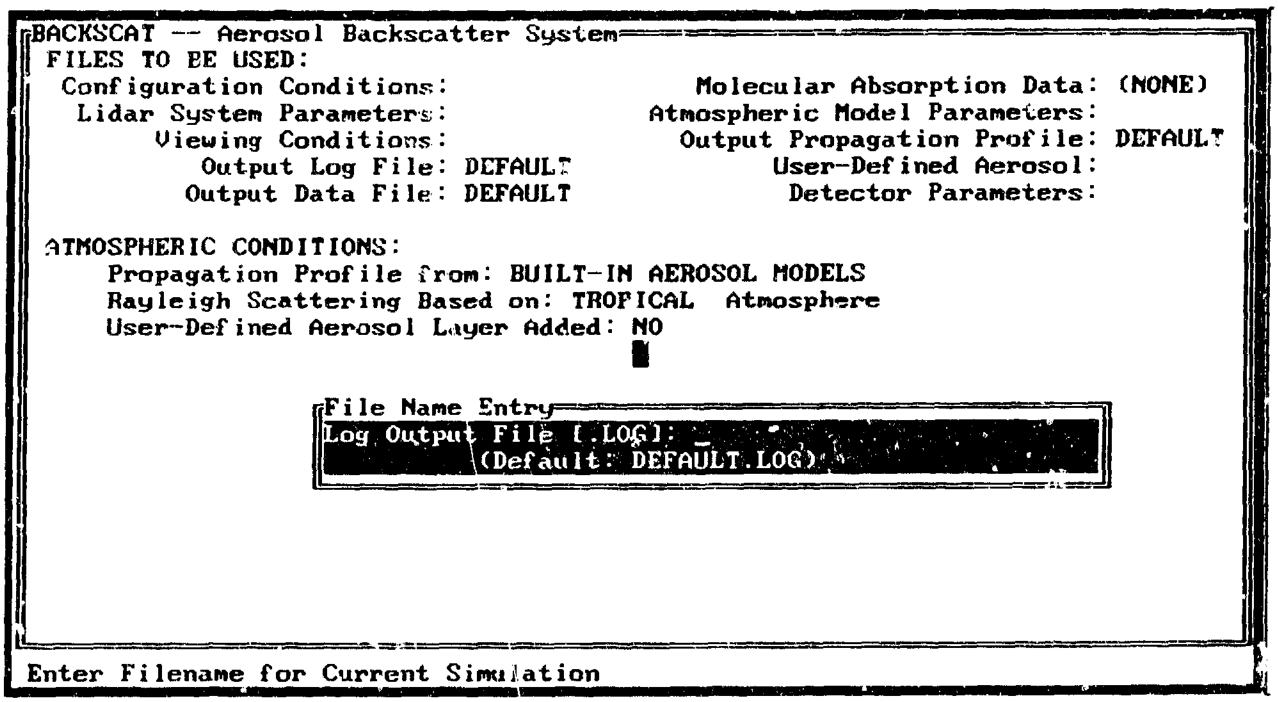

Figure 23. BACKSCAT Submenu for Entering an Output Log File Name

5.1.3 Change Output Data File

The output data file contains the results for the current BACKSCAT simulation. It is similar to the log file output except it does not contain the input parameters and information about the propagation profile. The results are provided in a tabular form for use with off-line analysis and graphics programs. Depending on the type of lidar system, the output data file consists of seven or nine columns of data:

Column 1: Range (km)
Column 2: Altitude (km MSL)
Column 3: Optical Depth (-)
Column 4: Lidar Return (Watt)
Column 5: Range Independent Lidar Return (Watt m^2)
(equals lidar return multiplied by the square of the range)
Column 6: Range Accuracy (m)
Column 7: Signal-to-Noise (-)
Column 8: Radial Wind Speed Along Lidar Line-of-Sight (m/s, kts, or mph)
Column 9: Wind Speed Accuracy (m/s, kts, or mph)

where Columns 8 and 9 are only included for coherent Doppler lidar systems and the wind speed units are set by the user. BACKSCAT assigns a default name of *default* and the default extension is *.dat*. An example of the output data file is given in Appendix A.

To change the name of the output data file from the submenu in Figure 20, move the highlighted area to the "Change Output Data File" line and press RETURN, or type the letter "D" twice. The code provides a "popup" submenu in which the user can enter the output data file name, as shown in Figure 24. Type in a name of eight characters or less and hit RETURN. (The extension in brackets is not typed by the user, but it is supplied internally by the code.) BACKSCAT does not check to see if the name is already in use.

```
BACKSCAT -- Aerosol Backscatter System
 FILES TO BE USED:
  Configuration Conditions:                    Molecular Absorption Data: (NONE)
    Lidar System Parameters:                Atmospheric Model Parameters:
          Viewing Conditions:                  Output Propagation Profile: DEFAULT
             Output Log File: DEFAULT                 User-Defined Aerosol:
            Output Data File: DEFAULT                  Detector Parameters:

 ATMOSPHERIC CONDITIONS:
     Propagation Profile from: BUILT-IN AEROSOL MODELS
     Rayleigh Scattering Based on: TROPICAL Atmosphere
     User-Defined Aerosol Layer Added: NO

                     File Name Entry
                     Output Data File [.DAT]: _
                             (Default: DEFAULT.DAT)

Enter Filename for Current Simulation
```
Figure 24. BACKSCAT Submenu for Entering an Output Data File Name

5.1.4 Change Molecular Absorption File

This optional file contains molecular absorption data to be used in a simulation. It cannot be used when the user has selected the Raman lidar system option (see Section 5.5). The molecular absorption data file can be generated by the *mabs* package or it can be created off-line by the user in the required format. The format is described in Appendix A. Molecular absorption files are given the default extension, *.res*.

To select this option from the submenu in Figure 20, move the highlighted area to the "Change Molecular Absorption File" line and press RETURN, or type the letter "M" twice. The code will display a "popup" submenu that lists the names of molecular absorption files in the current working directory, as shown in Figure 25. Move the highlighted area to the desired molecular absorption file name and hit RETURN. If no files exist with the *.res* extension, BACKSCAT alerts users with a warning message shown in Figure 26. The user is then returned to the Main Menu.

5.2 Save Configuration Conditions

This Main Menu option saves the configuration conditions for the current simulation to a configuration file. To save the configuration conditions, move the cursor on the Main Menu to the "Save Configuration Conditions" line and press RETURN, or type the letter "S" twice. BACKSCAT then displays a "popup" submenu in which the user can enter the configuration file name, as shown in Figure 27. The code will display *default* or current configuration file name. Type in a new name and press RETURN. (The extension in brackets is not typed by the user, but it is supplied internally by the code.) If the file name already exists, BACKSCAT warns the user that the configuration file will be overwritten. BACKSCAT then asks the user if overwriting the file is acceptable. To overwrite the configuration file, press RETURN, or type "Y" and RETURN. To abort the operation, type "N" and RETURN.

5.3 Run Calculations

This Main Menu option performs a lidar simulation. To perform the simulation, move the highlighted area on the Main Menu to the "Run Calculations" line and press RETURN, or type the letter "R" twice. BACKSCAT then displays a window telling the user that the simulation is being performed, as shown in Figure 28. Additionally, this window displays any errors that occur during the simulation and it notifies the user when the simulation is complete. To return to the Main Menu, hit RETURN. Information about the simulation is written to the output log file (*.log*). This log includes a description of the input parameters and any warning messages that occurred during the simulation. For off-line graphics programs, the simulation results are stored in the output data file (*.dat*).

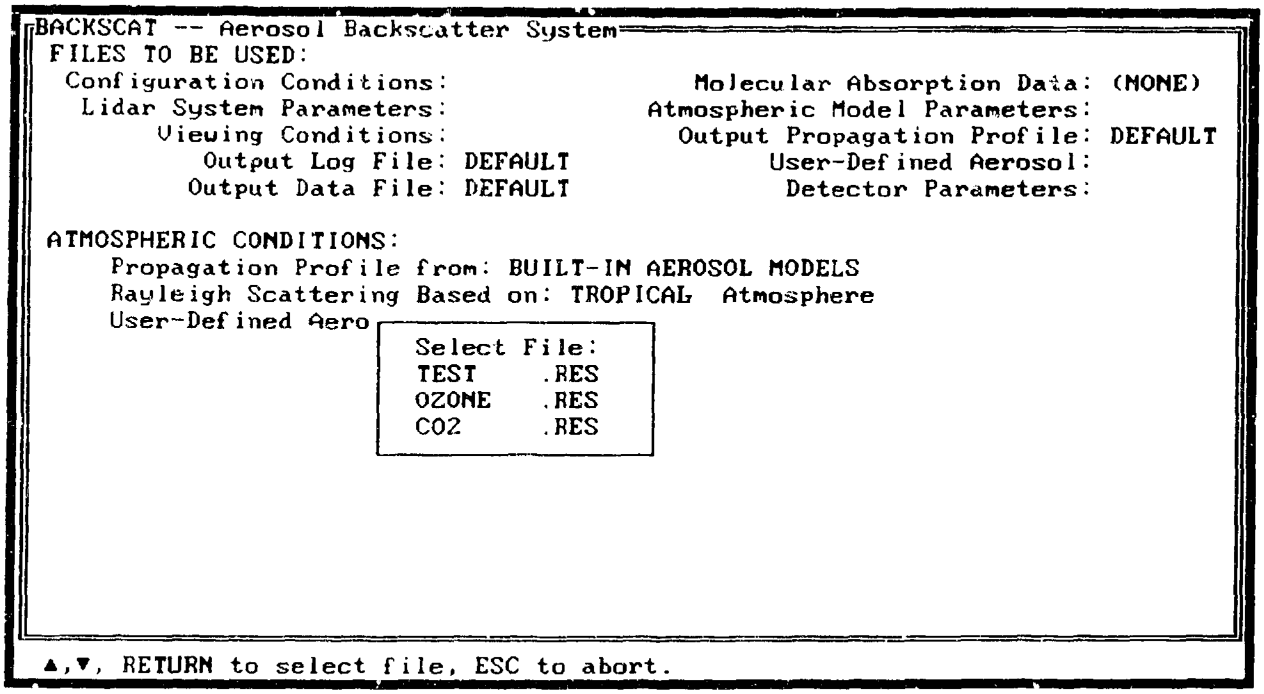

Figure 25. BACKSCAT Submenu for Selecting a Molecular Absorption File Name

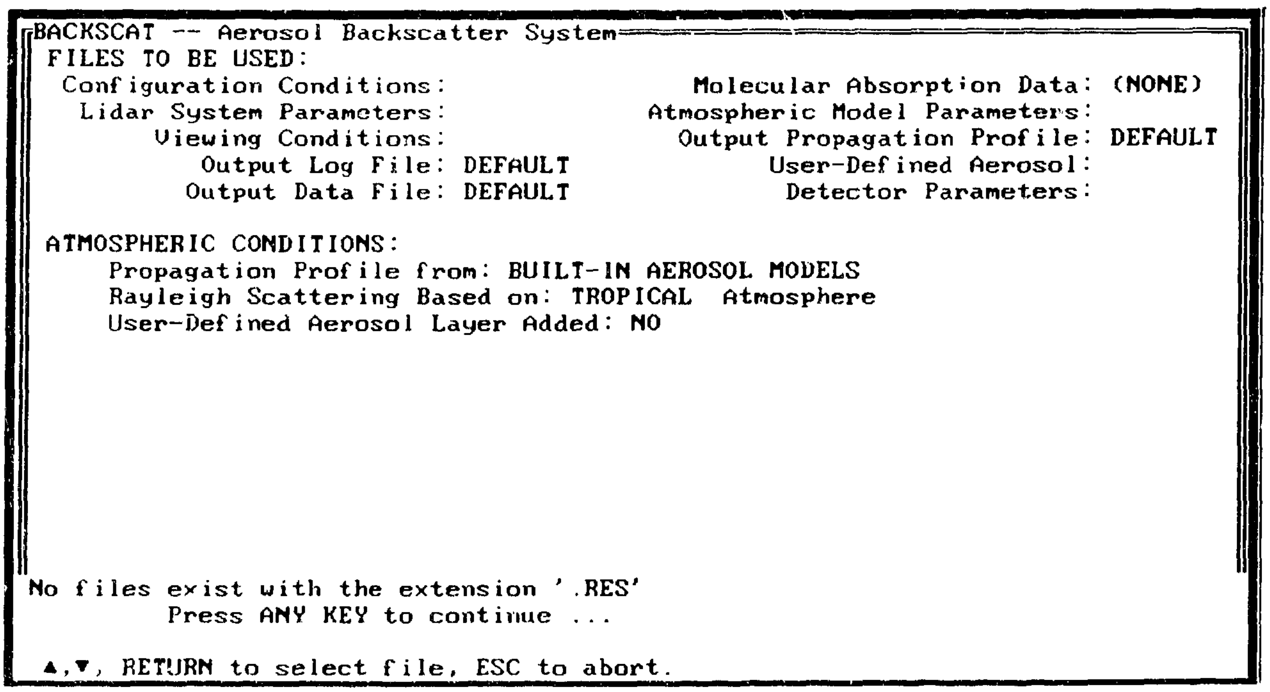

Figure 26. Warning Message Issued by BACKSCAT if No Molecular Absorption Files Exist in the Current Working Directory

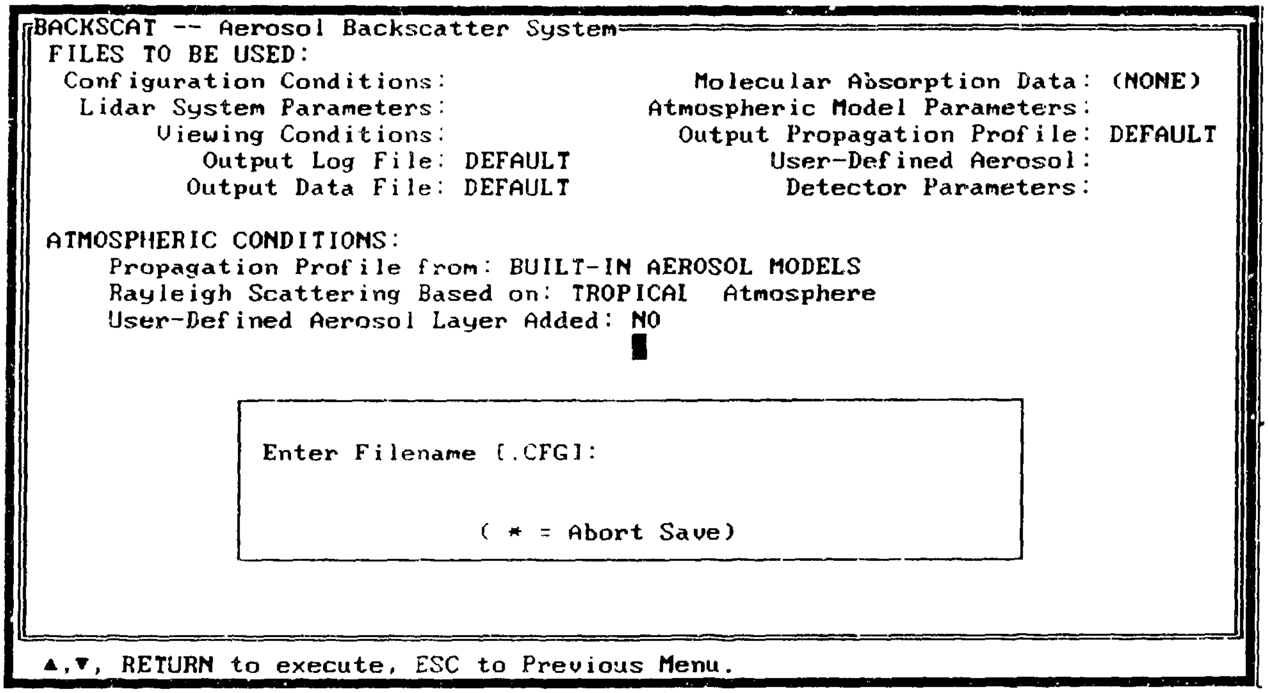

Figure 27. BACKSCAT Submenu for Saving Configuration Conditions to a Configuration File

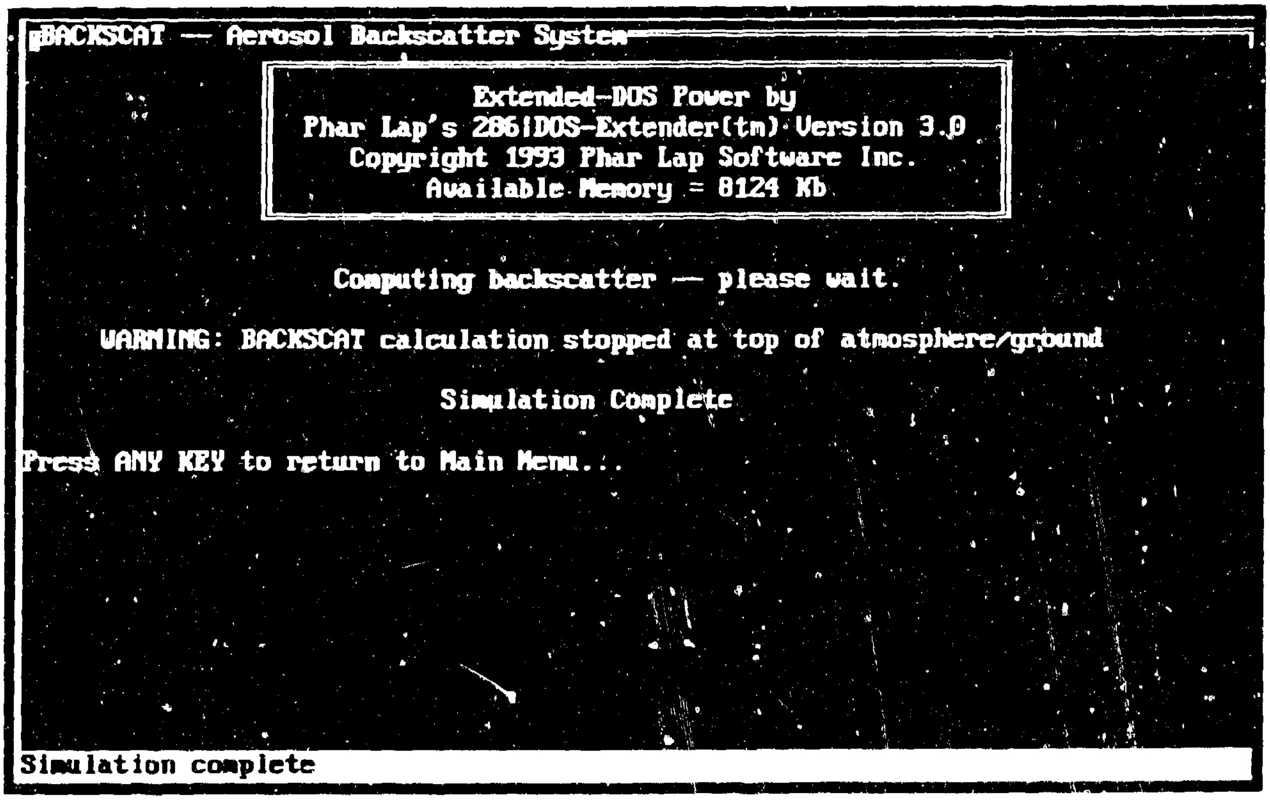

Figure 28. Message Displayed by BACKSCAT When a Simulation Is Performed

5.4 View Results

This Main Menu option is used to view results from the current simulation, or any previously conducted simulation. To create the plots, BACKSCAT accesses data in the output data files (*.dat*). In BACKSCAT Version 4.0, the plotting capabilities have been expanded to include signal-to-noise calculations.

To view the results from a simulation, move the highlighted area on the Main Menu to the "View Results" line and press RETURN, or type the letter "V" twice. Figure 29 shows the View Results Submenu that appears. Upon entering the View Results Submenu, BACKSCAT displays the current output data file name. The default values for the lowest and highest altitude/range are those used in the current simulation. To change the output data file to be plotted, type in a new file name. To change the lowest or highest altitude/range, move to the given entry and enter the new value.

In BACKSCAT Version 4.0, the users has four choices for the type of plot, (1) backscatter coefficient as a function of altitude; (2) backscatter coefficient as a function of range; (3) signal-to-noise as a function of altitude; or (4) signal-to-noise as a function of range. To select from the four options, move the highlighted area to the "Type of Plot" field and hit the F1 key. A "popup" menu appears with the four choices listed, (1) ALTITUDE vs. BACKSCATTER; (2) BACKSCATTER vs. RANGE; (3) ALTITUDE vs. SIGNAL-TO-NOISE; and (4) SIGNAL-TO-NOISE vs. RANGE, as shown in Figure 30. Use the cursor keys to select the desired plot type and press RETURN.

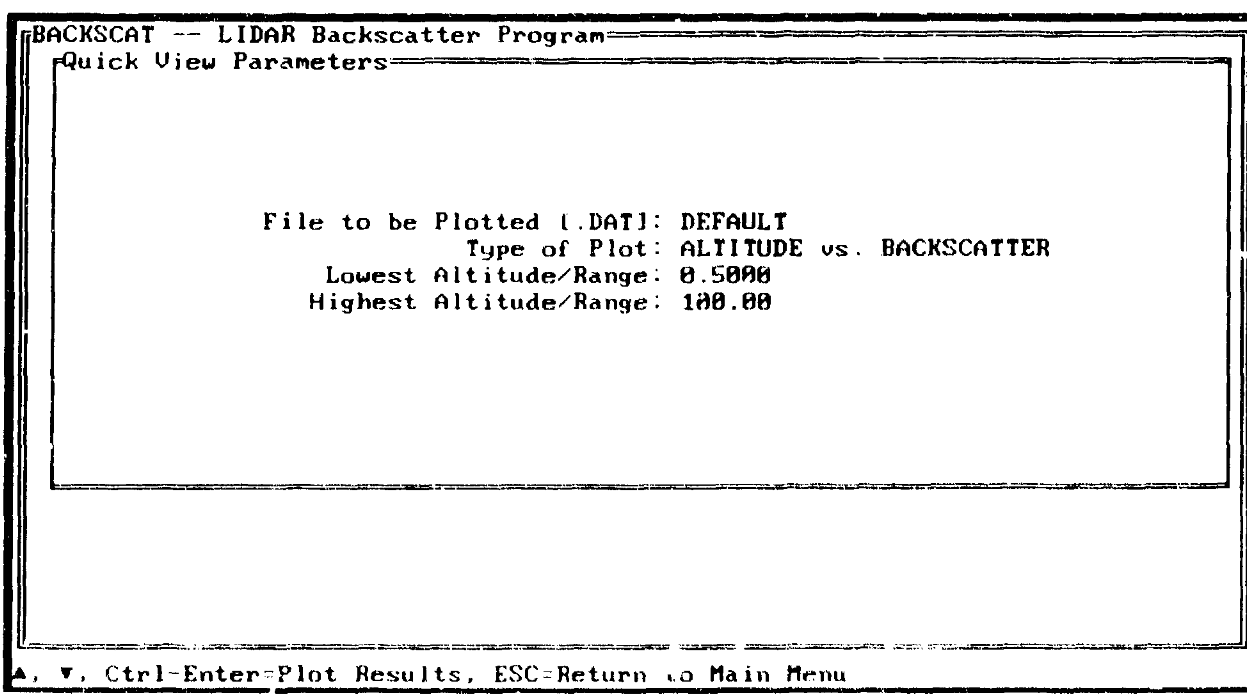

Figure 29. BACKSCAT Submenu for Viewing the Results of a Simulation

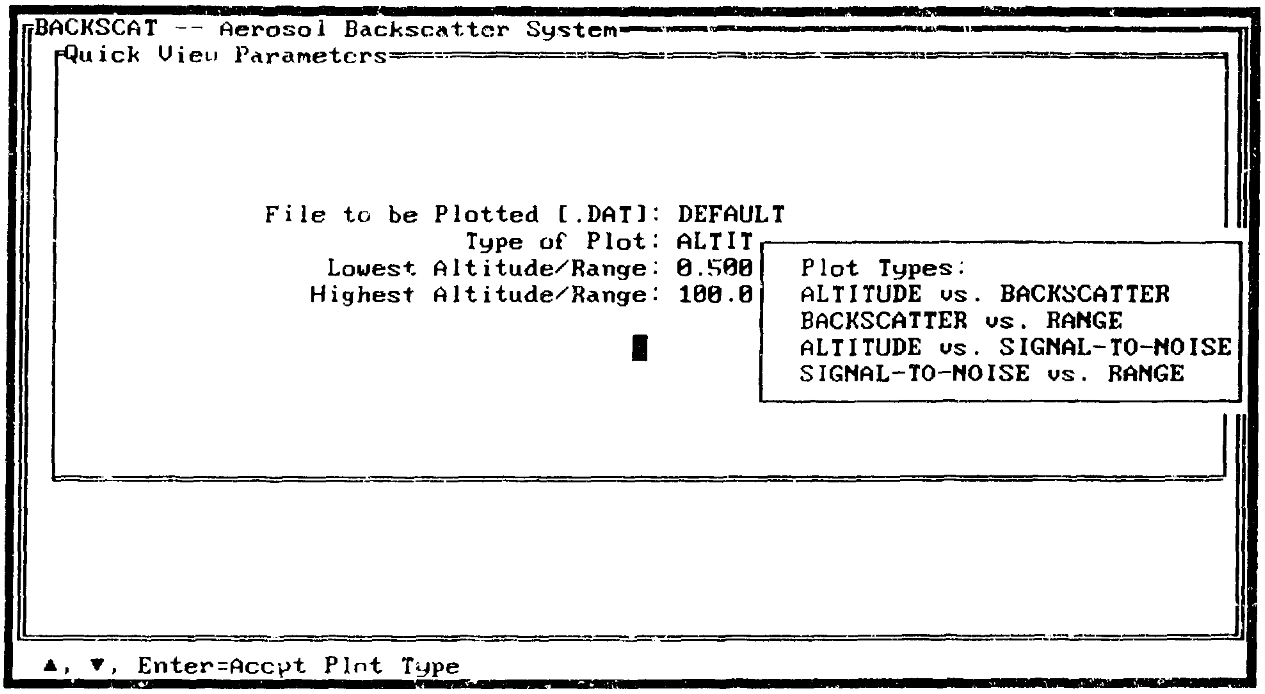

Figure 30. BACKSCAT "Popup" Menu for Selecting the Type of Plot To Be Viewed

To create the plot, hit the CTRL ENTER keys. A plot similar to Figure 31 will appear. Be aware that SNR values less than one are meaningless, but numerically permitted. (Note that the plot will not be created unless the computer system being used has graphics capabilities. If the plot cannot be created, BACKSCAT issues an error message that says it cannot set the graphics mode correctly. Additionally, the axis labels are not plotted unless the font file *modern.fon* is located in the current directory. If axis labels cannot be plotted, BACKSCAT issues an error message that tells the user to move this file to the current directory.) The user can scale the altitude or range axis by hitting the F1 key to decrease the maximum altitude/range by a factor of ten, or the F2 key to increase the maximum altitude/range by a factor of ten. The maximum altitude or range value plotted cannot be decreased less than the minimum value, and it cannot be increased greater than the maximum altitude/range in the results. After viewing the plot, hit ESC to return to the View Results Submenu. To return to the Main Menu, hit ESC again. The user is asked to confirm the exit to the Main Menu.

5.5 Change Lidar System

The user can switch between aerosol backscatter, Raman scattering, and coherent Doppler lidar systems, by selecting the option "Change Lidar System" from the Main Menu. After the lidar system is changed, BACKSCAT updates the top portion of the Main Menu so it displays information relevant to the chosen lidar system.

To change lidar systems, move the highlighted area on the Main Menu to the "Change Lidar System" line and press RETURN, or type the letter "H" twice. Figure 32 shows the "popup" menu that appears. Move the highlighted area to the line for the desired lidar system and press

RETURN, or type its highlighted letter twice. The user is then returned to the Main Menu and the current lidar system is displayed in the upper left hand corner of the Main Menu.

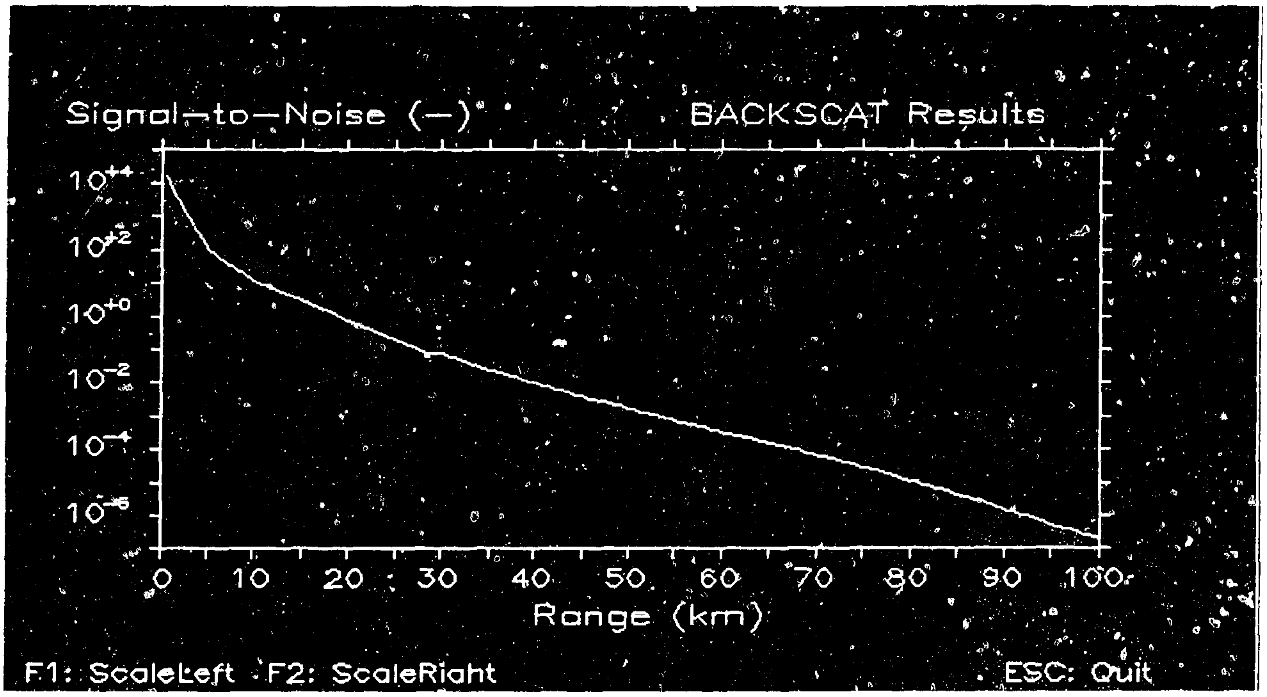

Figure 31. Sample Plot of Signal-to-Noise Ratio Versus Range That Is Created in the View Results Option. Users should remember that SNR values less than one are meaningless

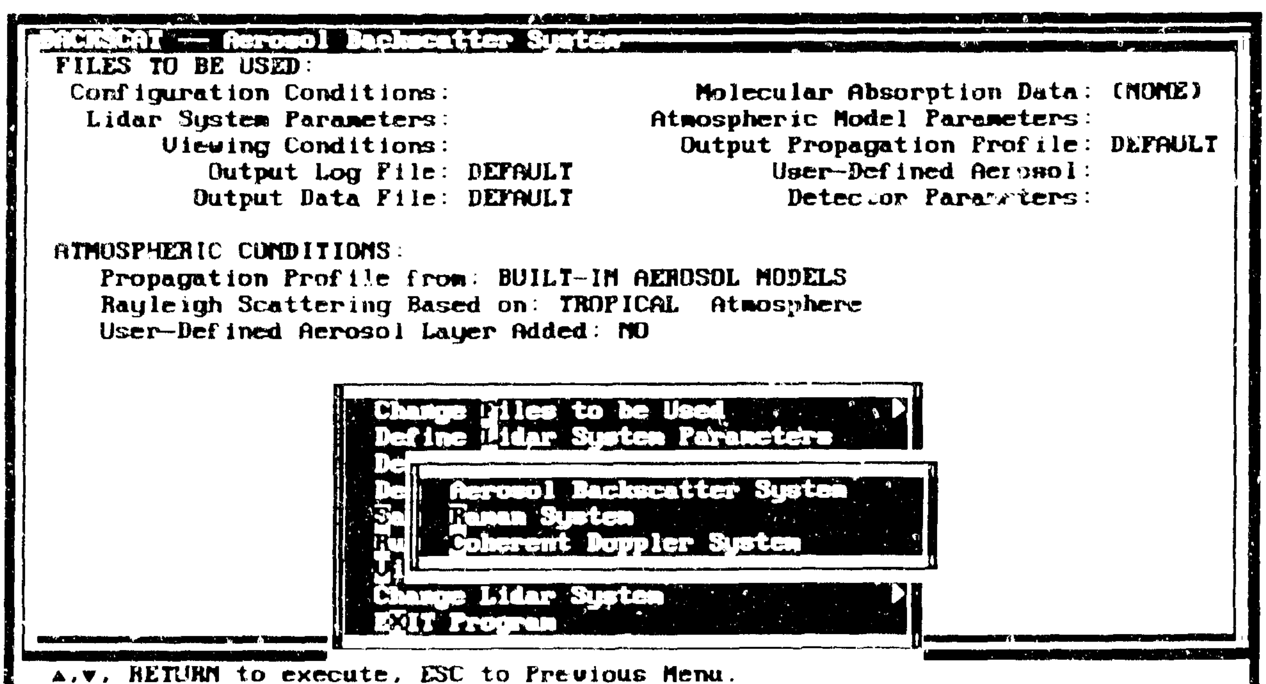

Figure 32. BACKSCAT Submenu for Changing the Type of Lidar System

6 DEFINE LIDAR SYSTEM PARAMETERS

The Main Menu option "Define Lidar System Parameters" describes the characteristics of the transmitter and receiver. In BACKSCAT Version 4.0, additional lidar system parameters have been added for the signal-to-noise calculations. Also, the user must select from five built-in detectors to be used in the simulation, or specify the parameters for a user-defined detector.

6.1 Entering the Lidar System Parameters Submenu

Lidar system parameters are set by selecting the Main Menu option "Define Lidar System Parameters". To select this option, move the highlighted area to the "Define Lidar System Parameters" line and press RETURN, or press the "L" key twice. The Lidar System Parameters Submenu will appear as shown in Figure 33. The values shown in Figure 33 are the default values in BACKSCAT Version 4.0. If the user employs a configuration file that includes a lidar system parameters file, the values in that file will appear instead of those shown in Figure 23 and the file name will appear at the top of the menu instead of "NONE."

```
BACKSCAT -- Aerosol Backscatter System
 Lidar Parameters
            Lidar System File: NONE
          Read parameters from new File?  N

                   Wavelength (microns): 0.5500
                  Pulse Energy (Joules): 1.0000
               Duration of Pulse (usec): 1.0000
        Telescope Aperture Diameter (cm): 100.00
          Obscuring Mirror Diameter (cm): 2.0000
      Transmitter Optical Efficiency (-): 1.0000
         Receiver Optical Efficiency (-): 1.0000
          Receiver Field-of-View (urad): 300.00
        B'ground Radiance (W/(m2*sr*um)): 0.0000
              Spectral Filter Width (A): 0.0000
                                Detector: PMT-VIS (R636)

▲, ▼, Ctrl-Enter=Accpt Changes, ESC=Quit
```

Figure 33. BACKSCAT Submenu for Defining Lidar System Parameters. The values shown are the default values in BACKSCAT Version 4.0

6.2 Accessing Lidar System Parameters from File

BACKSCAT allows lidar system parameters to be saved in a file and then easily recalled into the menu interface system. These files are given the default extension, *.ldr*, and are described in Appendix A. The name of an existing lidar system parameters file can be included in the configuration file.

When the Lidar System Parameters Submenu first appears, the user is asked if he or she wants to read parameters from an existing lidar system file. (This occurs even if a lidar system parameters file was specified by means of a configuration file.) If the answer is "Y", the code displays a "popup" menu that lists the lidar system parameter files in the current working directory. An example is shown in Figure 34. Move the cursor to the desired file name and hit RETURN. The values in the *.ldr* file will replace those in the Lidar System Parameters Submenu. To exit this "popup" menu and not select a new lidar system parameters file, hit ESC. If no files exist in the current directory with the *.ldr* extension, BACKSCAT alerts the user with a warning and then returns to the Lidar System Parameters Submenu. If the user chooses not to read in a new file by responding with a "N" on the Lidar System Parameters Submenu, the highlighted area will move to the edit fields for the individual lidar system parameters.

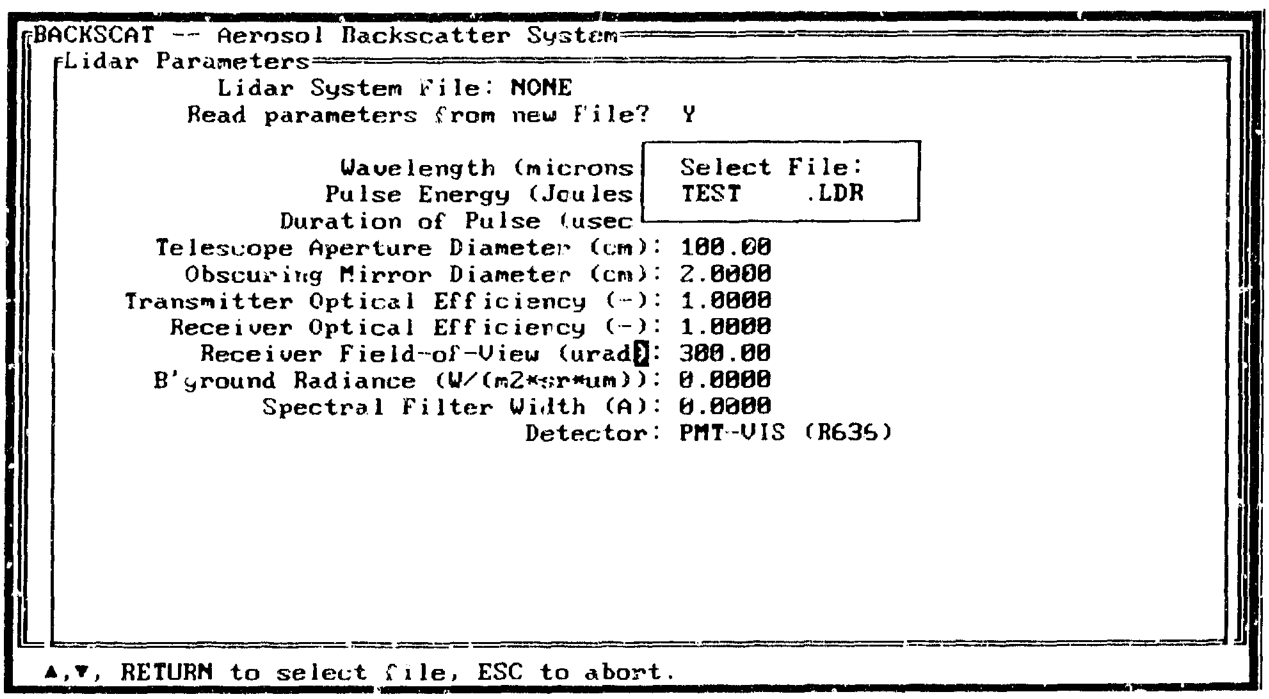

Figure 34. BACKSCAT "Popup" Menu for Selecting a Lidar System File

6.3 Editing Individual Lidar System Parameters

To selectively modify any or all lidar system parameters, move the highlighted area to the desired parameter (using the up or down arrow keys), type in the new value, and hit RETURN. BACKSCAT verifies that the new value is within the range limits for that parameter. If a new value is not within the range limits, BACKSCAT displays an error message that gives the acceptable range for the parameter and then it prompts the user to correct the entry. An example is shown in Figure 35. For reference, Table 11 gives the valid ranges for the lidar system parameters. In Table 11, the receiver field-of-view parameter must exceed the diffraction limit of the receiver optics which equals $4\lambda/\pi D_R$ (see Eq. 14). If it does not, BACKSCAT automatically sets the receiver field-of-view to the diffraction limit and issues a warning message in the log file.

When the user changes the lidar wavelength, BACKSCAT verifies that the new lidar wavelength applies to the current detector in the Lidar System Parameters Submenu. If it does not, BACKSCAT informs the user that the lidar wavelength cannot be used with the current detector. An example is shown in Figure 36. Note that BACKSCAT only issues an informative message, so the user needs to remember to change the type of detector.

6.4 Selecting a Detector

The last parameter in the Lidar System Parameters Submenu is used to select the type of detector for the simulation. To select a detector, move the highlighted area to the type of detector edit field and hit the F1 key. A "popup" menu will appear as shown in Figure 37. The "popup" menu contains the five built-in detectors and two user-defined detectors. The procedures to select the different detectors are given below.

6.4.1 Built-In Detectors

To select a built-in detector from the "popup" menu shown in Figure 37, simply move the highlighted area to the desired built-in detector and hit RETURN. BACKSCAT then displays the name of the new detector in the Lidar System Parameters Submenu. If the built-in detector does not apply to the current lidar wavelength, BACKSCAT issues an error message that says the user has selected an invalid detector. An example is shown in Figure 38. The user must then hit any key to continue and BACKSCAT returns to the "popup" menu for selecting the type of detector. For reference, Table 12 lists the valid wavelength ranges for the built-in detectors. Note that BACKSCAT does not permit the user to leave the type of detector edit field unless a user-defined detector or a valid built-in detector is selected.

6.4.2 Files with Parameters for User-Defined Detectors

BACKSCAT allows the parameters for a user-defined detector to be saved in a file and then easily recalled into the menu interface system. The name of an existing user-defined detector file can be included in the configuration file or it can be specified in one of two Detector Parameters Submenus (see Sections 6.4.3 and 6.4.4). User-defined detector files are given the default extension, *.det*, and are described in Appendix A.

```
BACKSCAT -- Aerosol Backscatter System
 Lidar Parameters
        Lidar System File: NONE
      Read parameters from new File?  N

                  Wavelength (microns): -9
                 Pulse Energy (Joules): 1.0000
              Duration of Pulse (usec): 1.0000
      Telescope Aperture Diameter (cm): 100.00
        Obscuring Mirror Diameter (cm): 2.0000
    Transmitter Optical Efficiency (-): 1.0000
       Receiver Optical Efficiency (-): 1.0000
         Receiver Field-of-View (urad): 300.00
     B'ground Radiance (W/(m2*sr*um)): 0.0000
             Spectral Filter Width (A): 0.0000
                              Detector: PMT-VIS (R636)


Lidar Wavelength must be in the range: 0.2 - 40.0 um
          Press ANY KEY to continue ...

▲, ▼, Ctrl-Enter=Accpt Changes, ESC=Quit
```

Figure 35. Example of an Error Message Issued by BACKSCAT When the User Enters an Incorrect Value for a Lidar System Parameter

Table 11. Lidar System Parameters for BACKSCAT Version 4.0, Units, Default Values, and Limits. The * denotes new lidar system parameters in BACKSCAT Version 4.0.

LIDAR SYSTEM PARAMETER	UNITS	DEFAULT VALUE	LIMITS
Wavelength	μm	0.55	0.2-40.0
Pulse energy	Joules	1.0	>0.0
Pulse duration	μsec	1.0	>0.0 ≤Range resolution
Telescope aperture diameter	cm	100.0	>0.0 >Obscuring mirror diameter
Obscuring mirror diameter	cm	2.0	≥0.0 <Telescope aperture diameter
Transmitter optical efficiency*	(-)	1.0	0.0-1.0
Receiver optical efficiency*	(-)	1.0	0.0-1.0
Receiver field-of-view*	μrad	300.0	>Diffraction limit of receiver optics
Background radiance*	W/(m^2 sr μm)	0.0	≥0.0
Spectral filter width*	Å	0.0	≥0.0

```
BACKSCAT -- Aerosol Backscatter System
 Lidar Parameters
            Lidar System File: NONE
          Read parameters from new File?  N

                    Wavelength (microns): 4.5
                   Pulse Energy (Joules): 1.0000
                Duration of Pulse (usec): 1.0000
         Telescope Aperture Diameter (cm): 100.00
           Obscuring Mirror Diameter (cm): 2.0000
       Transmitter Optical Efficiency (-): 1.0000
          Receiver Optical Efficiency (-): 1.0000
            Receiver Field-of-View (urad): 300.00
      B'ground Radiance (W/(m2*sr*um)): 0.0000
              Spectral Filter Width (A): 0.0000
                                Detector: PMT-VIS (R636)




NOTE:    This lidar wavelength does not apply to the chosen detector.
         PMT-VIS detector is for wavelengths between 0.18 and 0.90 um.
         Press ANY KEY to continue ...
▲, ▼, Ctrl-Enter=Accpt Changes, ESC=Quit
```

Figure 36. Example of the Informative Message Issued by BACKSCAT When the User Enters a Lidar Wavelength That Does Not Apply to the Current Detector

```
BACKSCAT -- Aerosol Backscatter System
 Lidar Parameters
            Lidar System File: NONE
          Read parameters from new File?  N

                    Wavelength (microns):  .5500
                   Pulse Energy (Joules): 1.0000
                Duration of Pulse (usec): 1.0000
         Telescope Aperture Diameter (cm): 100.00
           Obscuring Mirror Diameter (cm): 2.0000
       Transmitter Optical Efficiency (-): 1.0000
          Receiver Optical Efficien
            Receiver Field-of-View       Detector Types:
      B'ground Radiance (W/(m2*s         APD
              Spectral Filter Wid        Dimpled APD
                                De       PMT-VIS (R636)
                                         PMT-UV (R375)
                                         HgCdTe
                                         Other w/ NEP
                                         Other w/o NEP


 ▲, ▼, Enter=Accept Detector Type
```

Figure 37. BACKSCAT "Popup" Menu for Selecting the Type of Detector

```
BACKSCAT -- Aerosol Backscatter System
 Lidar Parameters
            Lidar System File: NONE
          Read parameters from new File?  N

                    Wavelength (microns): 0.5500
                   Pulse Energy (Joules): 1.0000
                Duration of Pulse (usec): 1.0000
        Telescope Aperture Diameter (cm): 100.00
          Obscuring Mirror Diameter (cm): 2.0000
     Transmitter Optical Efficiency (-): 1.0000
        Receiver Optical Efficiency (-): 1.0000
          Receiver Field-of-View (urad): 300.00
      B'ground Radiance (W/(m2*sr*um)): 0.0000
              Spectral Filter Width (A): 0.0000
                               Detector: PMT-VIS (R636)




Invalid Detector: Dimpled APD detector is for wavelengths from 1.04 to 1.06 um.
          Press ANY KEY to continue ...

▲, ▼, Ctrl-Enter=Accpt Changes, ESC=Quit        F1=Display Available Detectors
```

Figure 38. Example of the Error Message Issued by BACKSCAT When the User Selects a Built-In Detector That Does Not Apply to the Current Lidar Wavelength. Note that the previous detector remains in the detector edit field until an appropriate detector is selected

Table 12. Wavelength Ranges for Built-In Detectors in BACKSCAT

DETECTOR	WAVELENGTH RANGE (μm)
APD (C30919)	0.45-1.15
Dimpled APD	1.04-1.06
PMT-VIS (R636)	0.18-0.90
PMT-UV (R315)	0.16-0.70
HgCdTe	10.6

6.4.3 User-Defined Detectors with Spectral Noise Equivalent Power

To specify a user-defined detector with the spectral noise equivalent power, move the highlighted area on the detector "popup" menu (Figure 37) to the "OTHER w/NEP" option and hit RETURN. The Detector Parameters Submenu will appear as shown in Figure 39. The values shown in Figure 39 are the default values in BACKSCAT Version 4.0. If the user employs a configuration file that includes a user-defined detector file name, the values in that file will appear instead of those shown in Figure 39 and the file name will appear at the top of the menu instead of "NONE."

```
BACKSCAT -- Aerosol Backscatter System
 Lidar Parameters
            Lidar System File: NONE
          Read parameters from new File?  N
             Detector Parameters With Spectral NEP
                        Detector File: NONE
                      Read parameters from new File?  N

      Teles                     Quantum Efficiency (-): 0.1546
        Obs                           Current Gain (-): 1.8e+005
    Transmi          Detector Excess Noise Factor (-): 1.2000
       Rece
         Re                Spectral NEP (W/sqrt(Hz)): 0
     B'gro






▲, ▼, Ctrl-Enter=Accpt Changes, ESC=Quit
```

Figure 39. BACKSCAT Submenu for Specifying the Parameters for a User-Defined Detector With the Spectral Noise Equivalent Power. The values shown are the default values in BACKSCAT Version 4.0

When the Detector Parameters Submenu first appears, BACKSCAT asks the user if he or she wants to read parameters from an existing user-defined detector file. (This will occur even if a user-defined detector file was specified by means of a configuration file.) If the answer is "Y", BACKSCAT displays a "popup" menu that lists the user-defined detector files in the current working directory. An example is shown in Figure 40. Move the cursor to the desired file name and hit RETURN. The values in the *.det* file will replace those in the submenu. (Note that the spectral NEP is set to 0.0 when the user selects a user-defined detector file that describes a detector without the spectral NEP.) To exit the "popup" menu and not select a new user-defined detector file, hit ESC. If no files exist in the current directory with the *.det* extension, BACKSCAT alerts the user with a warning message and then returns to the Detector Parameters Submenu. If the user chooses not to read a new file by responding with a "N" on the Detector Parameters Submenu, the highlighted area will move to the edit fields for the individual detector parameters.

To selectively modify any or all detector parameters, move the highlighted area to the desired parameter (using the up and down arrow keys), type in the new value, and hit RETURN. BACKSCAT verifies that the new value is within the range limits for that parameter. If a new value is not within the range limits, BACKSCAT displays an error message that gives the acceptable range for the parameter and then it prompts the user to correct the entry. An example is shown in Figure 41. For reference, Table 13 lists the valid ranges for user-defined detectors with the spectral NEP.

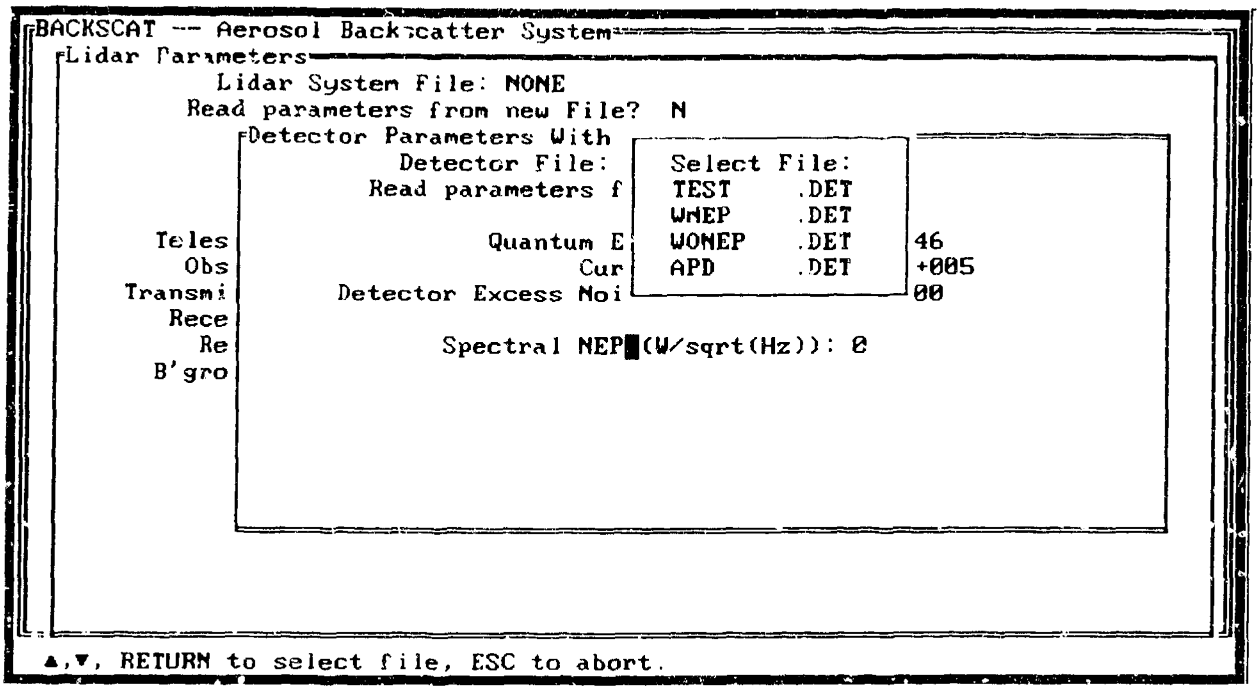

Figure 40. BACKSCAT "Popup" Menu for Selecting a User-Defined Detector File

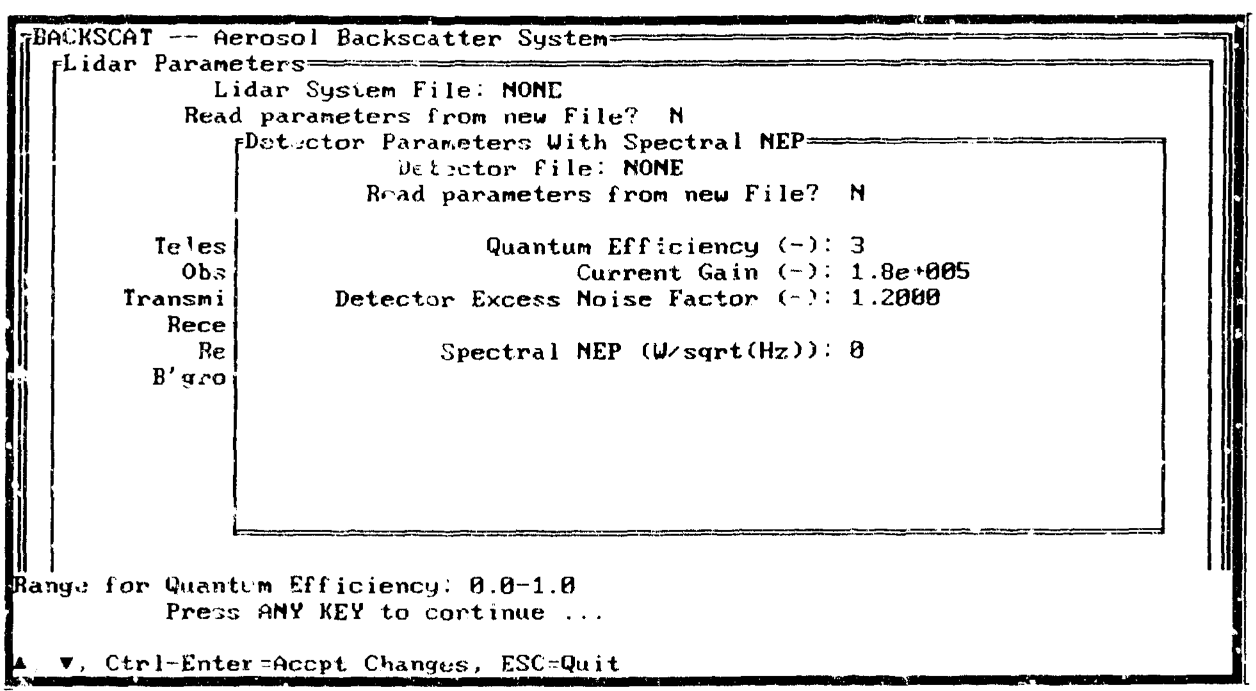

Figure 41. Example of an Error Message Issued by BACKSCAT When the User Enters an Incorrect Value in the Detector Parameters Submenu

Table 13. Parameters for a User-Defined Detector With the Spectral Noise Equivalent Power, Units, Default Values, and Limits. Note that the user must input the spectral NEP

DETECTOR PARAMETER	UNITS	DEFAULT VALUE	LIMITS
Quantum efficiency	(-)	0.15462	0.0-1.0
Current gain	(-)	1.8×10^5	≥ 1.0
Detector excess noise factor	(-)	1.2	>0.0
Spectral noise equivalent power density (NEP)	$W/(Hz)^{1/2}$	0.0	≥ 0.0

6.4.4 User-Defined Detectors without Spectral Noise Equivalent Power

To specify a user-defined detector without the spectral noise equivalent power, move the highlighted area on the detector "popup" menu (Figure 37) to the "OTHER w/oNEP" option and hit RETURN. The Detector Parameters Submenu will appear as shown in Figure 42. (Note that this submenu differs slighdy from that shown in Figure 39.) The values shown in Figure 42 are the default values in BACKSCAT Version 4.0. If the user employs a configuration file that includes a user-defined detector file name, the values in that file will appear instead of those shown in Figure 42 and the file name will appear at the top of the menu instead of "NONE."

```
BACKSCAT -- Aerosol Backscatter System
 Lidar Parameters
            Lidar System File: NONE
          Read parameters from new File?  N
                 Detector Parameters Without Spectral NEP
                       Detector File: NONE
                     Read parameters from new File?  N

     Teles                   Quantum Efficiency (-): 0.1546
       Obs                         Current Gain (-): 1.8e+005
   Transmi          Detector Excess Noise Factor (-): 1.2300
      Rece
        Re               Anode Dark Current (namp): 0.1000
     B'gro                     Load Resistor (ohm): 50.000
                     Effective Load Temperature (K): 300.00
            Other Amplifier/Detector Noise (namp): 0.0000

▲, ▼, Ctrl-Enter=Accpt Changes, ESC=Quit
```

Figure 42. BACKSCAT Submenu for Specifying the Parameters for a User-Defined Detector Without the Spectral Noise Equivalent Power. The values shown are the default values in BACKSCAT Version 4.0

When the Detector Parameters Submenu first appears, BACKSCAT asks the user if he or she wants to read parameters from an existing user-defined detector file. (This will occur even if a user-defined detector file was specified by means of a configuration file.) If the answer is "Y", BACKSCAT displays a "popup" menu similar to Figure 40 that lists the user-defined detector files in the current working directory. Move the cursor to the desired file name and hit RETURN. The values in the *.det* file will replace those in the submenu. (Note that the anode dark current, load resistor, effective load temperature, and other amplifier/detector noise current are set to 0.0 when the user selects a user-defined detector file that describes a detector with the spectral NEP.) To exit the "popup" menu and not select a new user-defined detector file, hit ESC. If no files exist in the current directory with the *.det* extension, BACKSCAT alerts the user with a warning message and then returns to the Detector Parameters Submenu. If the user chooses not to read a new file by responding with a "N" on the Detector Parameters Submenu, the highlighted area will move to the edit fields for the individual detector parameters.

To selectively modify any or all detector parameters, move the highlighted area to the desired parameter (using the up and down arrow keys), type in the new value, and hit RETURN. BACKSCAT verifies that the new value is within the range limits for that parameter. If a new value is not within the range limits, BACKSCAT displays an error message similar to Figure 41 that gives the acceptable range for the parameter and then it prompts the user to correct the entry. For reference, Table 14 lists the valid ranges for user-defined detectors without the spectral NEP.

Table 14. Parameters for a User-Defined Detector Without the Spectral Noise Equivalent Power, Units, Default Values, and Limits

DETECTOR PARAMETER	UNITS	DEFAULT VALUE	LIMITS
Quantum efficiency	(-)	0.15462	0.0-1.0
Current gain	(-)	1.8×10^5	≥1.0
Detector excess noise factor	(-)	1.2	>0
Anode dark current	namp	0.1	≥0.0
Load resistor	ohm	50.0	>0.0
Effective load temperature	K	300.0	≥0.0
Other amplifier/detector noise current	namp	0.0	≥0.0

6.5 Exiting the Lidar System Parameters Submenu

To exit the Lidar System Parameter Submenu and save any changes made to the lidar system parameters, hit the CTRL-ENTER keys. BACKSCAT asks the user if he or she wants to write the lidar system parameters to a *.ldr* file. Answer with a "Y" or "N." If the answer is "Y," the user is prompted for the file name. The name of the current lidar system file is provided as the default choice. To use this file name, press RETURN. BACKSCAT reminds the user that the file already exists and then asks for confirmation to overwrite it. Answer with a "Y" or "N." If the user wants to save the lidar systems parameters to a new *.ldr* file, type in the new file name and press RETURN. After the file is saved, the user is returned to the Main Menu.

To return to the Main Menu without saving any changes made to the lidar system parameters, hit ESC at any time during the editing process. BACKSCAT asks the user to confirm this operation because any changes to the lidar system parameters are lost, including any new file read in.

7 DEFINE VIEWING CONDITIONS

The Main Menu option "Define Viewing Conditions" specifies the altitude and viewing orientation of the lidar, the range and resolution of the simulation output, and the albedo of the underlying surface. Note that this option and its accompanying menus are unchanged from BACKSCAT Version 3.0.

7.1 Entering the Viewing Conditions Submenu

To set the viewing condition parameters, move the highlighted area to the "Define Viewing Conditions" line on the Main Menu and press RETURN, or press the "C" key twice. The Viewing Conditions Submenu will appear as shown in Figure 43. The values shown in Figure 43 are the default values in BACKSCAT Version 4.0. If the user employs a configuration file that includes a viewing conditions file name, the values in that file will appear instead of those shown in Figure 43 and the file name will appear at the top of the menu instead of "NONE."

7.2 Accessing Viewing Conditions Parameters from File

BACKSCAT allows viewing conditions parameters to be saved in a file and then easily recalled into the menu interface system. These files are given the default extension, *.vuw*, and are described in detail in Appendix A. The name of an existing viewing conditions file can be included in the configuration file.

When the Viewing Conditions Submenu first appears, the user will be asked if he or she wants to read in parameters from an existing viewing conditions file. (This occurs even if a viewing conditions file was specified in a user-supplied configuration file.) If the answer is "Y", the code displays a "popup" menu that lists the viewing conditions files in the current working directory. An example is shown in Figure 44. Move the cursor to the desired file name and hit RETURN. The values in the *.vuw* file will replace those in the Viewing Conditions Submenu. To exit this "popup" menu and not select a new viewing conditions file, hit ESC. If no files exist in the current directory with the *.vuw* extension, BACKSCAT alerts the user with a warning message and then returns to the Viewing Conditions Submenu. If the user chooses not to read a new file by responding with a "N" on the Viewing Conditions Submenu, the highlighted area will move to the edit fields for the individual viewing conditions parameters.

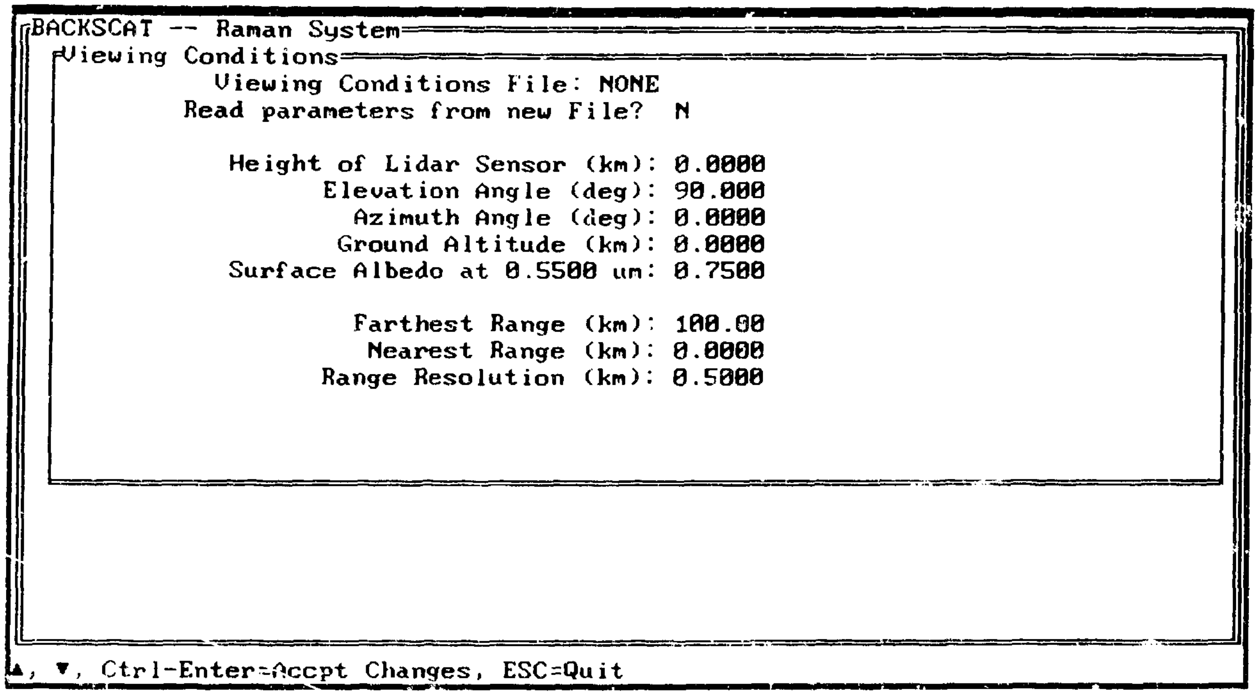

Figure 43. BACKSCAT Submenu for Specifying the Lidar Viewing Conditions

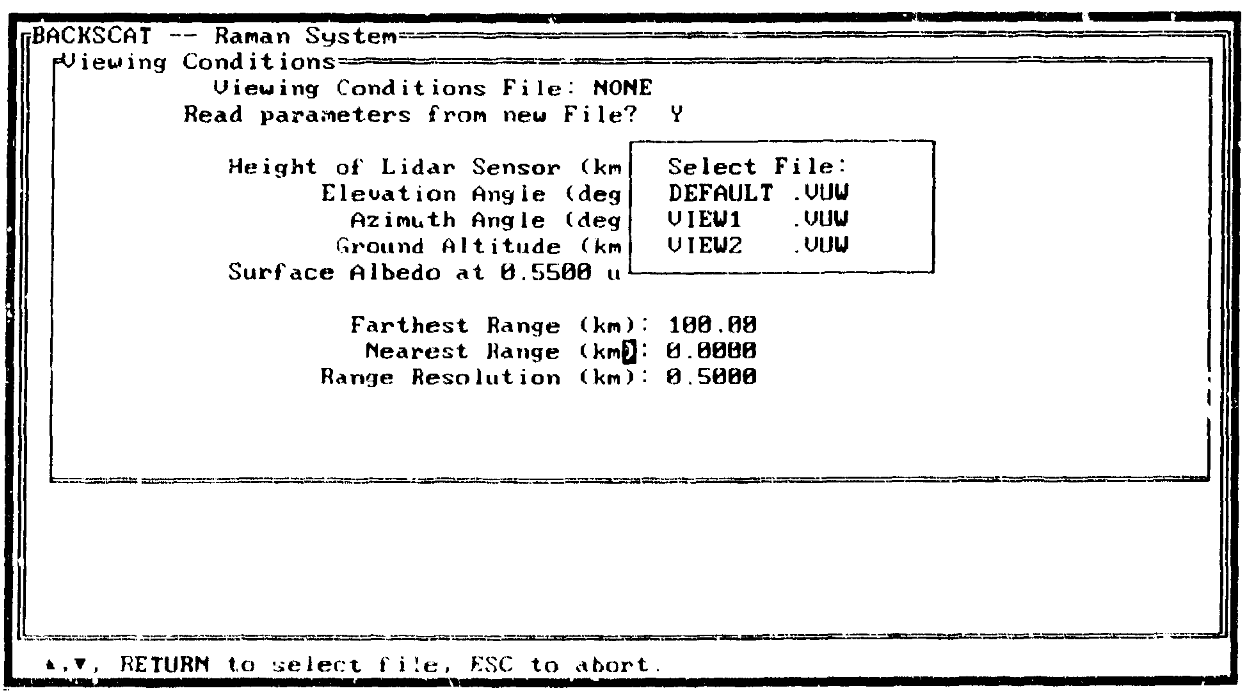

Figure 44. BACKSCAT "Popup" Menu for Selecting a Viewing Conditions File

7.3 Editing Individual Viewing Conditions Parameters

To selectively modify any or all of the viewing condition parameters, move the highlighted area to the desired parameter (using the up or down arrow keys), type in the new value, and hit RETURN. BACKSCAT verifies that the new value is within the range limits for that parameter. If a new value is not within the range limits, BACKSCAT displays an error message that gives the acceptable range for the parameter and then it prompts the user to correct the entry. For reference, Table 15 gives the valid ranges for the viewing conditions parameters. Note that in Table 15, the altitude of the lidar platform can be above 100 km even though the "top" of the atmosphere is usually set to 100 km. This feature allows the user to simulate a lidar on a space platform. For this scenario, BACKSCAT does not attenuate or backscatter the lidar beam between the top of the atmosphere and the lidar platform, but it does adjust the viewing elevation angle to compensate for earth curvature as well as issue a message in the log file.

Table 15. Viewing Conditions Parameters for BACKSCAT Version 4.0, Units, Default Values, and Limits

VIEWING PARAMETER	UNITS	DEFAULT VALUE	LIMITS
Height of lidar sensor	km MSL	0.0	≥ 0
Viewing elevation angle	deg	90.0	-90.0 - 90.0 (≥ 0.0 for ground-based lidar)
Viewing azimuth angle	deg	0.0	0 - 360
Ground altitude	km MSL	0.0	≥ 0 and ≤ lidar sensor height
Surface albedo at lidar wavelength	-	0.25	0.0 - 1.0
Farthest range for output	km	100.0	> 0 and > nearest range
Nearest range for output	km	0.0	> 0 and < farthest range
Range resolution for output	km	0.5	< farthest minus nearest range, and ≥ pulse duration × 0.1498625

7.4 Exiting the Viewing Conditions Submenu

To exit the Viewing Conditions Submenu and save any changes made to the viewing conditions parameters, hit the CTRL-ENTER keys. BACKSCAT asks the user if he or she wants to write the viewing conditions parameters to a *.vew* file. Answer with a "Y" or "N." If the answer is "Y," the code prompts the user for the file name. The name of the current viewing conditions file is provided as the default choice. To use this file name, press RETURN. BACKSCAT reminds the user that the file already exists and then asks for confirmation to overwrite it. Answer with a "Y" or "N." If the user wants to save the viewing conditions parameters to a new *.vew* file, type in the new file name and press RETURN. After BACKSCAT saves the file, the user is returned to the Main Menu.

To return to the Main Menu without saving any changes made to the viewing conditions parameters, hit ESC at any time during the editing process. BACKSCAT asks the user to confirm this operation because any changes to the viewing conditions parameters are lost, including any new file read in.

8 DEFINE ATMOSPHERIC CONDITIONS

The Main Menu option "Define Atmospheric Conditions" defines the atmospheric conditions for a BACKSCAT simulation. To select this option, move the highlighted area to the "Define Atmospheric Conditions" line and press RETURN, or press the "A" key twice.

8.1 Overview of the "Define Atmospheric Conditions" Option

In BACKSCAT, the state of the atmosphere is described with a "propagation profile" which characterizes the atmosphere in terms of basic parameters required by the lidar equation. The parameters include profiles of aerosol and molecular attenuation at the lidar wavelength and, if applicable, at the Raman wavelength. For coherent Doppler simulations, the wind field is also included. A propagation profile can either be provided by the user as an input file or it can be calculated by BACKSCAT using a built-in library of aerosol, molecular, and wind field models. For reference, Appendix A contains a description of the propagation profile for each type of lidar system.

In the "Define Atmospheric Conditions" option, the user can select the source of the propagation profile and based on this selection, specify or change the associated filenames, modeling options, atmospheric parameters, and other optional features in BACKSCAT. The layout of the "Define Atmospheric Conditions" option depends on the source of the propagation profile (user-defined or built-in models) and the type of lidar being simulated (aerosol backscatter, Raman scattering, or coherent Doppler). An example of an Atmospheric Conditions Submenu is shown in Figure 45. The top portion of the submenu gives general information about the current atmospheric conditions. The bottom portion of the submenu displays a list of available options.

The following sections describe how to use the "Define Atmospheric Conditions" option. For aerosol backscatter and coherent Doppler systems, the layout and flow through the "Define Atmospheric Conditions" option are the same, except wind field information is added for coherent Doppler systems. The available options are summarized in Table 16. Table 17 summarizes the available options for Raman scattering systems.

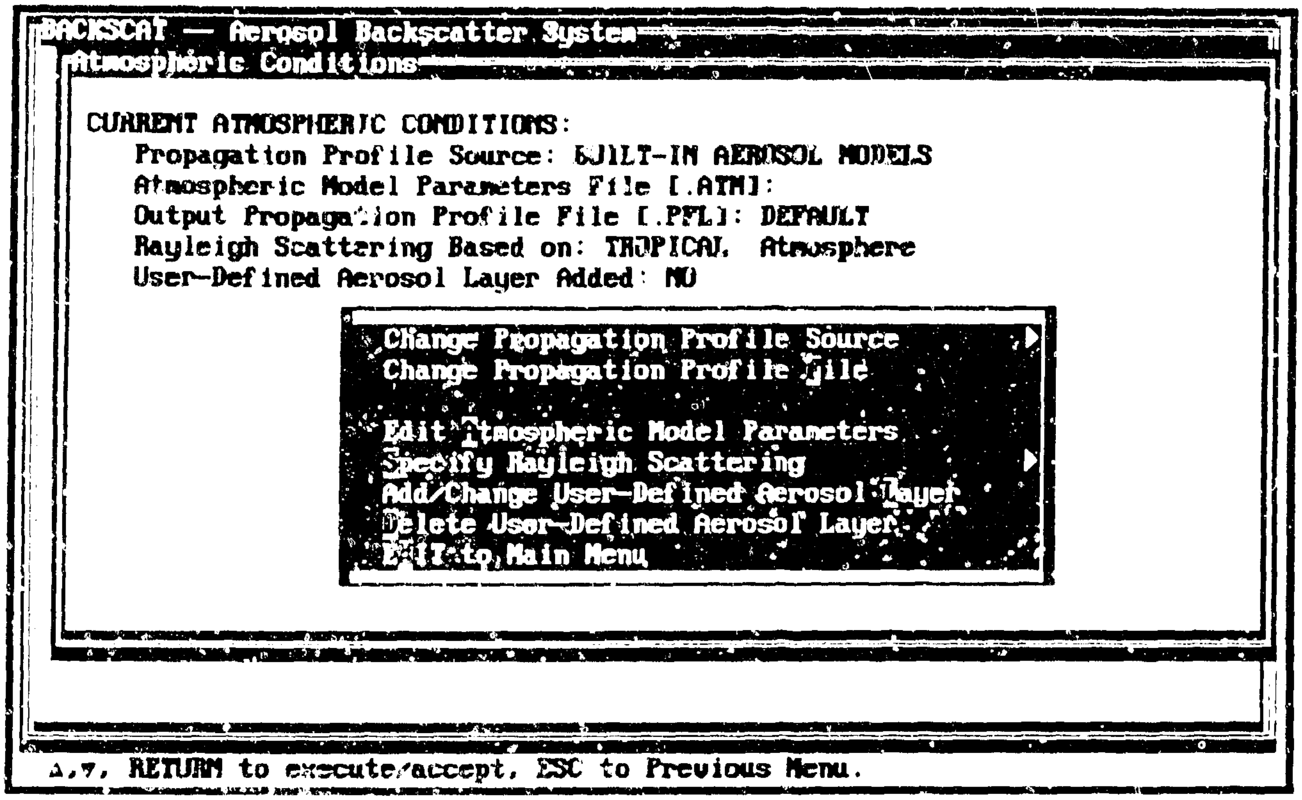

Figure 45. Atmospheric Conditions Submenu When the Simulation Is For an Aerosol Backscatter System and the Source of the Propagation Profile Is the Built-In Aerosol Models

Table 16. Available Options in the Atmospheric Conditions Submenu for Aerosol Backscatter and Coherent Doppler Lidar Systems

SUBMENU OPTION	BUILT-IN MODELS	USER-SUPPLIED PROFILE
Change propagation profile source	Yes	Yes
Change propagation profile file	Yes[1]	Yes[2]
Edit built-in (aerosol) model parameters	Yes	No
Specify Rayleigh scattering/wind field[3]	Yes	Yes
Add/change user-defined aerosol layer	Yes	No
Delete user-defined aerosol layer	Yes	No
Exit to Main Menu	Yes	Yes

1: Output file containing propagation profile (based on built-in models)
2: Input file containing propagation profile to be used in simulation
3. Wind field included for coherent Doppler systems only

Table 17. Available Options in the Atmospheric Conditions Submenu for Raman Scattering Systems

BACKSCAT OPTION	BUILT-IN MODELS	USER-SUPPLIED PROFILE
Change propagation profile source	Yes	Yes
Change propagation profile file	Yes[1]	Yes[2]
Edit built-in (aerosol) model parameters	Yes	No
Change Rayleigh scattering source	Yes	Yes[3]
Include Rayleigh scattering	Yes	Yes
Change molecule to key on	Yes	Yes
Change molecular concentration source	Yes	Yes
Change molecular concentration file	Yes[1]	Yes[2]
Exit to Main Menu	Yes	Yes

1: Output file containing Raman propagation profile (Raman molecular concentration profile, plus aerosol and molecular attenuation coefficients)

2: Input file containing Raman molecular concentration profile, and **optional** aerosol and molecular attenuation coefficients

3: Only when input file does not contain aerosol and molecular attenuation coefficients

8.2 Atmospheric Conditions Submenu for Aerosol Backscatter and Coherent Doppler Simulations

In BACKSCAT, the default mode uses built-in models of aerosol, molecular, and wind profiles as the source of the propagation profile. For these simulations, the Atmospheric Conditions Submenu for aerosol backscatter systems was shown in Figure 45. Figure 46 shows the same Atmospheric Conditions Submenu for coherent Doppler systems. Note that the only differences are references to wind field data and the propagation profiles have *.dpf* extensions. When the source of the propagation profile is a user-supplied input file, BACKSCAT displays the Atmospheric Conditions Submenu shown in Figure 47.

8.2.1 Change Propagation Profile Source

In Figures 45 and 46, the first option sets the source of the propagation profile. The two options are the built-in models and a user-supplied input file. This option can be selected at anytime during an editing session. When this option is selected, BACKSCAT displays the "popup" menu shown in Figure 48. To make a selection, move the highlighted area to the desired choice and press RETURN. To return to the Atmospheric Conditions Submenu without making a selection, hit ESC.

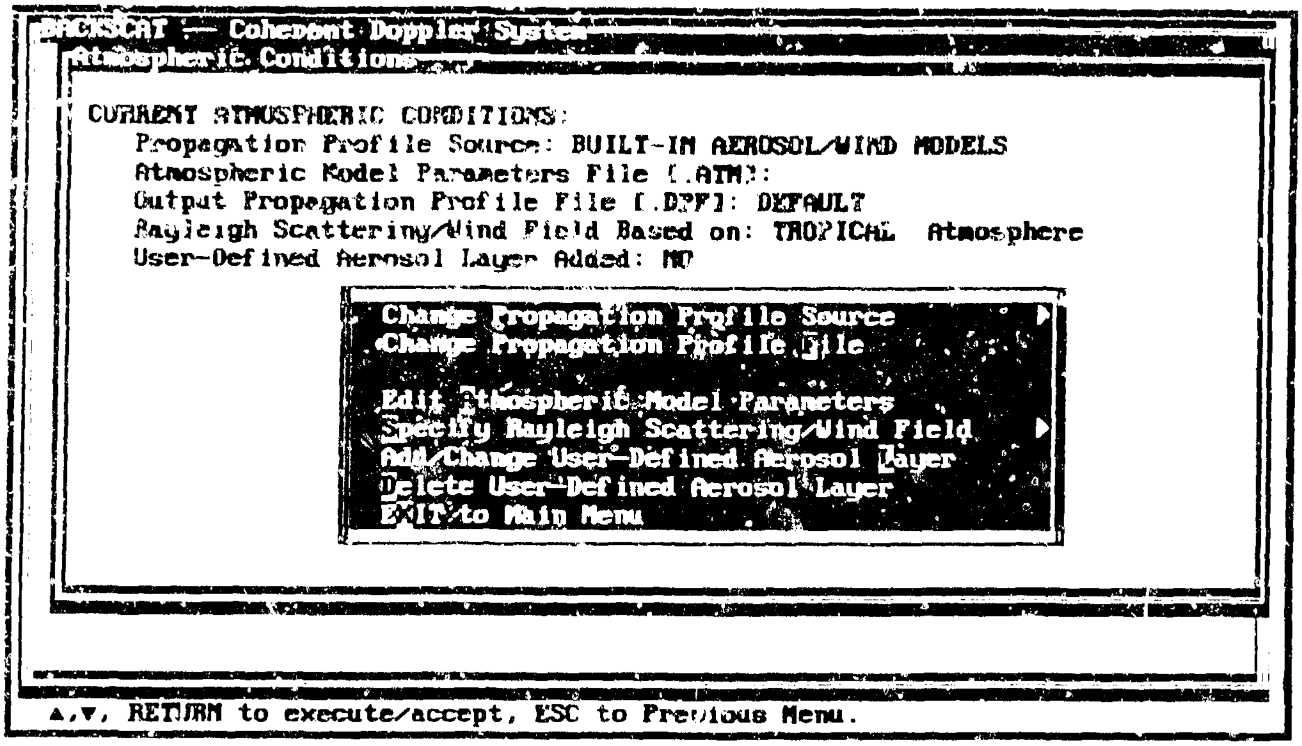

Figure 46. Atmospheric Conditions Submenu When the Simulation Is For a Coherent Doppler System and the Source of the Propagation Profile Is the Built-In Aerosol Models

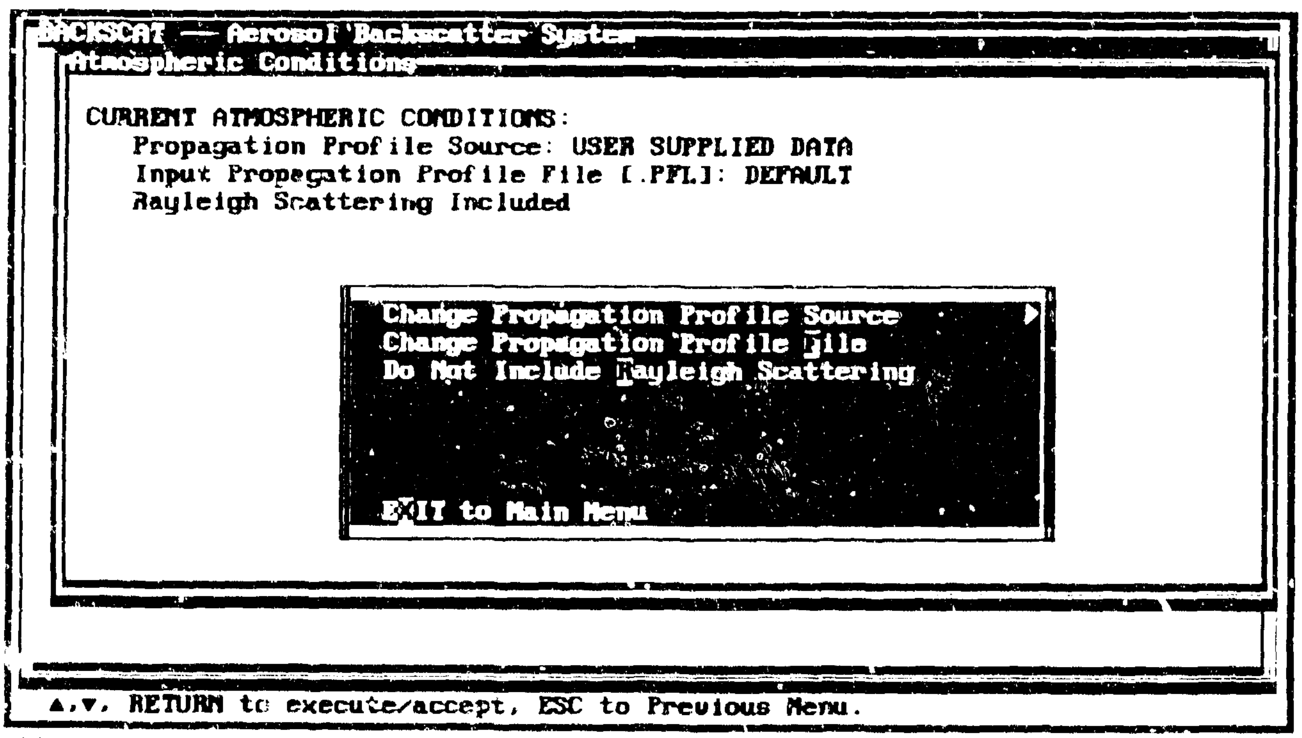

Figure 47. Atmospheric Conditions Submenu When the Simulation Is For an Aerosol Backscatter System and the Source of the Propagation Profile Is a User-Supplied Input File. A similar submenu is displayed for coherent Doppler systems

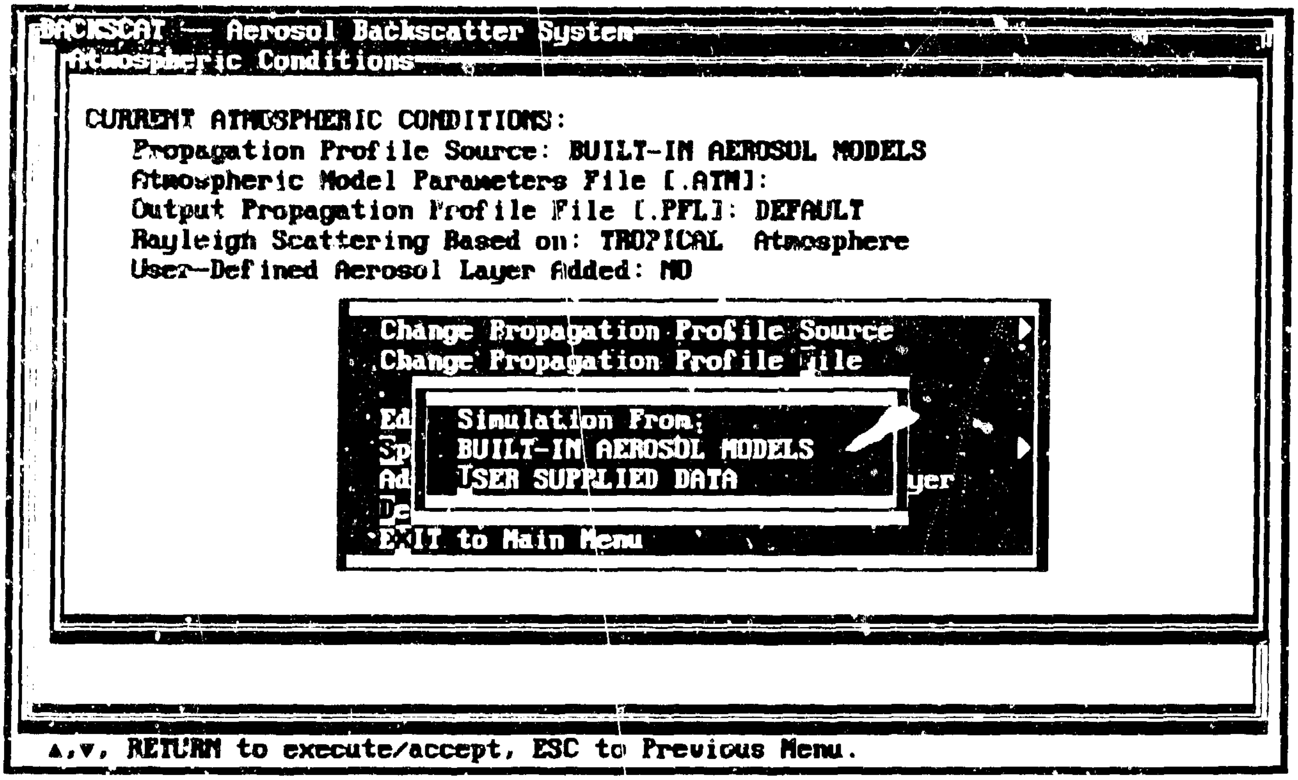

Figure 48. BACKSCAT "Popup" Menu for Changing the Source of a Propagation Profile for Aerosol Backscatter Systems. For coherent Doppler systems, the "popup" menu includes references to wind field data

If the "User Supplied Data" option is selected, BACKSCAT prompts the user for propagation profile file for the simulation. To aid the user, the code displays a "popup" menu that lists the propagation profile files in the current working directory. For aerosol backscatter systems, these files have a *.pfl* extension. For coherent Doppler systems, these files have a *.dpf* extension. An example is shown in Figure 49. Move the cursor to the desired propagation profile file and hit RETURN. (Note that the user must properly format the propagation profile file, see Appendix A). To exit this menu and not select a propagation profile file, hit ESC. If no file is selected, BACKSCAT uses the built-in aerosol models as the source of the propagation profile. If no propagation profiles exist in the current working directory, the code issues a warning message and returns to the Atmospheric Conditions Submenu. Here, the built-in aerosol models are used as the source of the propagation profile. The top portion of the Atmospheric Conditions Submenu always displays the current source of the propagation profile.

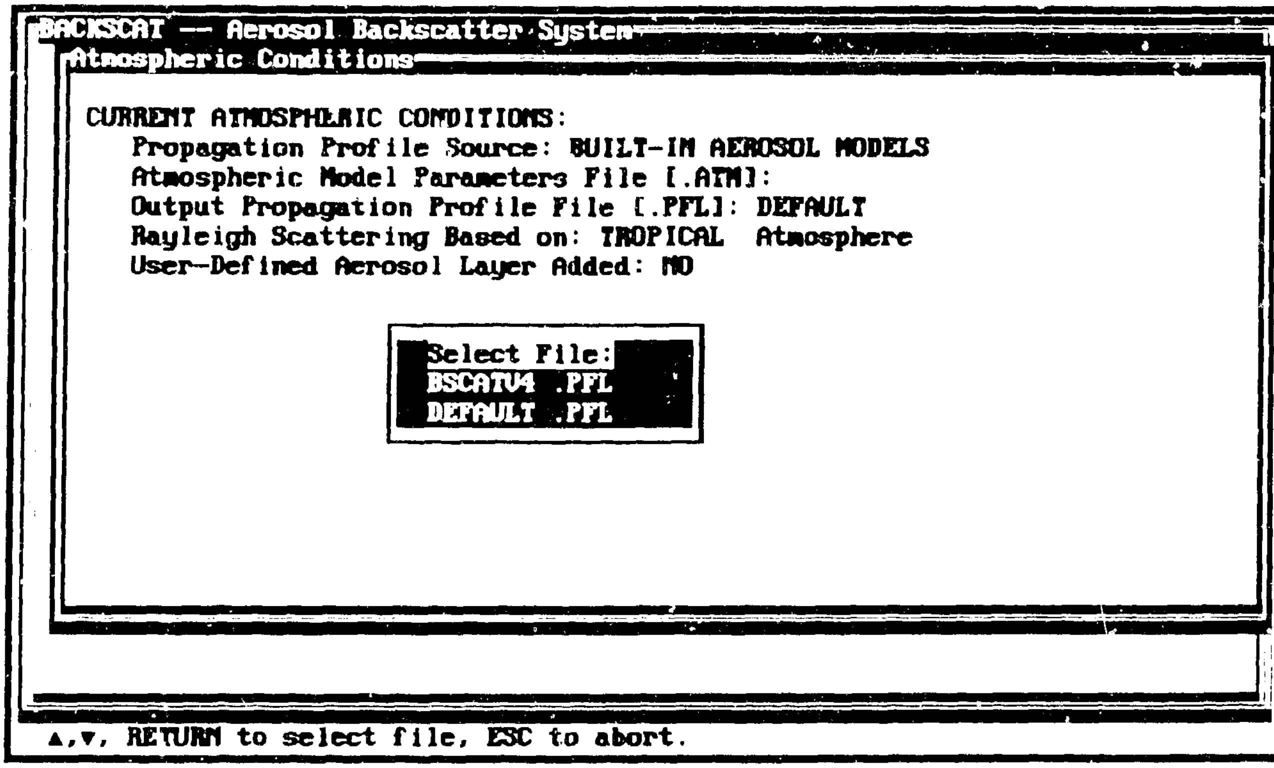

Figure 49. BACKSCAT "Popup" Menu for Selecting a Propagation Profile File To Be Used in an Aerosol Backscatter Simulation. For coherent Doppler simulations, the "popup" menu only lists files with *.dpf* extensions

8.2.2 Change Propagation Profile File

In Figures 45 and 46, the second option changes the propagation profile file for the simulation. When the source of the propagation profile is built-in models, BACKSCAT prompts the user for the output file name, as shown in Figure 50. In this case, the specified file is where BACKSCAT **writes** simulation data. When the source of the propagation profile is a user-supplied input file, BACKSCAT displays a "popup" menu that lists the propagation profile files in the current working directory, as previously shown in Figure 49. Move the cursor to the desired propagation profile file name and hit RETURN. In this case, BACKSCAT **reads** the propagation profile from the specified file.

8.2.3 Specify Rayleigh Scattering/Wind Field

Although a "proper" lidar simulation should include the effects from Rayleigh (*i.e.*, molecular) scattering and backscattering, it can be "turned off" from the Atmospheric Conditions Submenu. This feature is helpful for research studies in which the user wants to estimate aerosol and molecular contributions to the lidar signal. Note that the top portion of the Atmospheric Conditions Submenu always displays the current status of Rayleigh scattering.

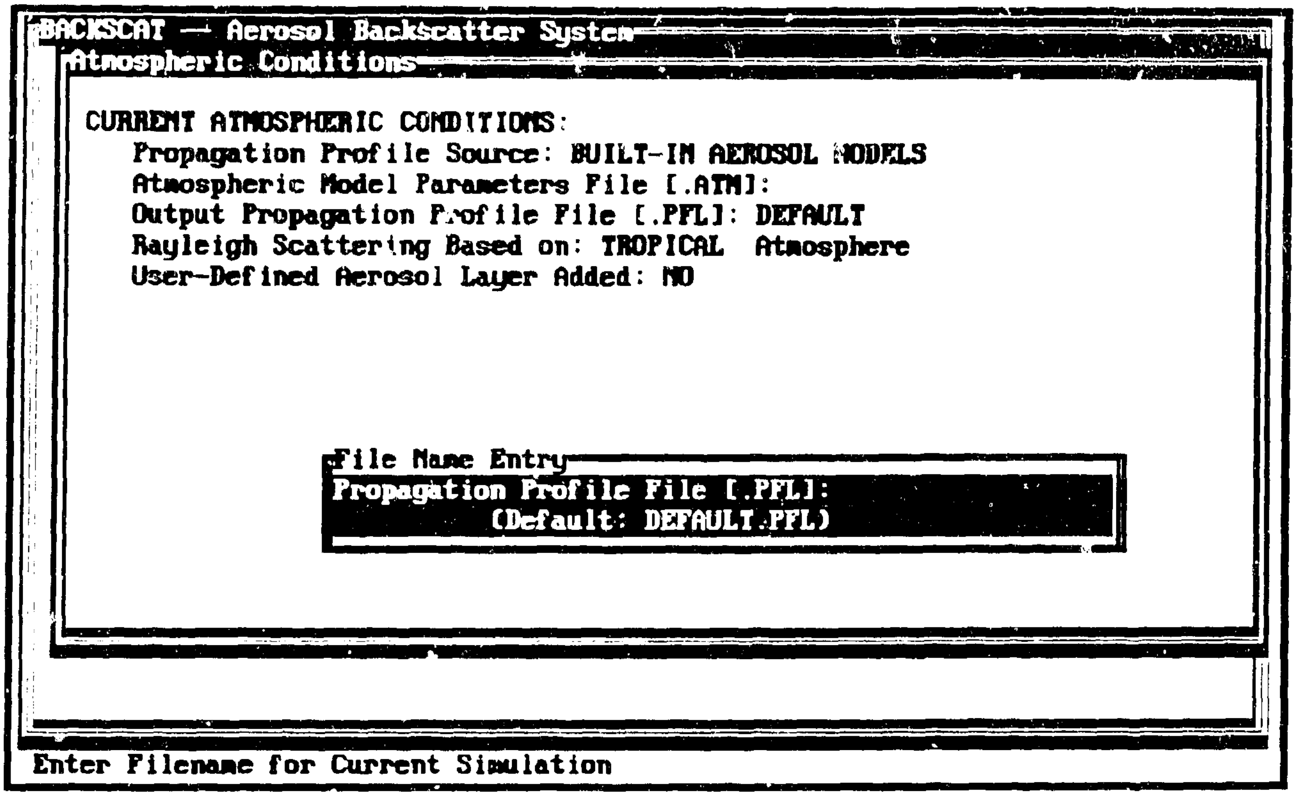

Figure 50. BACKSCAT Prompt for Entering the Output Propagation Profile File Name for Aerosol Backscatter Simulations. For coherent Doppler simulations, the output file has a *.dpf* extension

When investigating coherent Doppler systems, care should be exercised when the Rayleigh backscattering is of the same order as the aerosol backscatter. For a "proper" lidar simulation, the total extinction should include the absorption and scattering from both the Rayleigh and aerosol components. However, the return signal power should be calculated using only the aerosol backscatter coefficient, β_{aer} (and not include the Rayleigh backscatter coefficient) because the Doppler shift from molecules cannot be used to estimate the wind velocity. That is, the molecules are traveling with a mean velocity near the speed of sound[18] so the energy from their return is spread over a wide spectrum with little energy with each velocity bin.

8.2.3.1 Simulations with User-Supplied Propagation Profiles

When the source of the propagation profile is a user-supplied input file, Rayleigh contributions can be disabled in two ways. The first way is to supply a propagation profile file (a *.pfl* file or a *.dpf* file, depending on the type of lidar) in which the molecular scattering and backscattering coefficients equal 0.0. The second way is to select the "Include Rayleigh

[18] Moody, S.E. (1987) "Evaluation of Laser Technologies for On-Aircraft Wind Shear Detection," SPIE Vol. 783, p. 124.

Scattering" option, as previously shown in Figure 47. This option acts as a toggle between "Include" and "Do Not Include" Rayleigh scattering. To make a change, move the highlighted area to the "Include Rayleigh Scattering" option and press RETURN, or press "R" twice. When Rayleigh scattering is included, BACKSCAT uses the profiles of molecular scattering and backscattering in the user-supplied propagation profile file. Note that selecting "Do Not Include Rayleigh Scattering" does not affect the status of molecular absorption.

8.2.3.2 Simulations with Built-In Models

When the source of the propagation profile is built-in models, the status and source of Rayleigh scattering is changed with the "Specify Rayleigh Scattering" option for aerosol backscatter simulations (see Figure 45). For coherent Doppler simulations, the option is titled "Specify Rayleigh Scattering/Wind Field" (see Figure 46). When this option is selected, BACKSCAT displays a "popup" menu where the user defines the status of Rayleigh scattering, as shown in Figure 51. Move the highlighted area to the desired status and press RETURN. If Rayleigh scattering is included, BACKSCAT displays a "popup" menu from which the user selects the source of Rayleigh scattering (see Figure 52). The choices for Rayleigh scattering are built-in model atmospheres or radiosonde data. Move the highlighted area to the desired selection and hit RETURN. Note that for coherent Doppler simulations, wind field data always come from the same source as the Rayleigh scattering.

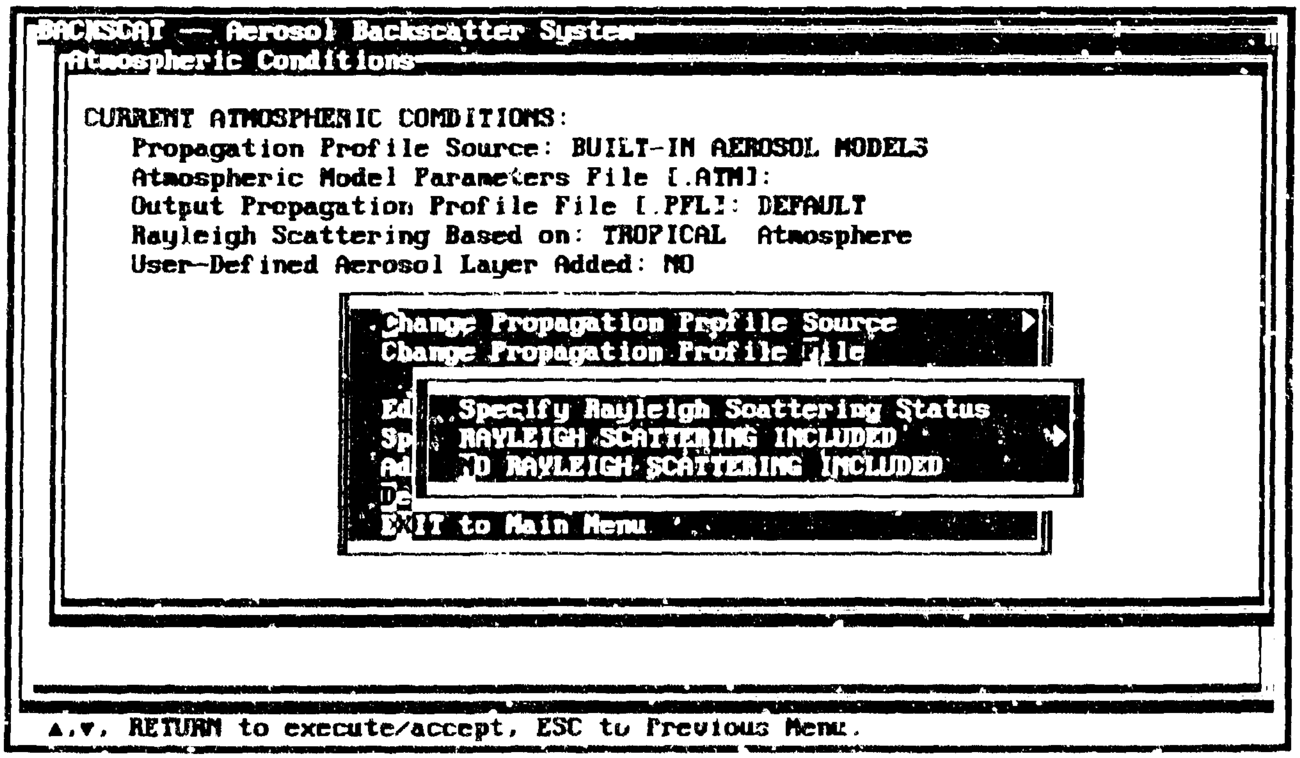

Figure 51. BACKSCAT "Popup" Menu for Changing the Status of Rayleigh Scattering When the Simulation Is For an Aerosol Backscatter System and Source of the Propagation Profile Is the Built-In Models

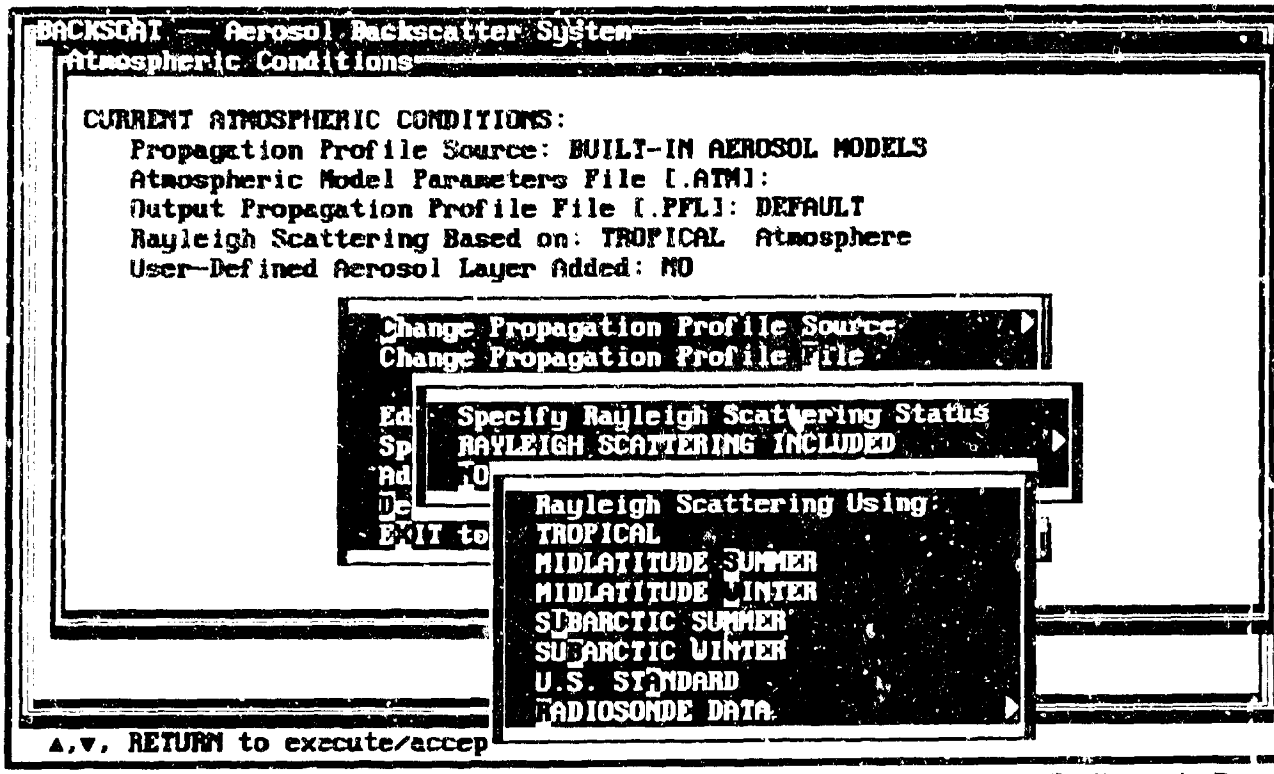

Figure 52. BACKSCAT "Popup" Menu for Selecting a Model Atmosphere or Radiosonde Data To Be Used for the Rayleigh Scattering Profile. For coherent Doppler simulations, the "popup" menu includes references to wind field data

When the source of Rayleigh scattering is "Radiosonde Data," BACKSCAT displays a "popup" menu where the user must select an existing radiosonde data file or create a new radiosonde data file, as shown in Figure 53. If the "Existing Radiosonde Data File" option is selected, BACKSCAT displays a "popup" menu that lists radiosonde data files (*.*rsd*) in the current working directory. Move the highlighted area to the desired radiosonde file and hit RETURN. To exit this "popup" menu and not select a radiosonde file, hit ESC. If no file is selected or no files exist in the current directory with the *.rsd* extension, BACKSCAT returns to the "popup" menu to choose an existing radiosonde file or create a new one. The option "Create/Edit Radiosonde Data File" is discussed in greater detail in Chapter 10.

If Rayleigh scattering is disabled from the "popup" menu previously shown in Figure 51, BACKSCAT returns to the Atmospheric Conditions Submenu when the simulation is for an aerosol backscatter system. For coherent Doppler simulations, however, BACKSCAT displays the "popup" menu previously shown in Figure 52 so the user can specify the source for wind field data. Note that selecting "Do Not Include Rayleigh Scattering" does not affect the status of molecular absorption.

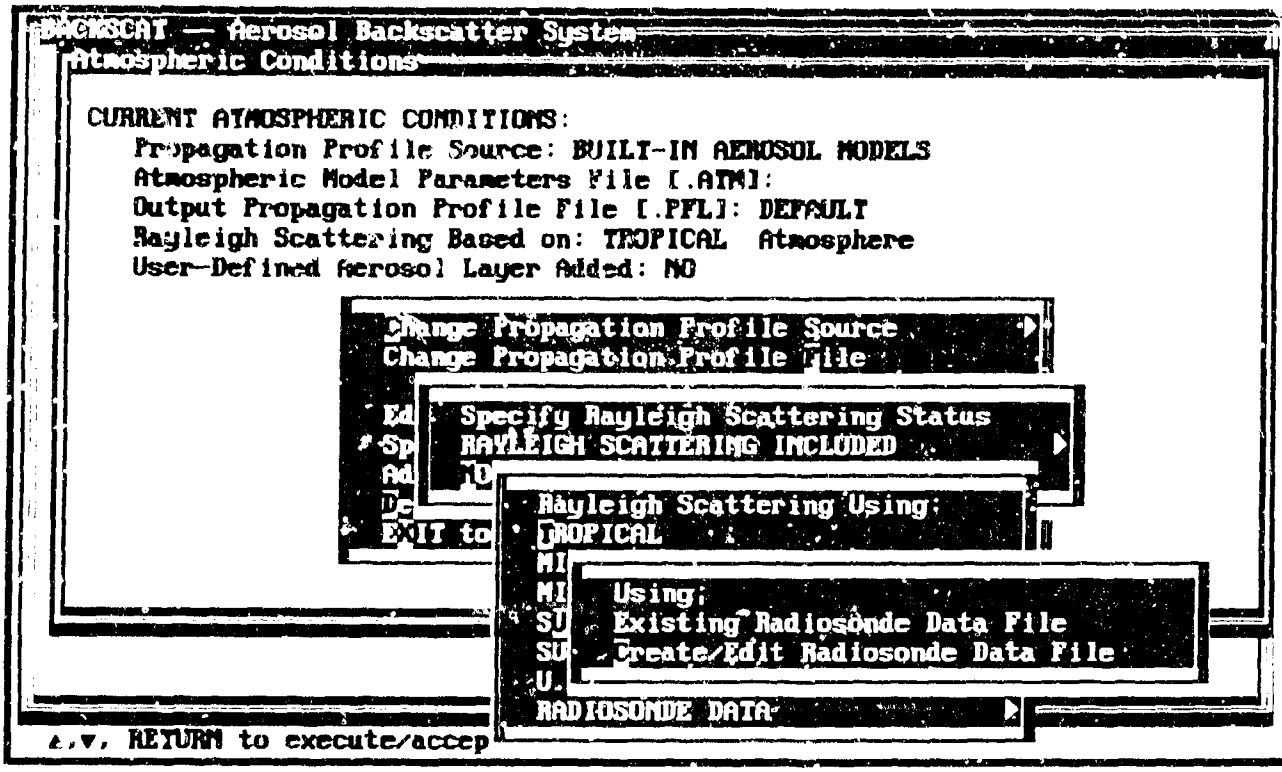

Figure 53. BACKSCAT "Popup" Menu for Specifying the Source of Radiosonde Data for a Simulation. For coherent Doppler simulations, the wind field data also come from the same radiosonde data file

8.2.4 Edit Atmospheric Model Parameters

The user can edit atmospheric model parameters **only** when the source of the propagation profile is the built-in models. This option permits the user to define the aerosol properties for four layers of the atmosphere and define the properties of clouds. To select this option from the Atmospheric Conditions Submenu, move the highlighted area to the "Edit Atmospheric Model Parameters" line and press RETURN, or press the "A" key twice. Because the "Edit Atmospheric Model Parameters" option is lengthy and popular among BACKSCAT users, it is discussed in a separate section (see Section 8.4).

8.2.5 Add/Change a User-Defined Aerosol Layer

This option allows the user to add a customized aerosol layer to the built-in profile. The user can add or change a user-defined aerosol layer **only** when the source of the propagation profile is the built-in models. To select this option from the Atmospheric Conditions Submenu, move the highlighted area to the "Add/Change User-Defined Aerosol Layer" line and press RETURN, or press the "L" key twice. The user-defined aerosol layer parameters are described in more detail in Chapter 9.

8.2.6 Delete a User-Defined Aerosol Layer

The user can delete a user-defined aerosol layer **only** when the source of the propagation profile is the built-in models. To delete a user-defined aerosol layer from the current simulation, move the highlighted area to the "Delete User-Defined Aerosol Layer" line of the Atmospheric Conditions Submenu and press RETURN, or press the "D" key twice. When selected, the user-defined aerosol layer will not be added to the built-in aerosol model profile. The top portion of the Atmospheric Conditions Submenu always displays the current status of user-defined aerosol layer.

8.3 Atmospheric Conditions Submenu for Raman Scattering Simulations

For Raman scattering simulations, many of the available options in the Atmospheric Conditions Submenu depend on how the user defines the Raman propagation profile. In the broadest sense, there are three methods of defining the Raman propagation profile in BACKSCAT Version 4.0. As summarized in Table 18, the first two methods are essentially the same as those for aerosol backscatter and coherent Doppler simulations. (Note that user-supplied propagation profile files for Raman lidar simulations have *.rpf* extensions and contain additional parameters, see Appendix A.) In the third method, the user can supply a Raman molecular concentration profile in a *.rpf* file, but still use the built-in models for aerosols and Rayleigh scattering.

Table 18. Methods of Defining the Raman Propagation Profile for Raman Lidar Simulations. The available options in the Atmospheric Conditions Submenu depend on how the Raman propagation profile is defined

METHOD NUMBER	PROPAGATION PROFILE SOURCE	PARAMETERS USED FROM USER-SPECIFIED INPUT FILES	COMMENTS
1	Built-in models	None (*.rpf* file is an output file)	Raman molecular concentration and Rayleigh scattering profiles use same built-in model atmosphere (1-6)
2	User-supplied input file (requires a *.rpf* file)	Raman molecular concentration profile, aerosol and Rayleigh attenuation profiles at lidar and Raman wavelengths	
3	Built-in models and user-supplied input file (requires a *.rpf* file)	Raman molecular concentration profile	Profiles of aerosol and Rayleigh attenuation appended to *.rpf* file

8.3.1 Entering the Atmospheric Conditions Submenu

In BACKSCAT, the default mode uses built-in models of aerosol and molecular profiles as the source of the propagation profile. For Raman scattering simulations, the Atmospheric Conditions Submenu contains seven options as shown in Figure 54. From this submenu, the user can

- Change molecule to key on
- Change molecular concentration source
- Change molecular concentration file
- Change propagation profile source
- Edit atmospheric model parameters
- Change Rayleigh scattering source
- Exit to Main Menu.

When the simulation uses a user-supplied propagation profile file, the Atmospheric Conditions Submenu contains six options as shown in Figure 55. From this submenu, the user can

- Change molecule to key on
- Change molecular concentration source
- Change molecular concentration file
- Change propagation profile source
- Include Rayleigh scattering
- Exit to Main Menu.

```
BACKSCAT -- Raman System
 Atmospheric Conditions

  CURRENT ATMOSPHERIC CONDITIONS:
                            Molecule to Key On: N2
   Molecule Concentration Profile Based On: TROPICAL  Atmosphere
      Output Molecular Profile File [.RPF]: DEFAULT

   Propagation Profile Source: BUILT-IN AEROSOL MODELS
   Atmospheric Model Parameters File [.ATM]:
   Rayleigh Scattering Included

                    Change Molecule to Key On                ▶
                    Change Molecular Concentration Source    ▶
                    Change Molecular Concentration File
                    Change Propagation Profile Source        ▶
                    Edit Atmospheric Model Parameters
                    Change Rayleigh Scattering Source        ▶
                    EXIT to Main Menu

 ▲,▼, RETURN to execute/accept, ESC to Previous Menu.
```

Figure 54. Atmospheric Conditions Submenu When the Simulation Is For a Raman Scattering System and the Source of the Propagation Profile Is the Built In Aerosol Models

```
BACKSCAT -- Raman System
 Atmospheric Conditions

  CURRENT ATMOSPHERIC CONDITIONS:
                              Molecule to Key On: N2
   Molecule Concentration Profile Based On: USER-SUPPLIED DATA
   Input Molecular Profile File [.RPF]: DEFAULT

   Propagation Profile Source: USER SUPPLIED DATA  (DEFAULT.RPF)

   Rayleigh Scattering Included

                    Change Molecule to Key On                ►
                    Change Molecular Concentration Source    ►
                    Change Molecular Concentration File
                    Change Propagation Profile Source        ►

                    Change Rayleigh Scattering Source        ►
                    EXIT to Main Menu

 ▲,▼, RETURN to execute/accept, ESC to Previous Menu.
```

Figure 55. Atmospheric Conditions Submenu When the Simulation Is For a Raman Scattering System and the Source of the Propagation Profile Is a User-Supplied Input File

8.3.2 Change Molecule to Key On

To change the molecule to be used in a Raman simulation, select the first option "Change Molecule to Key On" from the Atmospheric Conditions Submenus (Figures 54 and 55). BACKSCAT displays a "popup" menu from which the user can select from five molecules, as shown in Figure 56. The available molecules are N_2, CO_2, H_2O, O_3, and O_2. Move the cursor to the desired molecule and hit RETURN. To exit this "popup" menu and not select a molecule, hit ESC. Note that the top portion of the Atmospheric Conditions Submenu always displays the current Raman molecule.

8.3.3 Change Molecular Concentration Source

This option changes the source of the molecular concentration profile for a Raman simulation. The two choices are a model atmosphere profile or the profile in a user-supplied propagation profile. To change the source of the molecular concentration profile, select the second option "Change Molecular Concentration Source" from the Atmospheric Conditions Submenus (Figures 54 and 55). BACKSCAT displays a "popup" menu in which the user can change the molecular concentration source, as shown in Figure 57. Move the highlighted area to the desired choice and press RETURN. To return to the Atmospheric Conditions Submenu and not change the molecular concentration source, hit ESC. Note that the top portion of the Atmospheric Conditions Submenu always displays the current source for the molecular concentration profile.

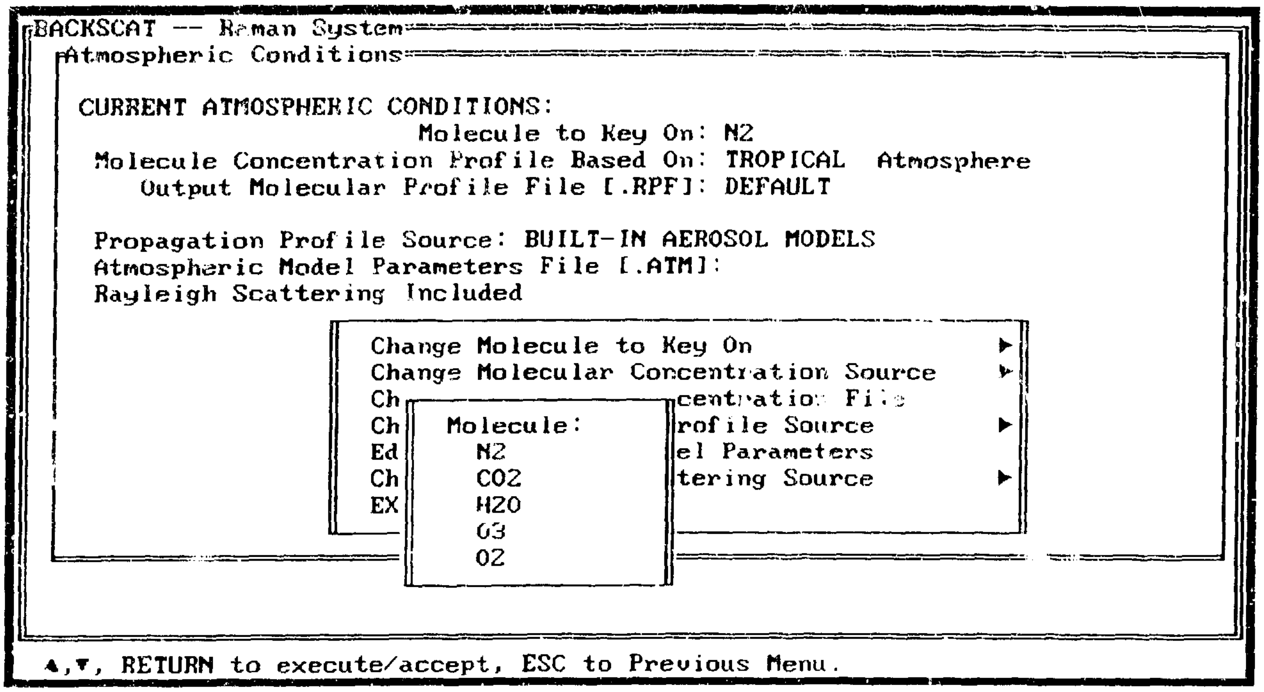

Figure 56. BACKSCAT "Popup" Menu for Changing the Raman Molecule to Key On

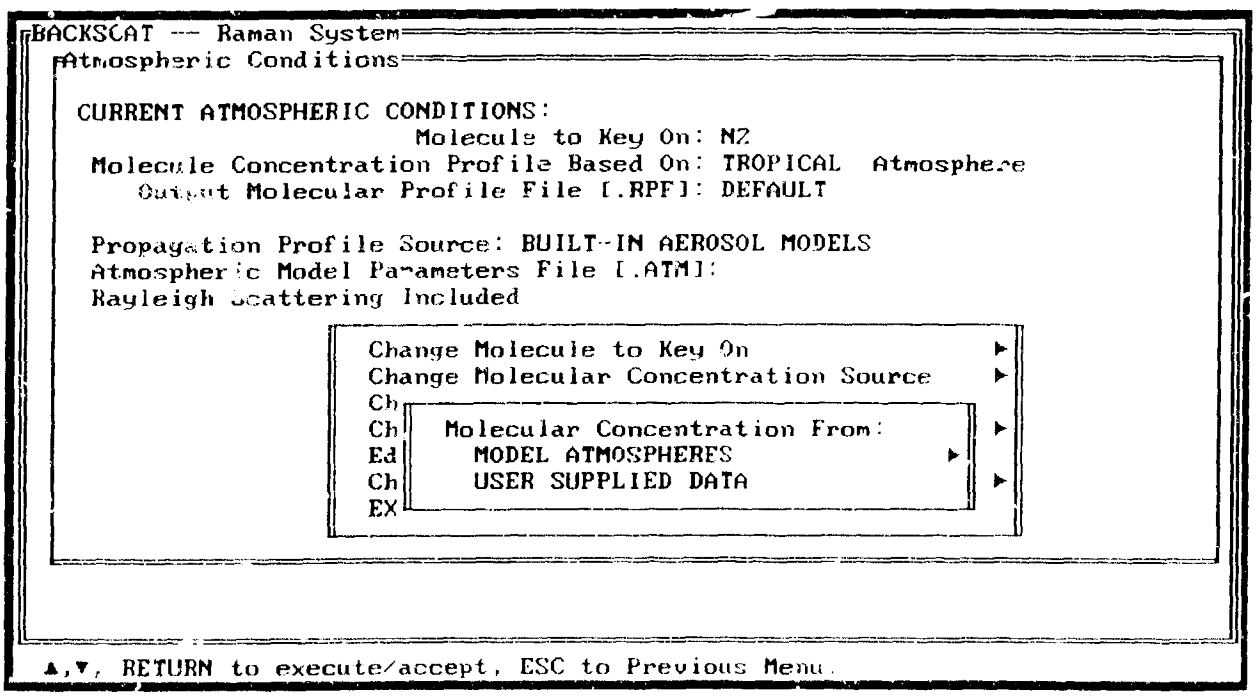

Figure 57. BACKSCAT "Popup" Menu for Changing the Source of the Molecular Concentration Profile in a Raman Lidar Simulation

When the "Model Atmospheres" option is selected, BACKSCAT displays a "popup" menu where the user must choose from six built-in model atmospheres, as shown in Figure 58. BACKSCAT then checks that the current simulation also uses the built-in models (*i.e.*, the first method in Table 18). If not, BACKSCAT issues a warning message and uses the built-in aerosol models for the propagation profile. During the simulation, BACKSCAT will **write** the molecular concentration profile (corresponding to the chosen model atmosphere) to the Raman propagation profile file. Note that the same model atmosphere is used for Rayleigh scattering contributions.

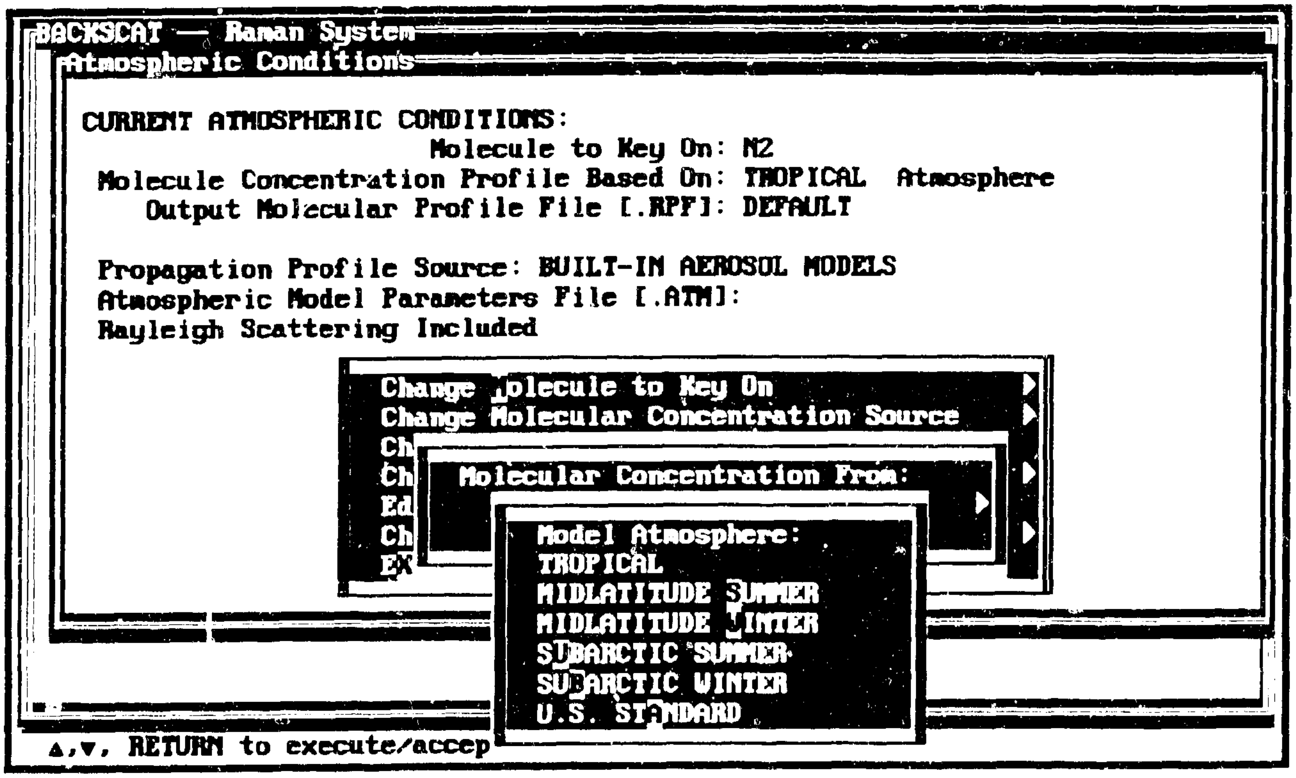

Figure 58. BACKSCAT "Popup" Menu for Selecting the Model Atmosphere To Be Used for the Molecular Concentration Profile in a Raman Lidar Simulation

When the "User-Supplied Data" option is selected, BACKSCAT displays a "popup" menu that lists the Raman propagation profile files (**.rpf*) in the current working directory, as shown in Figure 59. Move the cursor to the desired file and hit RETURN. During the simulation, BACKSCAT **reads** the molecular concentration profile from the selected *.rpf* file. To exit the "popup" menu and not select a Raman propagation profile, hit ESC. If no file is selected or no Raman propagation profile files exist, BACKSCAT uses the molecular concentration profile for the default built-in model atmosphere. Note that any user-supplied *.rpf* file with a molecular concentration profile must be properly formatted (see Appendix A).

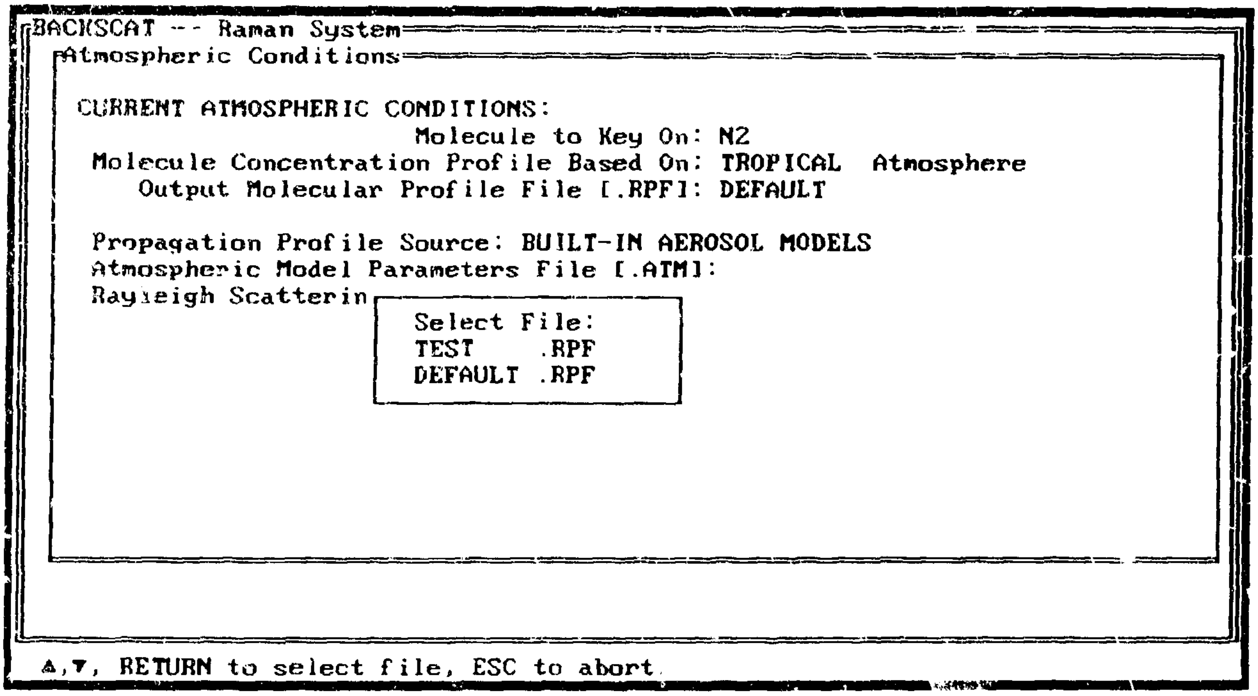

Figure 59. BACKSCAT "Popup" Menu for Selecting an Existing Raman Propagation Profile File To Be Used for the Molecular Concentration Profile

8.3.4 Change Molecular Concentration File

To change the file name for a molecular concentration profile, select the third option "Change Molecular Concentration File" from the Atmospheric Conditions Submenus (Figures 54 and 55). When the source of the molecular concentration profile is built-in models, BACKSCAT prompts the user for the output file name, as shown in Figure 60. The specified file is where BACKSCAT **writes** simulation data.

When the source of the molecular concentration profile is a user-supplied propagation profile, BACKSCAT displays a "popup" menu that lists Raman propagation profile files (**.rpf*) in the current working directory, as previously shown in Figure 59. Move the cursor to the desired propagation profile file and hit RETURN. During the simulation, BACKSCAT **reads** the molecular concentration profile from the specified Raman propagation profile file.

8.3.5 Change Propagation Profile Source

This option in Atmospheric Conditions Submenus (Figures 54 and 55) specifies how aerosol profiles are defined for a Raman simulation. To select this option, move the highlighted area to the "Change Propagation Profile Source" line and press RETURN. BACKSCAT then displays one of two "popup" menus, depending on the current source of the molecular concentration profile. Note that the top portion of the Atmospheric Conditions Submenu always displays the current source of the propagation profile.

```
BACKSCAT -- Raman System
 Atmospheric Conditions

  CURRENT ATMOSPHERIC CONDITIONS:
                              Molecule to Key On: N2
   Molecule Concentration Profile Based On: TROPICAL  Atmosphere
      Output Molecular Profile File [.RPF]: DEFAULT

   Propagation Profile Source: BUILT-IN AEROSOL MODELS
   Atmospheric Model Parameters File [.ATM]:
   Rayleigh Scattering Included


                   File Name Entry
                   Output Molecular Profile File [.RPF]: _
                            (Default: DEFAULT.PFL)



 Enter Filename for Current Simulation
```

Figure 60. BACKSCAT Prompt for Entering the Output File Name for a Raman Propagation Profile That Includes the Molecular Concentration Profile

When the molecular concentration profile is from a built-in model atmosphere. BACKSCAT displays a "popup" menu that forces the user to select the built-in aerosol models, as shown in Figure 61. This choice corresponds to the first method in Table 18. To return to the Atmospheric Conditions Submenu and not make a selection, hit ESC.

When the molecular concentration profile is from a user-supplied propagation profile file, BACKSCAT displays a "popup" menu where the user can select either built-in aerosol models or a user-supplied propagation profile file, as shown in Figure 62. To make a selection, move the highlighted area to the desired choice and press RETURN. When the "User-Supplied Data" option is selected, BACKSCAT **reads** the aerosol profile and the Raman molecular concentration profile from the same *.rpf* file (*i.e.*, the second method in Table 18). Conversely, when the "Built-In Aerosol Models" option is selected, BACKSCAT **appends** the built-in aerosol profile to the *.rpf* file that contains user-supplied Raman molecular concentration profile (*i.e.*, the third method in Table 18). Any existing aerosol data in the file are **overwritten** during the simulation. To return to the Atmospheric Conditions Submenu and not make a selection, hit ESC.

```
BACKSCAT -- Raman System
Atmospheric Conditions

 CURRENT ATMOSPHERIC CONDITIONS:
                          Molecule to Key On: N2
  Molecule Concentration Profile Based On: TROPICAL  Atmosphere
     Output Molecular Profile File [.RPF]: DEFAULT

  Propagation Profile Source: BUILT-IN AEROSOL MODELS
  Atmospheric Model Parameters File [.ATM]:
  Rayleigh Scattering Included

                     Change Molecule to Key On                  ►
                     Change Molecular Concentration Source      ►
                     Ch
                     Ch   Propagation Profile Built From:       ►
                     Ed   BUILT-IN AEROSOL MODELS
                     Ch                                         ►
                     EX

 ▲,▼, RETURN to execute/accept, ESC to Previous Menu.
```

Figure 61. BACKSCAT "Popup" Menu for Selecting the Source of the Raman Propagation Profile When the Molecular Concentration Source Is Built-In Models. Note that the user can only select built-in models which corresponds to the first method in Table 18

```
BACKSCAT -- Raman System
Atmospheric Conditions

 CURRENT ATMOSPHERIC CONDITIONS:
                          Molecule to Key On: N2
  Molecule Concentration Profile Based On: USER-SUPPLIED DATA
  Input Molecular Profile File [.RPF]: TEST

  Propagation Profile Source: BUILT-IN AEROSOL MODELS
  Atmospheric Model Parameters File [.ATM]:
  Rayleigh Scattering Based on: TROPICAL  Atmosphere

                     Change Molecule to Key On                  ►
                     Change Molecular Concentration Source      ►
                     Ch
                     Ch   Propagation Profile Built From:
                     Ed   BUILT-IN AEROSOL MODELS
                     Ch   USER SUPPLIED DATA
                     EX

 ▲,▼, RETURN to execute/accept, ESC to Previous Menu.
```

Figure 62. BACKSCAT "Popup" Menu for Selecting the Source of the Raman Propagation Profile When the Molecular Concentration Source Is a User-Supplied Input File. Note that these two choices correspond to the second and third methods in Table 18

8.3.6 Edit Atmospheric Model Parameters

The user can edit atmospheric model parameters **only** when the source of the propagation profile is the built-in aerosol models. This option permits the user to define the aerosol properties for four layers of the atmosphere and define the properties of clouds. To select this option from the Atmospheric Conditions Submenu previously shown in Figure 54, move the highlighted area to the "Edit Atmospheric Model Parameters" line and press RETURN, or press the "A" key twice. Because the "Edit Atmospheric Model Parameters" option is lengthy and popular among BACKSCAT users, it is discussed separately in Section 8.4.

8.3.7 Change Rayleigh Scattering Source

This option specifies the status of Rayleigh (*i.e.*, molecular) scattering for Raman simulations. Specifically, it can be used to "turn off" Rayleigh scattering. Also, when the Raman propagation profile is defined via the third method in Table 18, this option is used to select a built-in model atmosphere for the Rayleigh scattering profile. Note that the top portion of the Atmospheric Conditions Submenu always displays the current status of Rayleigh scattering. Note that a "proper" lidar simulation should include the effects from Rayleigh scattering. However, "turning off" Rayleigh scattering can be helpful for research studies in which the user wants to estimate the aerosol and molecular contributions to the lidar signal. Because Raman scattering is a molecular process, a simulation without Rayleigh scattering still uses the molecular concentration profile, but molecular scattering and backscattering of the lidar beam is not included. Also, "turning off" Rayleigh scattering does not affect the status of molecular absorption.

To change the Rayleigh scattering source, select the sixth option "Change Rayleigh Scattering Source" on the Atmospheric Conditions Submenus (Figures 54 and 55). When the Raman propagation profile is defined via the first or second method in Table 18, BACKSCAT displays the "popup" menu shown in Figure 63. To make a selection, move the highlighted area to the desired choice and press RETURN. Note that when "Rayleigh Scattering Included" is opted, the Rayleigh scattering and Raman molecular concentration profiles are from the same source. Also, the user can "turn off" Rayleigh scattering by supplying a Raman propagation profile file (*.rpf*) in which the molecular scattering and backscattering coefficients equal 0.0.

When the Raman propagation profile is defined via the third method in Table 18, BACKSCAT displays the "popup" menu shown in Figure 64. To make a selection, move the highlighted area to the desired choice and press RETURN. If the "Rayleigh Scattering Using Model Atmospheres" option is selected, BACKSCAT displays a "popup" menu where the user must select a built-in model atmosphere for the Rayleigh scattering profile. Move the highlighted area to the desired built-in model atmosphere and press RETURN.

```
BACKSCAT -- Raman System
 Atmospheric Conditions

  CURRENT ATMOSPHERIC CONDITIONS:
                            Molecule to Key On: N2
   Molecule Concentration Profile Based On: TROPICAL  Atmosphere
       Output Molecular Profile File [.RPF]: DEFAULT

   Propagation Profile Source: BUILT-IN AEROSOL MODELS
   Atmospheric Model Parameters File [.ATM]:
   Rayleigh Scattering Not Included

                       Change Molecule to Key On              ►
                       Change Molecular Concentration Source  ►
                       Ch
                       Ch   Rayleigh Scattering Option:
                       Ed   RAYLEIGH SCATTERING INCLUDED
                       Ch   NO RAYLEIGH SCATTERING INCLUDED
                       EX

 ▲,▼, RETURN to execute/accept, ESC to Previous Menu.
```

Figure 63. BACKSCAT "Popup" Menu for Defining Rayleigh Scattering When the Raman Propagation Profile Is Defined Via the First or Second Method in Table 18. If Rayleigh scattering is included, the Rayleigh scattering and molecular concentration profiles are from the same source

```
BACKSCAT -- Raman System
 Atmospheric Conditions

  CURRENT ATMOSPHERIC CONDITIONS:
                            Molecule to Key On: N2
   Molecule Concentration Profile Based On: USER-SUPPLIED DATA
   Input Molecular Profile File [.RPF]: TEST

   Propagation Profile Source: BUILT-IN AEROSOL MODELS
   Atmospheric Model Parameters File [.ATM]:
   Rayleigh Scattering Not Included

                       Change Molecule to Key On              ►
                       Change Molecular Concentration Source  ►
                       Ch
                       Ch   Rayleigh Scattering Option:
                       Ed
                       Ch   NO RAYLEIGH SCATTERING INCLUDED
                       EX   RAYLEIGH SCATTERING USING MODEL ATMOSPHERES  ►

 ▲,▼, RETURN to execute/accept, ESC to Previous Menu.
```

Figure 64. BACKSCAT "Popup" Menu for Defining Rayleigh Scattering When the Raman Propagation Profile Is Defined Via the Third Method in Table 18

8.4 Edit Atmospheric Model Parameters

The "Edit Atmospheric Model Parameters" option is where the user can change atmospheric model parameters for four aerosol layers in the atmosphere and define the properties of clouds. This option appears in the Atmospheric Conditions Submenu **only** when the current source for propagation profile is the built-in models. It is available for aerosol backscatter, Raman scattering, and coherent Doppler lidar systems (see Figures 45, 46, and 54).

8.4.1 Entering the Atmospheric Parameters Submenu

To set atmospheric model parameters, move the highlighted area on the Atmospheric Conditions Submenu to the "Edit Atmospheric Model Parameters" line and press RETURN, or press the "A" key twice. BACKSCAT displays the Atmospheric Parameters Submenu, as shown in Figure 65. The values in Figure 65 are the default values in BACKSCAT Version 4.0. If the user employs a configuration file that includes an atmospheric conditions file, the parameters in that file will appear instead of those shown in Figure 65 and the file name will appear at the top of the menu instead of "NONE."

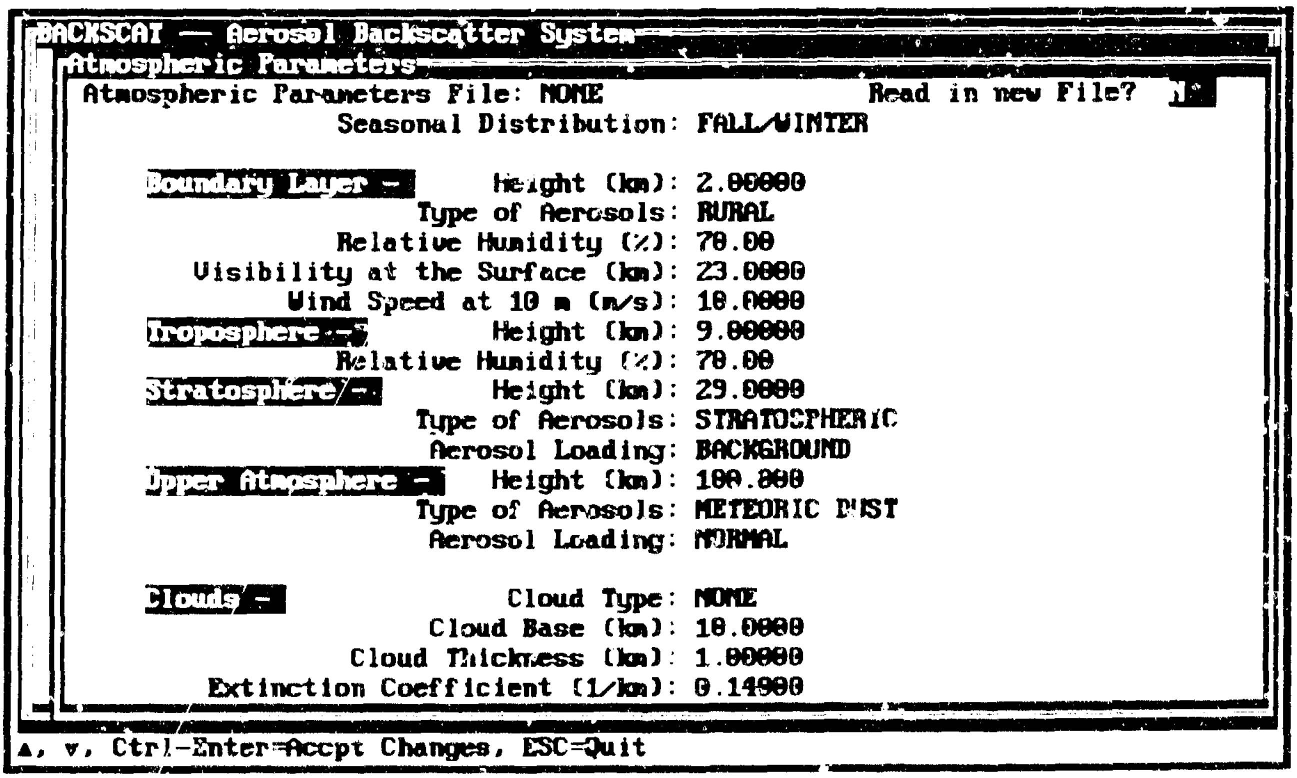

Figure 65. BACKSCAT Submenu Used for Specifying the Atmospheric Model Parameters for the Built-In Aerosols

8.4.2 Accessing Atmospheric Model Parameters From File

BACKSCAT allows atmospheric model parameters to be saved in a file and then easily recalled into the menu interface system. These files are given the default extension, *.atm*, and are described in detail in Appendix A. The name of an existing atmospheric conditions file can be included in the configuration file.

When the Atmospheric Parameters Submenu first appears, the user will be asked if he or she wants to read in model parameters from an existing atmospheric conditions file. (This occurs even if an atmospheric conditions file was specified in a user-supplied configuration file.) If the answer is "Y", BACKSCAT displays a "popup" menu that lists the atmospheric conditions files in the current working directory. Move the cursor to the desired file name and hit RETURN. The values in the *.atm* file will replace those in the Atmospheric Parameters Submenu. To exit this "popup" submenu and not select a new atmospheric conditions file, hit ESC. If no files exist in the current directory with the *.atm* extension, BACKSCAT alerts the user with a warning message and returns to the Atmospheric Parameters Submenu. If the user does not read a new file by responding with a "N" on the Atmospheric Parameters Submenu, the highlighted area will move to the record fields for the individual atmospheric model parameters.

8.4.3 Editing Individual Atmospheric Model Parameters

In the built-in aerosol models, the atmosphere is divided into four layers. From the ground upward, these layers are the boundary layer, the troposphere, the stratosphere, and the upper atmosphere. As shown in Figure 65, the user can change the height and aerosol type of each layer. The seasonal distribution parameter refers to the seasonal distribution of the aerosols in the troposphere and stratosphere. The clouds are optional. Table 19 lists the units and ranges of the parameters for the built-in aerosol models.

To selectively modify any or all of the atmospheric model parameters, move the highlighted area to the desired parameter (using the up or down arrow keys), type in the new value, and hit RETURN. BACKSCAT verifies that the new value is within the range limits for that parameter. If it is not, BACKSCAT displays an error message that gives the acceptable range for the parameter and then prompts the user to correct the entry. To display the options for text-related atmospheric model parameters, hit F1. BACKSCAT then displays a "popup" menu that lists the possible choices. To make a selection, move the highlighted area (using the up and down arrow keys) to the desired choice and hit RETURN, or type the highlighted letter twice. The Atmospheric Parameters Submenu is then updated with the new choice.

Table 19. Atmospheric Model Parameters for the Built-In Aerosol, Units, Default Values, and Limits. The default cloud base and thickness for water clouds are given in Table 2

ATMOSPHERIC PARAMETER	UNITS	DEFAULT VALUE	LIMITS/CHOICES
Seasonal Distribution	-	Fall/Winter	Fall/Winter, Spring/Summer
Boundary Layer			
Height	km	2.0	> 0 < Heights of troposphere, stratosphere, and top of atmosphere
Type of aerosol	-	Rural	Rural, maritime, urban, tropospheric, desert, oceanic, advection fog, radiation fog
Relative humidity	%	70.0	0 - 100
Visibility at the surface	km	23.0	0 - 300
0.55 μm extinction coef. at the surface	km^{-1}	0.158	> 0
Wind speed at 10 m*	m/s	10.0	0 - 30
Troposphere			
Height	km	9.0	> 0, Height of boundary layer < Heights of stratosphere and top of atmosphere
Relative humidity	%	70.0	0 - 100
Stratosphere			
Height	km	29.0	> 0, Heights of boundary layer and stratosphere < Top of atmosphere
Type of aerosol	-	Stratospheric	Stratospheric, aged volcanic, fresh volcanic
Aerosol loading	-	Background	Background, moderate, high volcanic, extreme volcanic
Upper Atmosphere			
Height	km	100.0	> 0, Heights of boundary layer, troposphere, stratosphere
Type of aerosol		Meteoric Dust	Meteoric dust
Aerosol loading		Normal	Normal, extreme
Clouds		None	None, standard cirrus, subvisual cirrus, cumulus, altostratus, stratus, stratocumulus, nimbostratus
Cloud base**	km	Cirrus: 10.0 (see Table 2)	Cirrus: ≥ 0 and ≤ 30 km, top of atmosphere Water clouds: ≥ 0 and ≤ 10 km, troposphere height
Cloud thickness**	km	Cirrus, 1.0 (see Table 2)	> 0 and ≤ 10
Extinction Coefficient**	km^{-1}	0.14	≥ 0‡

* Measured above surface. Used only with desert aerosols

** Used only when clouds are specified

‡ If 0, extinction coefficient equals 0.14 × cloud thickness

8.4.3.1 Boundary Layer Parameters

The atmospheric model parameters for the boundary layer include the height of the boundary layer, the type of aerosol, the relative humidity at the surface, and either the visibility at the surface or the extinction coefficient at the surface. To display the choices for the type of aerosol, move the highlighted area to the "Type of Aerosols" field and hit F1. BACKSCAT displays a "popup" menu, as shown in Figure 66. To change the type of aerosol, move the highlighted area (using the up and down arrow keys) to the desired choice and hit RETURN, or type the highlighted letter twice.

In the Atmospheric Parameters Submenu, the aerosol extinction profile in the boundary layer can be defined in terms of the visibility at the surface or the extinction coefficient. To switch from one to the other, hit F1 and then type the desired value.

When desert aerosols are chosen for the boundary layer, the user must also specify the wind speed at a height of 10 meters. Although it always appears on the Atmospheric Parameters Submenu, the wind speed cannot be changed unless desert aerosols are selected.

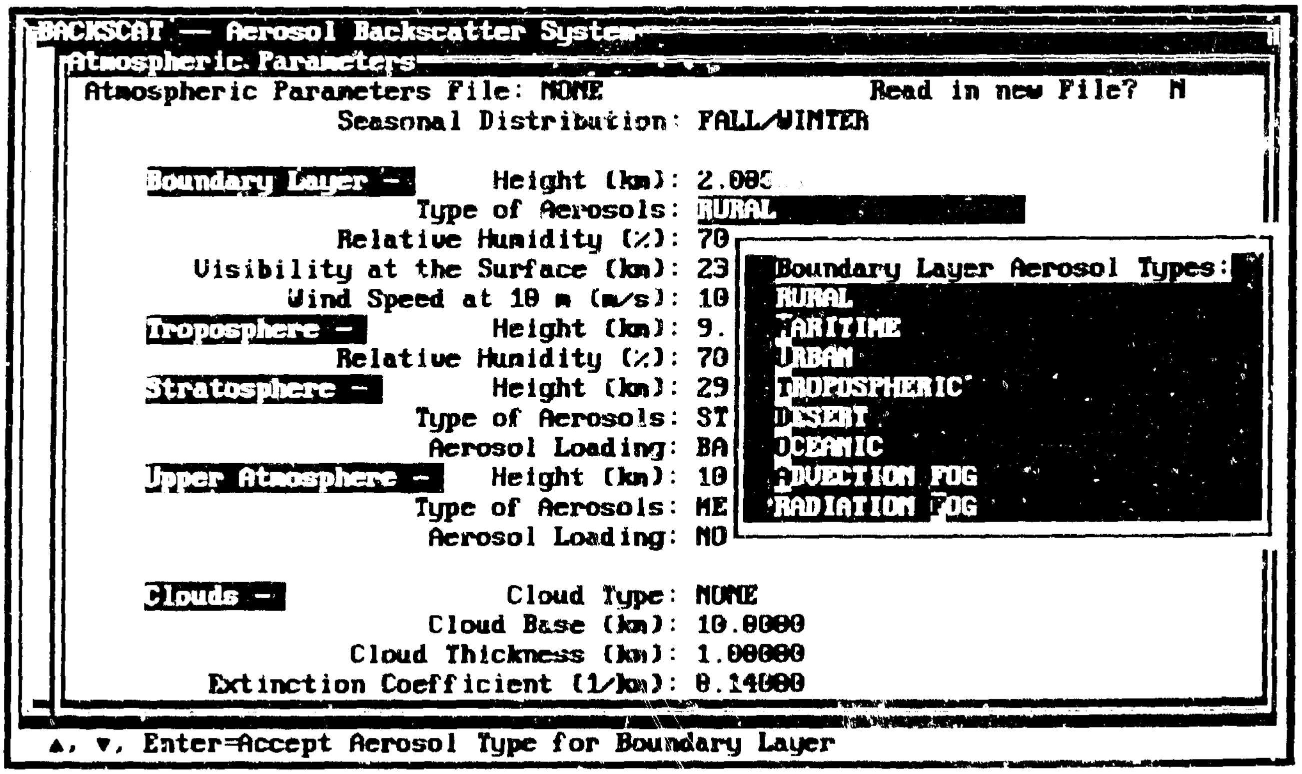

Figure 66. BACKSCAT "Popup" Menu for Selecting the Type of Boundary Layer Aerosol

8.4.3.2 Tropospheric Parameters

The atmospheric model parameters for the troposphere include the height of the troposphere and the relative humidity. To change the current values for these parameters, move the highlighted area to the desired choice and enter the new value. The tropospheric aerosol type is assumed throughout the troposphere.

8.4.3.3 Stratospheric Parameters

The atmospheric model parameters for the stratosphere include the height of the stratosphere, the type of stratospheric aerosol, and the amount of aerosol loading. To display the choices for the type of aerosol and aerosol loading, move the highlighted area to the desired parameter and hit F1. The choices are then displayed in "popup" menus. To make a selection, move the highlighted area (using the up and down arrow keys) to the desired choice and hit RETURN, or type the highlighted letter twice.

8.4.3.4 Upper Atmospheric Parameters

The atmospheric model parameters for the upper atmosphere include the height for the top of the atmosphere and the amount of aerosol loading. Currently, meteoric dust is the only aerosol type for the upper atmosphere. To display the choices for the aerosol loading, move the highlighted area to the "Aerosol Loading" field and hit F1. BACKSCAT displays a "popup" menu that contains the available choices. To change the aerosol loading, move the highlighted area (using the up and down arrow keys) to the desired choice and hit RETURN, or type the highlighted letter twice.

8.4.3.5 Cloud Parameters

The built-in aerosol models in BACKSCAT allow for clouds to be included in a simulation. To display the choices for the clouds, move the highlighted area to the "Cloud Type" field and hit F1. BACKSCAT displays a "popup" menu that lists the available choices, as shown in Figure 67. The water clouds are new to BACKSCAT Version 4.0. To change the cloud type, move the highlighted area to the desired selection and hit RETURN, or type the highlighted letter twice.

When a cloud is included in a simulation, the user can optionally define the cloud base, thickness, and extinction coefficient. Although they always appear on the Atmospheric Parameters Submenu, the cloud base, thickness, and extinction coefficient cannot be changed when the cloud type is set to "NONE".

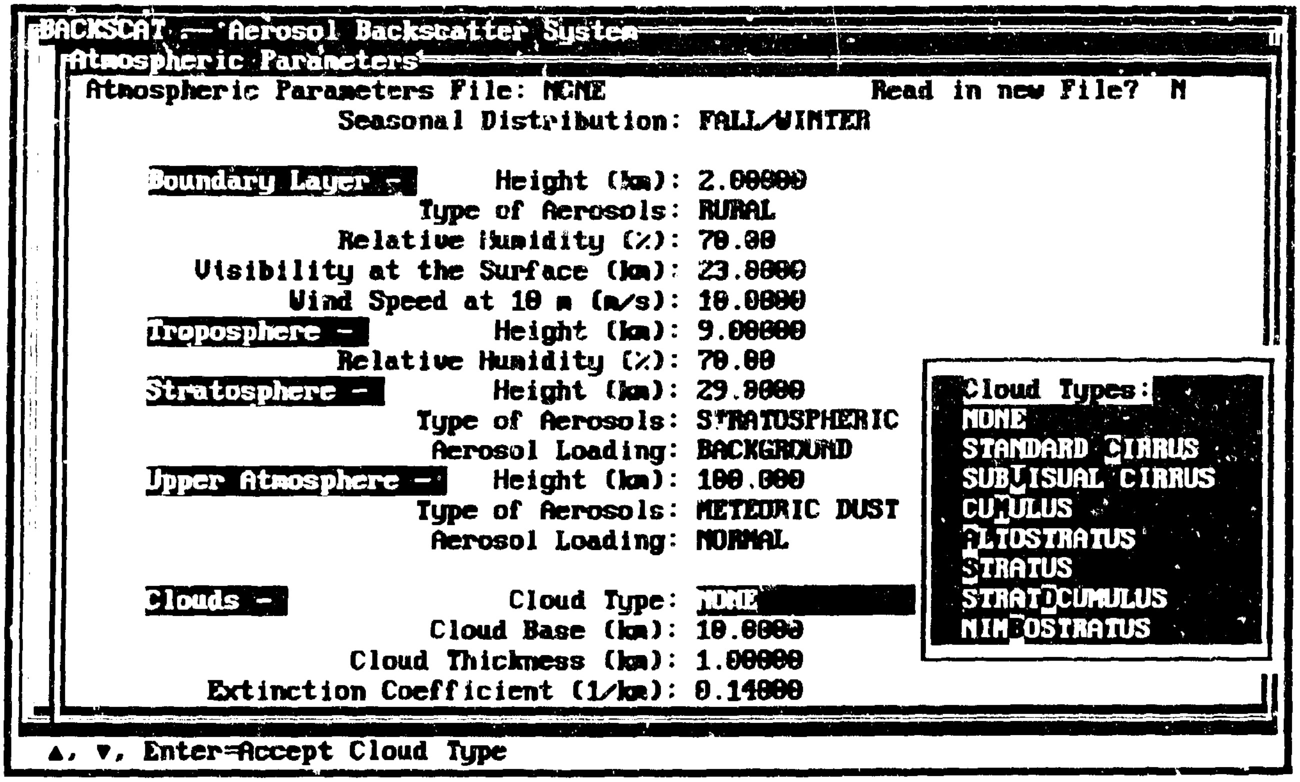

Figure 67. BACKSCAT "Popup" Menu for Selecting the Type of Cloud

8.4.3.6 Returning to the Atmospheric Conditions Submenu

To accept any changes made in the Atmospheric Parameters Submenu and return to the Atmospheric Conditions Submenu, hit CTRL-ENTER. BACKSCAT asks the user if he or she wants to write the atmospheric conditions parameters to a *.atm* file. Answer with a "Y" or "N." If the answer is "Y," the code prompts the user for the file name. The current atmospheric conditions file name is provided as the default choice. To use this file name, press RETURN. BACKSCAT reminds the user that the file already exists and then asks for confirmation to overwrite it. Answer with a "Y" or "N." If the user wants to save the atmospheric conditions parameters to a new *.atm* file, type in the new file name and press RETURN. After BACKSCAT saves the file, the user is returned to the Atmospheric Conditions Submenu

To return to the Atmospheric Conditions Submenu without saving any changes made to the viewing conditions parameters, hit ESC at any time during the editing process. BACKSCAT asks the user to confirm this operation because any changes to the atmospheric conditions parameters are lost, including any new file read in.

8.5 Exit the Atmospheric Conditions Submenu

To return to the BACKSCAT Main Menu from the Atmospheric Conditions Submenu, highlight the "Exit to Main Menu" option and hit RETURN, or simply hit ESC. In both cases, the changes made in the Atmospheric Conditions Submenu are saved.

9 ADDING A USER-DEFINED AEROSOL LAYER

This option defines the parameters for a customized user-defined aerosol layer. The option is available in the Atmospheric Conditions Submenu **only** when aerosol backscatter and coherent Doppler lidar systems are simulated and the source of the propagation profile is the built-in models (Figures 45 and 46). During the simulation, BACKSCAT adds the user-defined aerosol layer to the built-in profile. This option and its accompanying submenus are unchanged from BACKSCAT Version 3.0.

9.1 Entering the User-Defined Aerosol Layer Submenu

To add/change a user-defined aerosol layer, move the highlighted area to the "Add/Change User-Defined Aerosol Layer" line (Figures 45 and 46) and press RETURN, or press the "L" key twice. BACKSCAT displays the User-Defined Aerosol Layer Submenu as shown in Figure 68. The values in Figure 68 are the default values in BACKSCAT Version 4.0. If the user employs a configuration file that includes a user-defined aerosol file, the values in that file will appear instead of those shown in Figure 68 and the file name will appear at the top of the menu instead "NONE."

9.2 Accessing User-Defined Aerosol Layer Parameters From File

BACKSCAT allows user-defined aerosol parameters to be saved in a file and then easily recalled into the menu interface system. These files are given the default extension, *.lay*, and are described in detail in Appendix A. The name of an existing user-defined aerosol parameters file can be included in the configuration file. Also, the size distribution shape for a user-defined aerosol layer can be defined via a list of particle radii versus normalized aerosol number density. These data must be assembled off-line and put into files with the default extension, *.siz*. The format of the size distribution file is given in Appendix A. The size distribution file name (*.siz*) is included in the user-defined aerosol parameters file (*.lay*).

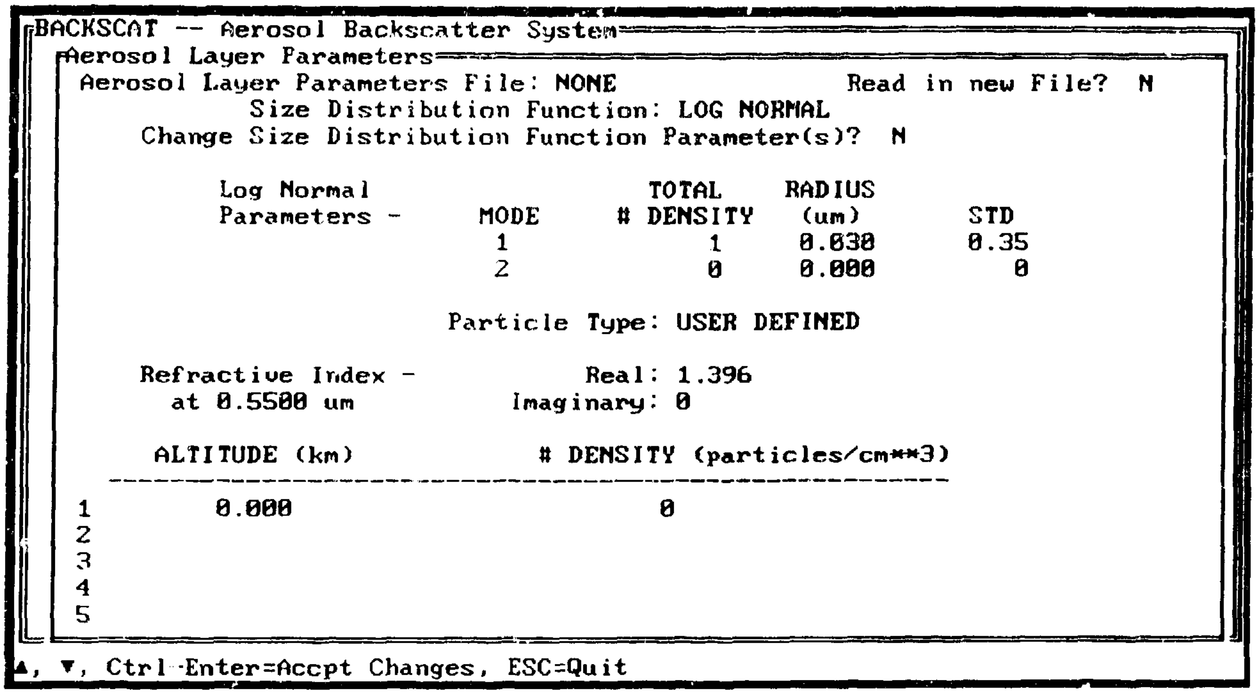

Figure 68. BACKSCAT Submenu for Specifying User-Defined Aerosol Parameters

When the User-Defined Aerosol Layer Submenu first appears, the user will be asked if he or she wants to read in parameters from an existing user-defined aerosol parameters file. (This will occur even if a user-defined aerosol parameters file was specified in a user-supplied configuration file.) If the answer is "Y", BACKSCAT displays a "popup" menu that lists the user-defined aerosol parameters files in the current working directory. Move the cursor to the desired file name and hit RETURN. The values in the *.lay* file will replace those in the User-Defined Aerosol Layer Submenu. To exit this "popup" menu and not select a new user-defined aerosol parameters file, hit ESC. If no files exist in the current directory with the *.lay* extension, BACKSCAT alerts the user with a warning message and returns to the User-Defined Aerosol Layer Submenu. If the user chooses not to read a new file by responding with a "N" on the User-Defined Aerosol Layer Submenu, the highlighted area will move to the record fields for the individual user-defined aerosol parameters.

9.3 Size Distribution Functions

The shape of the particle size distribution for a user-defined aerosol layer can be represented by one of three functions: log normal, modified gamma, or user-defined. To display these choices, move the highlighted area to the "Size Distribution Function" field and hit F1. BACKSCAT displays the "popup" menu as shown in Figure 69. Move the highlighted area to the desired function (using the up and down arrow keys) and hit RETURN, or type the highlighted letter twice. BACKSCAT then updates the User-Defined Aerosol Layer Submenu with the current parameters for the new function. If the user hits ESC at this "popup" menu, the default function becomes "USER-DEFINED".

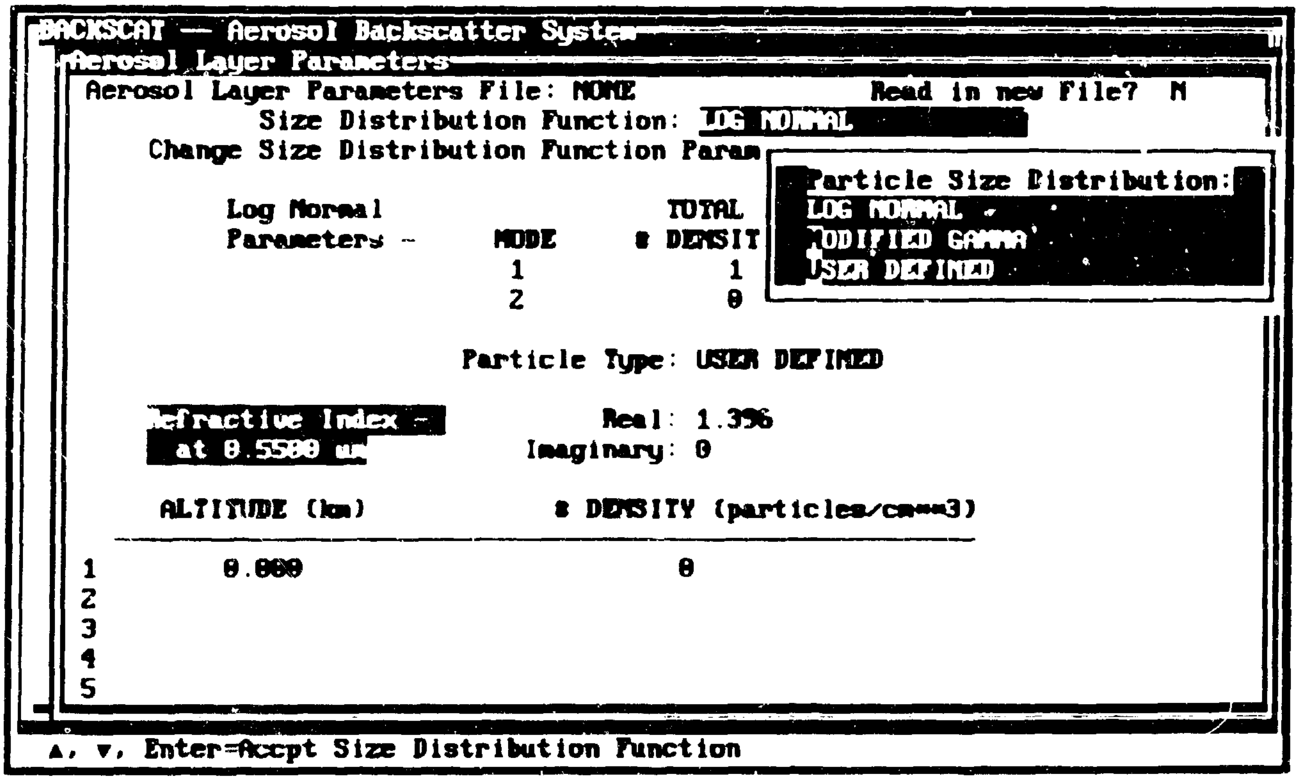

Figure 69 BACKSCAT "Popup" Menu for Selecting the Type of Particle Size Distribution Function

When the "USER-DEFINED" function is selected, the user must specify a size distribution file (*.siz*). To assist the user, BACKSCAT displays a "popup" menu that lists the existing *.siz* files in the current working directory. Move the highlighted area to the desired file name and hit RETURN. To exit this "popup" menu and not select a new size distribution file, hit ESC. If no files exist in the current directory with the *.siz* extension, BACKSCAT issues a warning message and returns to the "popup" menu to select the type of size distribution (Figure 69).

9.3.1 Log Normal Distribution Function

The log normal distribution function is commonly used to describe the size distribution of boundary layer aerosols. The number density as a function of particle radius, $N(r)$, is given by

$$N(r) = \sum_{i=1}^{2} \frac{n_i}{\ln(10)\, r \log\sigma_i \sqrt{2\pi}} \exp\left[-\frac{(\log r - \log r_i)^2}{2 \log\sigma_i^2} \right] \qquad (36)$$

where n_i, r_i, σ_i are the number density, mode radius, and standard deviation, respectively, of the i^{th} mode. Because BACKSCAT scales the log normal distribution function by the total number density profile, n_1+n_2 must equal 1.

To change the parameters for a log normal distribution function, move the highlighted area to the "Change Size Distribution Function Parameter(s)" line, type "Y", and hit RETURN. BACKSCAT displays a data entry buffer with the current log normal distribution parameters, as shown in Figure 70. To change a parameter, simply type the desired value and hit RETURN. To move between columns, hit RETURN only. To quickly move between Mode1 and Mode2, use the up and down arrow keys.

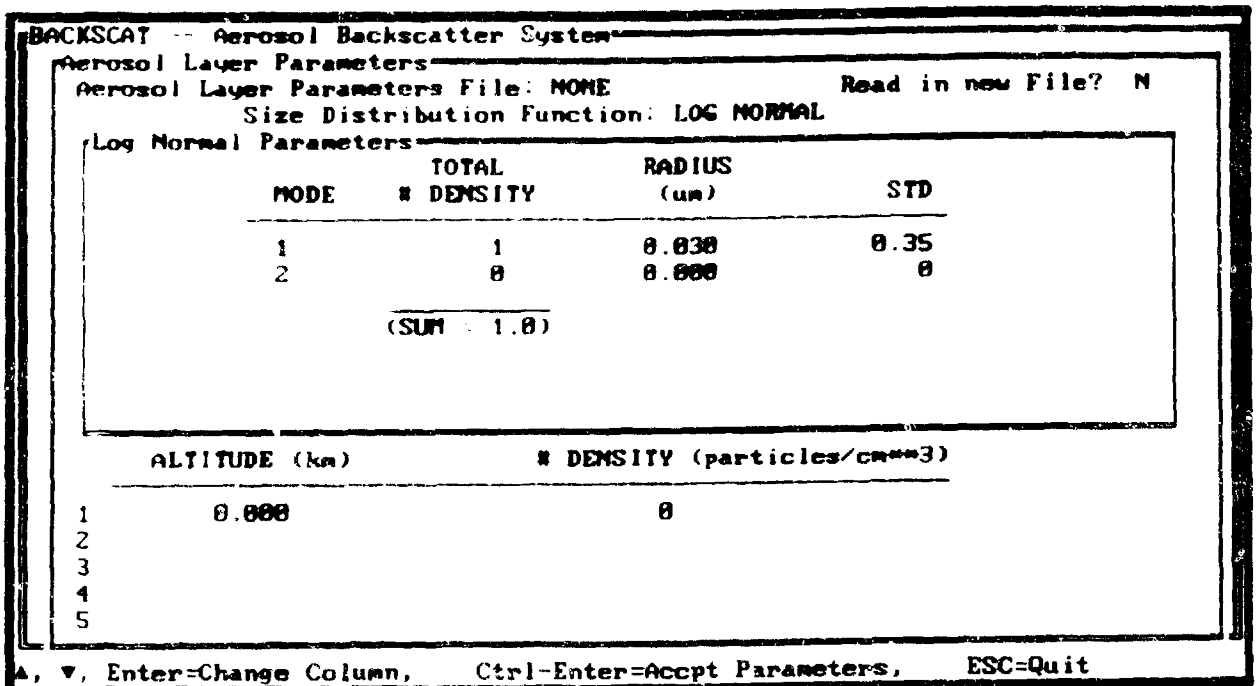

Figure 70. BACKSCAT Data Entry Buffer for Editing the Log Normal Distribution Function Parameters

To return to the User-Defined Aerosol Layer Submenu and accept the changes made to the log normal distribution parameters, hit CTRL-ENTER. BACKSCAT verifies that all log normal parameters are within their range limits. The range limits for the log normal parameters are given in Table 20. If a value is not within the range limits, BACKSCAT issues an error message similar to the one shown in Figure 71. The message includes the value of the parameter out of range, the applicable range, and the row number containing the error. The error message remains until the user corrects the erroneous parameter and hits CTRL-ENTER a second time. Currently, BACKSCAT only displays the first error it encounters. Subsequent errors are not found until the user tries to exit again. Upon a successful exit, the new values are displayed on the User-Defined Aerosol Layer Submenu. To return to the User-Defined Aerosol Layer Submenu without saving any changes, hit ESC anytime during the editing process.

Table 20. Log Normal Particle Size Distribution Parameters in BACKSCAT. Units, Default Values, and Limits

LOG NORMAL PARAMETER	UNITS	DEFAULT VALUE	LIMITS
Total number density (n)	[illegible]	$n = 1.0$	0.0 – 1.0
		$n = 0.0$	[illegible] n = 1.0
Mode radius	[illegible]	$r = 0.03$	0.001 – 1000.0
		$r = 0.00$	Set r = 0.0 if n = 0.0
Logarithm of the Standard		$\log\sigma = 0.35$	0.0 – [illegible]
Deviation ($\log\sigma$)		$\log\sigma = 0.00$	Set $\log\sigma$ = 0.0 if n = 0.0

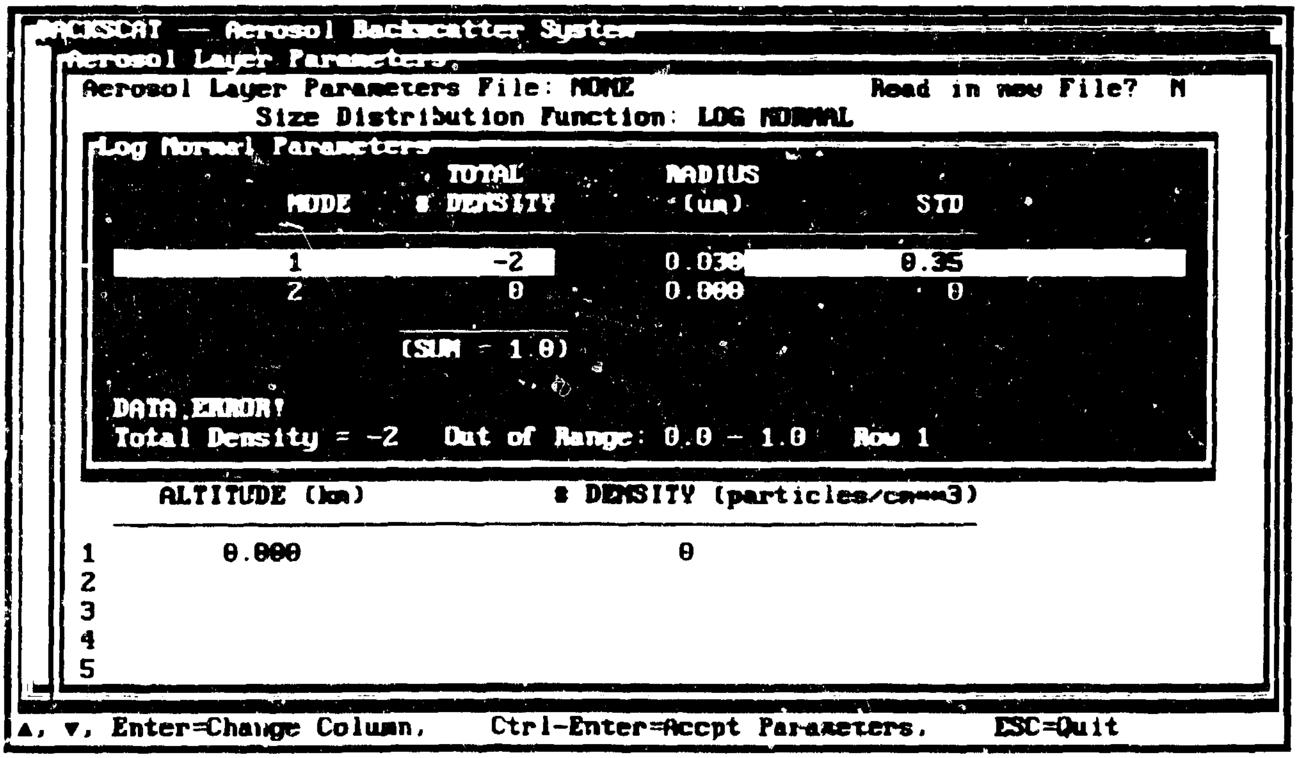

Figure 71. Sample Message Issued By BACKSCAT When a Parameter for the Log Normal Distribution Function Is Out of Range

9.3.2 Modified Gamma Distribution Function

The modified gamma distribution function is commonly used to describe the size distribution of clouds and fogs. The number density as a function of particle radius is given by

$$N(r) = \frac{[illegible] \exp(-[illegible])}{[illegible]} \qquad (37)$$

where a, α, b, γ are parameters defining the size distribution, and the total number of particles, N', is computed as

$$N' = \int_0^\infty a r^{\alpha} \exp(-b r^{\gamma}) dr . \tag{38}$$

To change the parameters for a modified gamma distribution function, move the highlighted area to the "Change Size Distribution Function Parameter(s)" line, type "Y", and hit RETURN. BACKSCAT displays a data entry buffer with the current modified gamma distribution parameters, as shown in Figure 72. To change a parameter, simply type the desired value and hit RETURN. As soon as the user changes a parameter, BACKSCAT verifies that it is within the allowable range. If it is not, BACKSCAT issues an error message similar to the one previously shown in Figure 71. The message includes the value of the parameter out of range and the applicable range, and the row number containing the error. For reference, the range limits for modified gamma parameters are given in Table 21.

To return to the User-Defined Aerosol Layer Submenu and accept the changes made to the modified gamma size distribution parameters, hit CTRL-ENTER. The new values are displayed on the User-Defined Aerosol Layer Submenu. To return to the User-Defined Aerosol Layer Submenu without saving any changes, hit ESC anytime during the editing process.

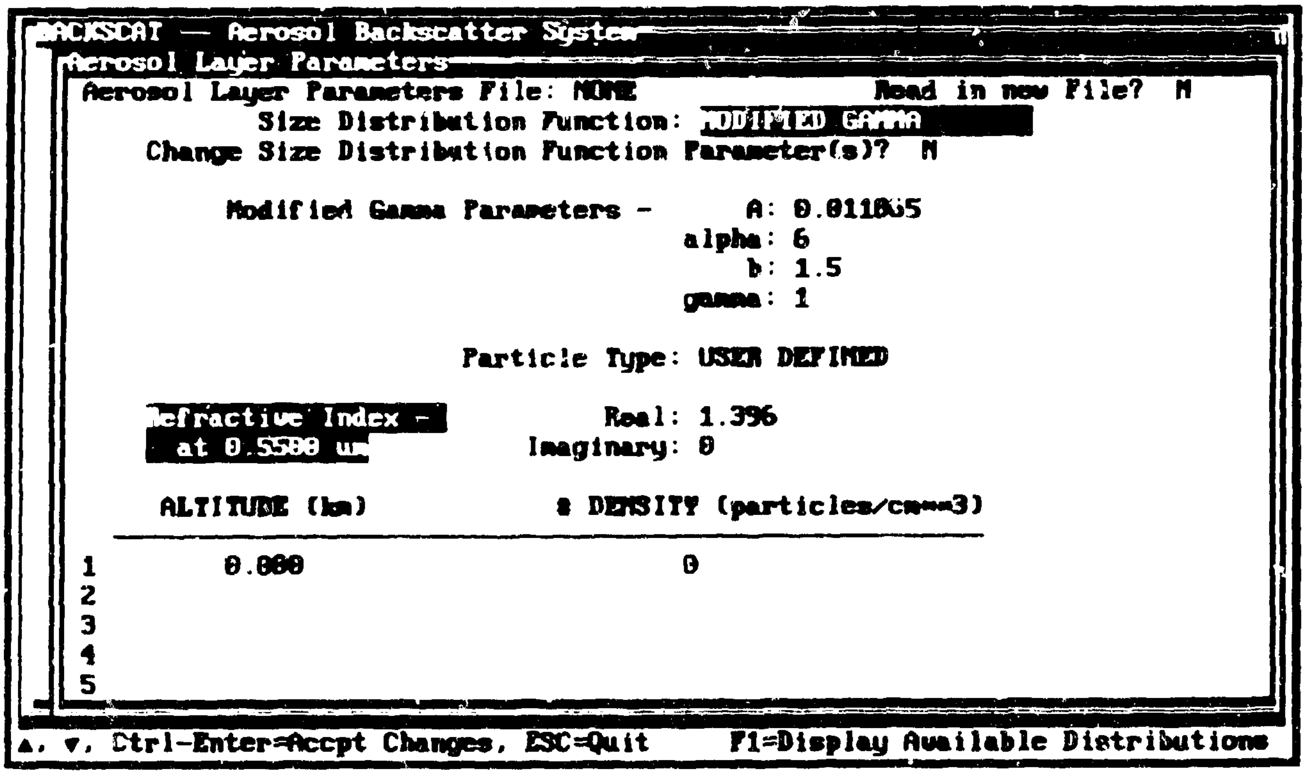

Figure 72. BACKSCAT Data Entry Buffer for Editing the Modified Gamma Distribution Function Parameters

Table 21. Modified Gamma Particle Size Distribution Parameters in BACKSCAT. Units. Default Values. and Limits. Note that the α and γ parameters are integers and dimensionless

PARAMETER	DEFAULT VALUE	LIMITS
a	0.011865	> 0
α	6	> 0
b	1.5	> 0
γ	1	> 0

9.3.3 User-Defined Distribution Function

To change the size distribution file (*.siz*) for a user-defined distribution function, move the highlighted area to the "Change Size Distribution Function Parameter(s)" line, type "Y", and hit RETURN. BACKSCAT displays a "popup" menu that lists the size distribution files (**.siz*) in the current working directory. Move the highlighted area to the desired file name and hit RETURN. To exit this "popup" menu and not select a new size distribution file, hit ESC.

9.4 Particle Type and Refractive Index

In BACKSCAT, there are seven types of particles for the user-defined aerosol. To list them, move the highlighted area to the "Particle Type" field and hit F1. BACKSCAT displays the "popup" menu in Figure 73. Move the highlighted area to the desired particle type (using the up and down arrow keys) and hit RETURN, or type the highlighted letter twice. If "USER DEFINED" is selected, the user must enter the complex refractive index (real and imaginary parts) on the next two lines of the User-Defined Aerosol Layer Submenu. The complex refractive index must be for the lidar wavelength in the simulation. If one of the other six particle types is chosen, BACKSCAT automatically displays the complex refractive index, but the user is unable to change it.

9.5 Number Density Profile

BACKSCAT assumes the shape of the particle size distribution to be constant throughout the user-defined aerosol layer. In turn, the attenuation properties of the normalized size distribution are scaled by a number density profile.

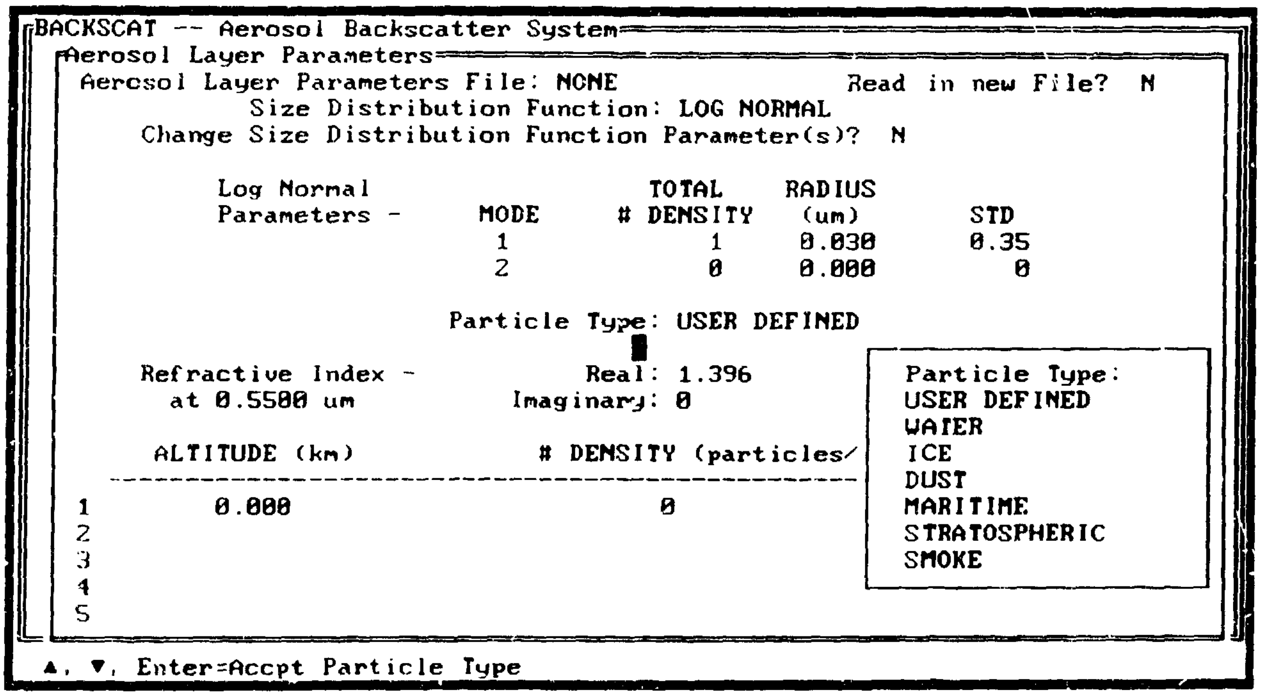

Figure 73. BACKSCAT Popup Menu for Choosing the Type of Particle for a User-Defined Aerosol Layer

To create or modify an existing number density profile, move the highlighted area into the data entry buffer at the bottom of the User-Defined Aerosol Layer Submenu. To change a value, simply type the new value and hit RETURN. To move between columns, hit RETURN only. To quickly move between rows, use the up and down arrow keys. The altitude (km) and its corresponding number density (particles/cm^3) must be specified for a minimum of two altitudes. The altitudes must be entered in increasing order and can range from 0 to 100 km. The altitude grid for the user-defined aerosol layer does not have to match that for the user-supplied propagation profile file, if used. Currently, a maximum of five altitudes are permitted. Number densities must be greater than zero, except they can equal zero at the first and last altitudes.

The number density profile are checked only when the user hits CTRL-ENTER to exit the User-Defined Aerosol Layer Submenu. BACKSCAT verifies that the values in the number density profile are within their range limits and in the correct order. If an error was made, BACKSCAT displays an error message that explains the problem. The error message remains until the user corrects the erroneous parameter and hits CTRL-ENTER a second time. Currently, BACKSCAT only displays the first error it encounters. Subsequent errors are not found until the user tries to exit again.

9.6 Returning to the Atmospheric Conditions Submenu

To accept any changes made in the User-Defined Aerosol Layer Submenu and to include the layer in the simulation, hit CTRL-ENTER. After checking for errors, BACKSCAT asks the user if he or she wants to write the user-defined aerosol parameters to a *.las* file. Answer with a

"Y" or "N." If the answer is 'N", the user is returned to the Atmospheric Conditions Submenu. If the answer is "Y." BACKSCAT prompts the user for the file name. The name of the current user-defined aerosol parameters file is provided as the default choice. To use this file, press RETURN. BACKSCAT reminds the user that the file already exists and then asks for confirmation to overwrite it. Answer with a "Y" or "N." If the user wants to save the user-defined aerosol parameters to a new *.lay* file, type in the new file name and press RETURN. After BACKSCAT saves the file, the user is returned to the Atmospheric Conditions Submenu. Note that it is not necessary to save the user-defined aerosol parameters to a *.lay* file. However, this option allows the user to easily recall the parameters for a future simulation.

To return to the Atmospheric Conditions Submenu without including the layer in the simulation, hit ESC at anytime during the editing process. BACKSCAT asks the user to confirm this operation, but any changes to the user-defined aerosol parameters are retained within the User-Defined Aerosol Layer Submenu. Note that the status of the user-defined aerosol layer is always shown in the Main Menu and the Atmospheric Conditions Submenu.

10 ENTERING RADIOSONDE DATA

The Radiosonde Data Entry Program is used to create and edit radiosonde data files that, in turn, can be used to describe Rayleigh (*i.e.*, molecular) scattering and backscattering profiles. In BACKSCAT Version 4.0, the program has been extended to include provisions for wind field data. This extension permits users to compare existing wind speeds along a lidar line-of-sight against wind speed accuracies for a coherent Doppler simulation.

Currently, radiosonde data can be used **only** when aerosol backscatter and coherent Doppler lidar systems are simulated and the source of the propagation profile is the built-in models. The vertical extent of the radiosonde data must encompass the minimum and maximum altitudes to be used in the lidar simulation.

To access the software for radiosonde data entry from BACKSCAT's menu interface system, proceed to the popup menu that indicates how radiosonde data are specified for a simulation (see Figure 53). Select the "Create/Edit Radiosonde Data" option. Alternately, to execute the program as a standalone, type *radio* at the MS-DOS prompt and press RETURN. Figure 74 shows the Main Menu for the Radiosonde Data Entry Program. The options are displayed in the middle of the menu and the window at the bottom contains the instructions for executing the options. To select an option, move the highlighted area to desired option and press RETURN, or type the highlighted letter twice.

10.1 Set and Change the Data Units

Radiosonde data can be entered in various physical units. Table 22 lists the default physical units, choices of physical units, and ranges for the various radiosonde parameters. The current physical units are displayed in the window at the top of the Main Menu. Physical units can be changed or reset using Main Menu options.

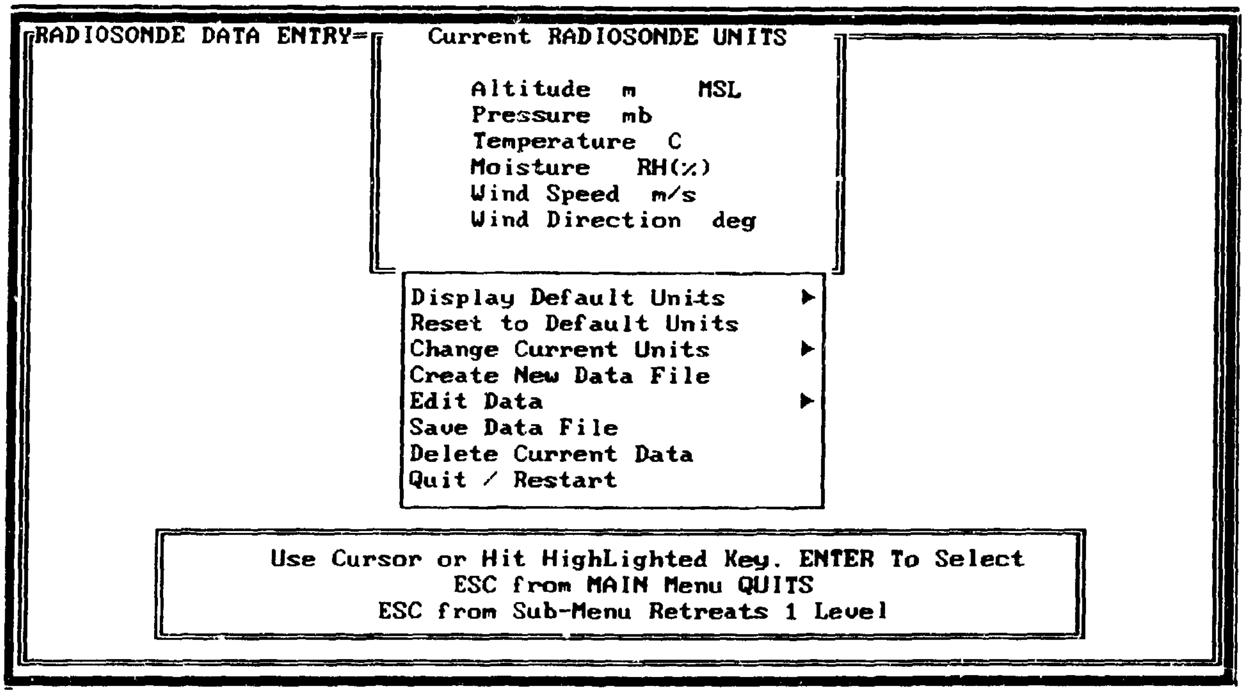

Figure 74. Main Menu of the Radiosonde Data Entry Program

10.1.1 Display Default Units

As shown in Table 22, the Radiosonde Data Entry Program contains a set of default physical units for the various radiosonde parameters. To display them, select the "Display Default Units" option from the Main Menu. The program displays a "popup" window that shows the default physical units.

10.1.2 Reset to Default Units

To reset the current physical units to the default physical units, select the "Reset to Default Units" option from the Main Menu. The program automatically changes the top window of the Main Menu such that it displays the default physical units.

Table 22. Radiosonde Parameters in the Radiosonde Data Entry Program. Default Units. Units Choices. and Limits on Parameter

RADIOSONDE PARAMETER	DEFAULT UNITS	UNITS CHOICES	RANGE
Altitude	m MSL*	m MSL. m AGL÷ ft MSL. ft AGL	0 - 100.000 0 - 330.000
Pressure	mb	mb. Pa	0.1 - 1100 mb 10 - 110.000 Pa
Temperature	C	C. K. F	-150 - 150 C 100 - 450 K -250 - 250 F
Relative humidity. Dew point temperature	% C	% C. K. F	0 - 100 -150 - 150 C 100 - 450 K -250 - 250 F
Station altitude	m MSL	m. ft	0 - 10.000 m 0 - 30.000 ft
Wind speed-Horizontal	m/s	m/s. mph. kts	0 - 450 m/s 0 - 200 mph 0 - 200 kts
Wind direction	deg	deg	0 - 360 deg 0=N. 90=E. *etc.*

* MSL - Mean sea level
÷ AGL - Above ground level

10.1.3 Change Current Units

To change the current physical units for a radiosonde parameter. select the "Change Current Units" option from the Main Menu. The program displays a "popup" menu that lists the radiosonde parameters. as shown in Figure 75. Move the highlighted area (using the up or down arrow keys) to the desired parameter and hit RETURN. The program then displays a "popup" menu that lists the available physical units for the selected parameter. as shown in Figure 76. Move the highlighted area to the desired physical units and hit RETURN. Note that if the altitude units are referenced as AGL. the user is asked to enter the station altitude in either meters or feet (in whichever units are chosen). To retreat one menu level at any time. hit ESC. After the physical units for a radiosonde parameter are selected. the user is returned to the Main Menu and the new physical units are displayed in the top window.

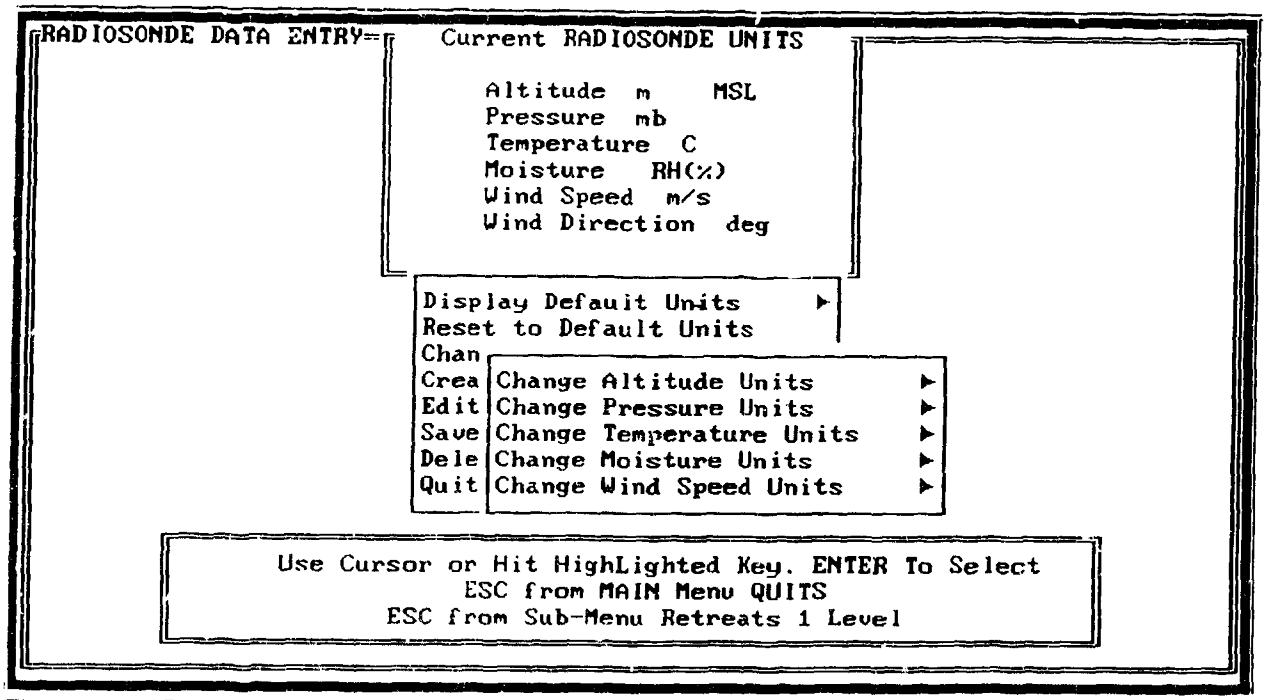

Figure 75. "Popup" Menu in the Radiosonde Data Entry Program for Displaying the Units of a Radiosonde Parameter

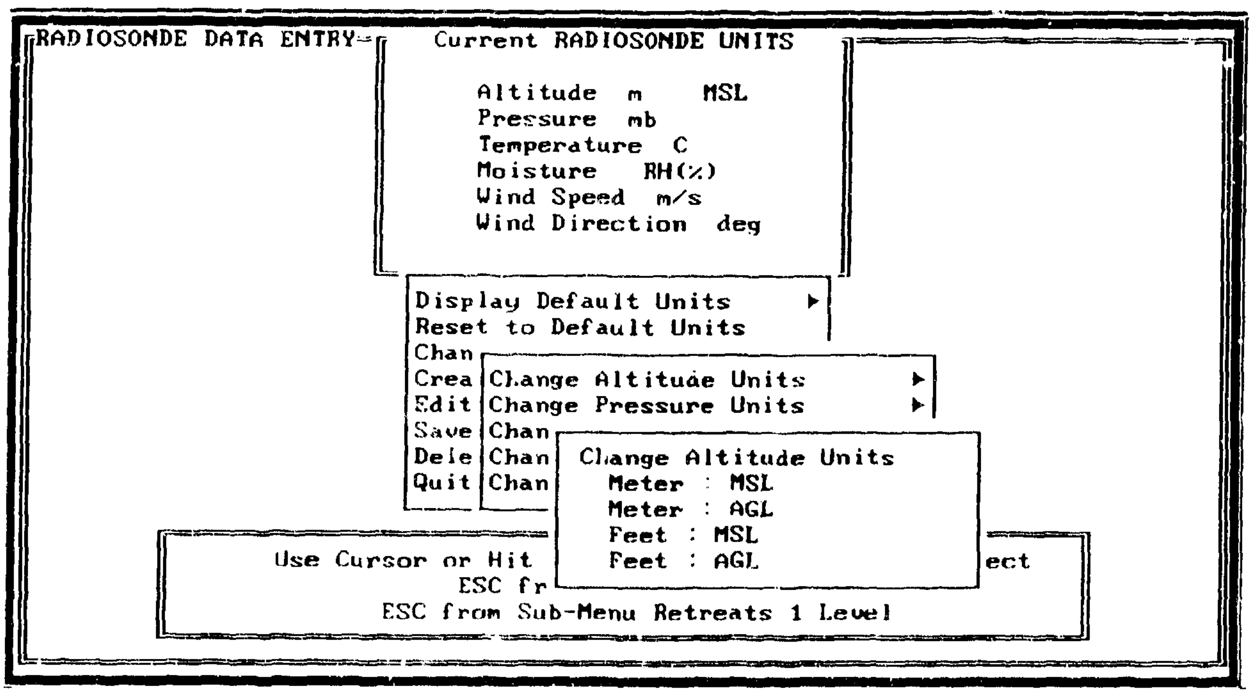

Figure 76. "Popup" Menu in the Radiosonde Data Entry Program for Changing the Altitude Units

10.2 Edit Existing Radiosonde Data

This option in the Radiosonde Data Entry Program is used to edit the radiosonde data either in an existing *.rsd* file or in the program's editing buffer. To perform each action, select the "Edit Data" option from the Main Menu. The program displays a "popup" menu in which the user must choose to edit an existing *.rsd* file or the data currently in the editing buffer, as shown in Figure 77. Move the highlighted area to the desired choice and press RETURN. If the "Edit Existing File" option is selected, the user must enter an existing radiosonde data file. Type the desired file name and press RETURN. If the file exists in the current directory, the Radiosonde Data Entry Program displays the size of the file and the last time it was modified. To accept the file and instruct the program to put the radiosonde data in the editing buffer, hit F1. Hit ESC to return to the Main Menu. If the specified file does not exist, the program issues an error message and returns to the Main Menu.

After the user has established the radiosonde data to be edited, Radiosonde Data Entry Program displays the editing buffer, as shown in Figure 78. In this example, the user has opted to edit an existing radiosonde data file. The current row and column in the editing buffer are highlighted. To change a value, simply type a value and press RETURN. To move from column to column in the buffer, hit RETURN. To move from row to row in the buffer, use the up and down arrow keys. To scroll down or up, use the "PgDn" and "PgUp" keys, respectively.

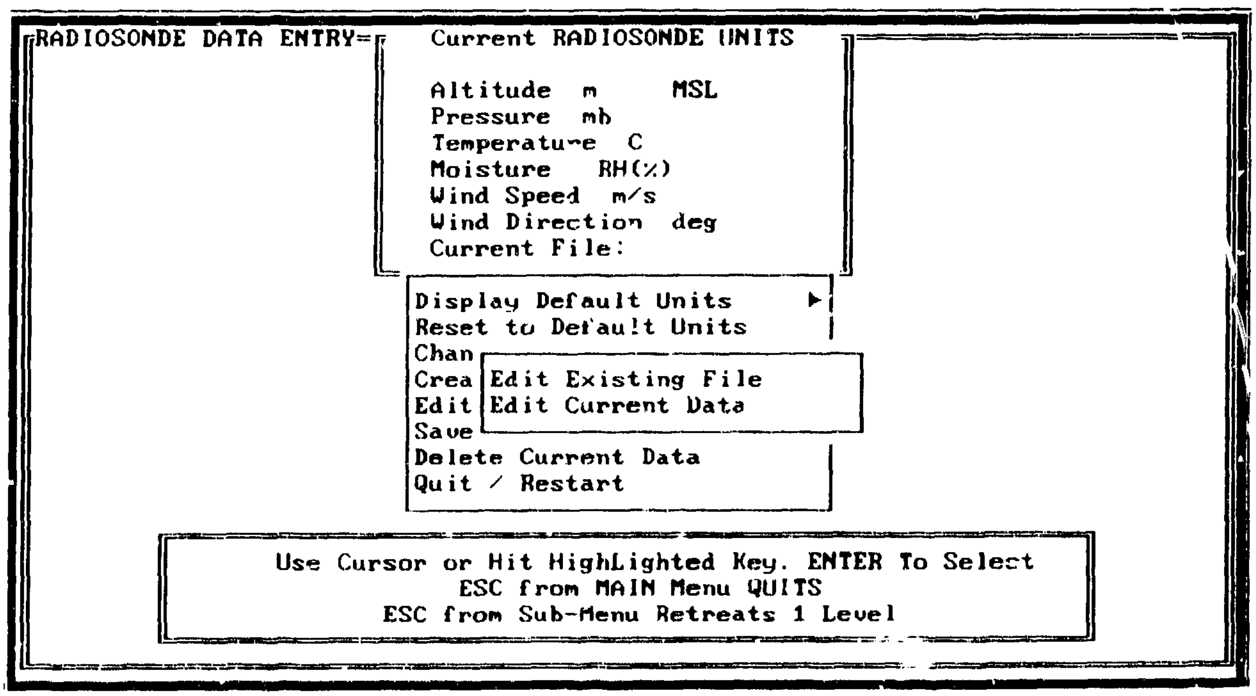

Figure 77. "Popup" Menu in the Radiosonde Data Entry Program for Selecting the Radiosonde Data To Be Edited

RADIOSONDE DATA ENTRY

	ALTITUDE (m)	PRESSURE (mb)	TEMPERATURE (C)	MOISTURE (RH(%))	WIND SPEED (m/s)	WIND DIRECTION (deg)
1	79.00	1005.80	27.90	64.00	11.00	120.00
2	300.00	980.93	23.70	70.00	12.00	123.00
3	600.00	947.81	19.60	85.00	11.00	121.00
4	900.00	915.44	17.80	82.00	7.00	111.00
5	1200.00	883.56	16.20	72.00	4.00	74.00
6	1500.00	853.38	14.20	69.00	4.00	46.00
7	1800.00	823.68	13.80	48.00	2.00	81.00
8	2100.00	795.03	14.60	22.00	1.00	72.00
9	2400.00	767.26	12.80	23.00	3.00	26.00
10	2700.00	740.29	10.60	25.00	4.00	26.00

Ctrl-ENTER To ACCEPT DATA
ESC to Main Menu
ALTITUDE REFERENCE MSL
UNITS Alt-> m :: P-> mb :: T-> C :: M-> RH(%) :: WSP-> m/s :: WDir-> deg

Figure 78. Editing Buffer in the Radiosonde Data Entry Program for Entering and Editing Radiosonde Data

After entering the desired changes, hit CTRL-ENTER to accept the changes. The Radiosonde Data Entry Program then returns to the "popup" menu previously shown in Figure 77. Hit ESC to return to the Main Menu. Note that CTRL-ENTER simply saves the changes within the program's editing buffer, but it does **not** save the changes into the data file. To do this, select the "Save Data File" option in the Main Menu (see Section 10.4). To exit to the Main Menu and not save any of the changes made in the editing buffer, hit ESC. The program asks the user to confirm the exit because all changes are lost.

When the user hits CTRL-ENTER to accept the changes in the editing buffer, the Radiosonde Data Entry Program verifies that the radiosonde data are within their range limits (see Table 22) and that they are entered in sequence. If an error is discovered, the program displays an error message similar to the one shown in Figure 79. The error message includes the value of the parameter out of range is given, followed by the applicable range and the row number containing the error. Note that the error message is not displayed until the user hits CTRL-ENTER to accept the changes in the editing buffer. Furthermore, the error message remains on the screen until the user corrects the problem and hits CTRL-ENTER a second time. In addition to range checking, the Radiosonde Data Entry Program makes sure that altitude and pressure data are entered in the correct sequence. Specifically, altitudes must be entered in increasing order and pressures must be entered in decreasing order. (The program does not check for hydrostatic equilibrium, however.) Currently, the program only displays the first error it encounters. Subsequent errors are not found until the user tries to exit again.

RADIOSONDE DATA ENTRY

	ALTITUDE (m)	PRESSURE (mb)	TEMPERATURE (C)	MOISTURE (RH(%))	WIND SPEED (m/s)	WIND DIRECTION (deg)
1	-20.00	1005.00	27.90	64.00	11.00	120.00
2	300.00	980.93	23.70	70.00	12.00	123.00
3	600.00	947.81	19.60	85.00	11.00	121.00
4	900.00	915.44	17.80	82.00	7.00	111.00
5	1200.00	883.96	16.20	72.00	4.00	74.00
6	1500.00	853.38	14.20	69.00	4.00	46.00
7	1800.00	823.68	13.80	48.00	2.00	81.00
8	2100.00	795.03	14.60	22.00	1.00	72.00
9	2400.00	767.26	12.80	23.00	3.00	26.00
10	2700.00	740.29	10.60	25.00	4.00	26.00

DATA ERROR!
Altitude = -20.00 Out of Range: 0.0 to 100000.0 Row 1

Ctrl-ENTER To ACCEPT DATA
ESC to Main Menu
ALTITUDE REFERENCE MSL
UNITS Alt-> m :: P-> mb :: T-> C :: M-> RH(%) :: WSP-> m/s :: WDir-> deg

Figure 79. Sample Error Message When Altitude Data Are Out of Range

10.3 Create a Radiosonde Data File

This option in the Radiosonde Data Entry Program creates a new radiosonde data file (*.rsd*). It is very similar to the "Edit Data" option because radiosonde data are entered in the program's editing buffer (Section 10.2).

To create a new radiosonde data file, select the "Create New Data File" option from the Main Menu. The user must then enter the radiosonde file, as shown in Figure 80. Type the desired file name and press F1. (The file name is automatically given a *.rsd* extension.) If the file already exists, the Radiosonde Data Entry Program informs the user and then displays the size of the file, as well as last time it was modified. The user can still accept the file name by hitting F1 or return to the Main Menu by hitting ESC.

After establishing the radiosonde data file name, Radiosonde Data Entry Program displays the editing buffer previously shown in Figure 78. To enter radiosonde data and save it in the editing buffer, use the commands that were described in Section 10.2. Note that the "Create New Data File" option does not, by itself, remove any existing radiosonde data in the editing buffer. To clear the editing buffer, use the "Delete Current Data" option in the Main Menu (see Section 10.5).

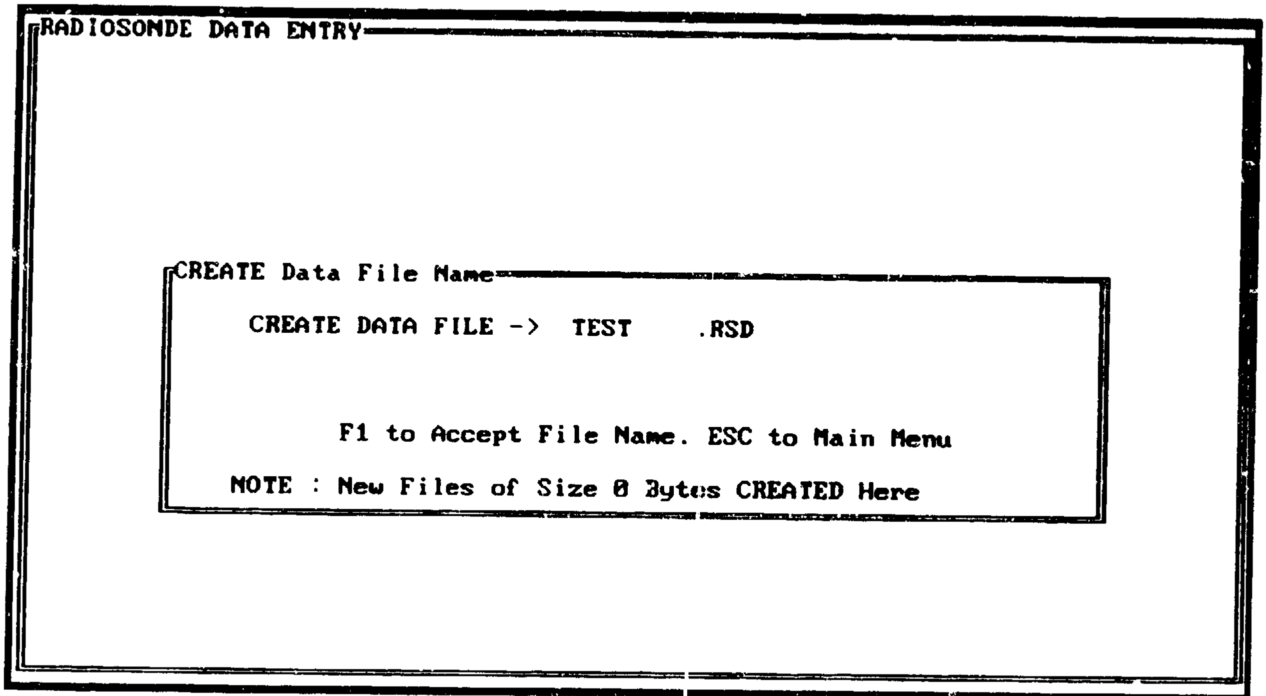

Figure 80. Prompt in the Radiosonde Data Entry Program for Creating a New Radiosonde Data File

10.4 Save Data File

To save radiosonde data in a new or existing file, choose the "Save Data File" option from the Main Menu. This option **must** be selected to save any changes made in the editing buffer. When "Save Data File" option is selected, the program displays a window that shows the current file name, its size and the time it was last modified, as shown in Figure 81. Hit F1 to save the data to this file. After the data are saved, the user is returned to the Main Menu. To select a different file name, hit F2. Type the desired file name at the prompt and press RETURN. To return to the Main Menu and not save the data, hit ESC.

10.5 Delete Current Data

This option in the Main Menu deletes the existing radiosonde data from the editing buffer. Because radiosonde data remain in the editing buffer (after exiting with CTRL-ENTER), this option can be helpful when the user wants to start with an empty editing buffer and create a new radiosonde data file.

To delete radiosonde data from the editing buffer, choose the "Delete Current Data" option from the Main Menu. The program prompts the user to confirm the action. Hit F1 to continue or ESC to abort. Note that this option does **not**, however, delete the current radiosonde data file from the working directory.

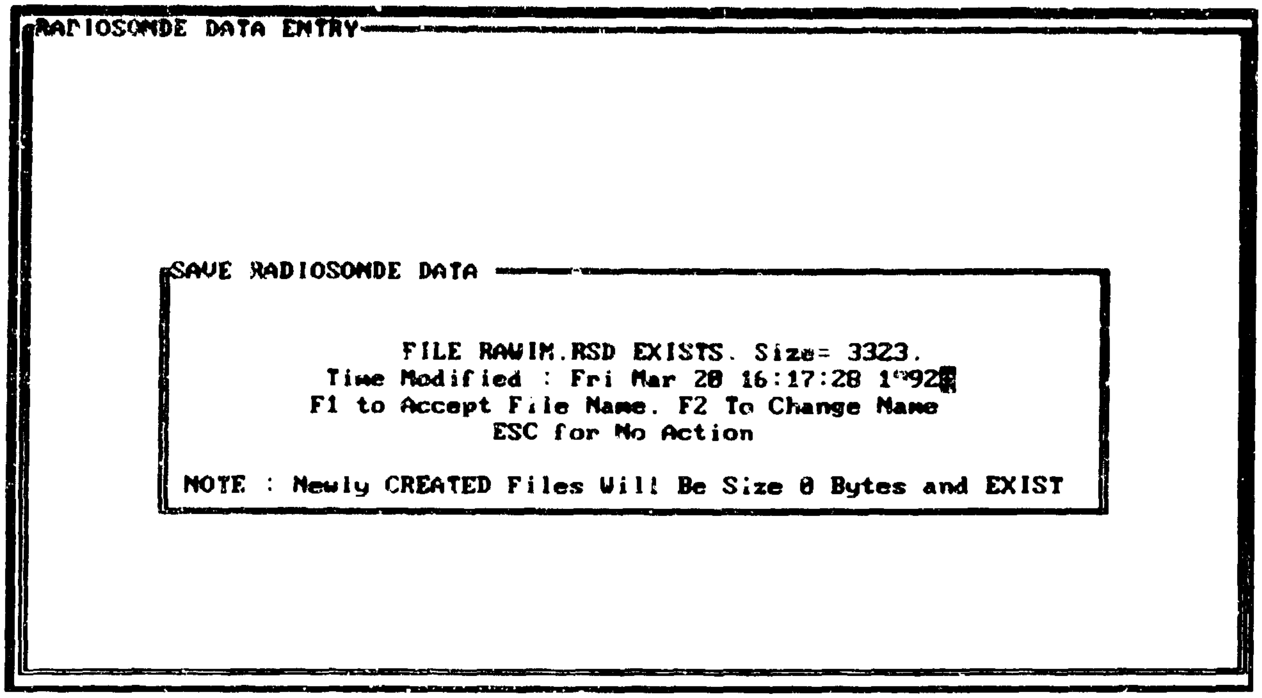

Figure 81. Information Shown By the Radiosonde Data Entry Program When the "Save Data File" Option Is Selected. The radiosonde data are saved to a *.rsd* file

10.6 Quit/Restart

This option either quits the Radiosonde Data Entry Program or restarts it with all parameters reset to their default values. When this option is selected, the program displays the message shown in Figure 82. Hit F1 to return to the Main Menu or hit F2 to restart the program with all the parameters reset to their default values. To confirm the quit and exit the Radiosonde Data Entry Program, hit ESC. Note that before quitting, any created and edited radiosonde files must be saved with the "Save Data File" option in the Main Menu, if desired.

After exiting the Radiosonde Data Entry Program, the menu shown in Figure 83 appears whenever the program was accessed from BACKSCAT's menu interface system. The user can choose to exit to DOS or return to BACKSCAT's menu interface. If the "Run BACKSCAT Menu Program" option is selected, the initial startup screen of BACKSCAT Version 4.0 appears displayed, **not** the Atmospheric Conditions Submenu from which the Radiosonde Data Entry Program was executed. The prior lidar system parameters, viewing conditions parameters, and the atmospheric conditions are retained however. To use a (just created) radiosonde data file, the user must enter the Atmospheric Conditions Submenu, select radiosonde data as the source for Rayleigh scattering/wind field, and then specify the radiosonde data file name.

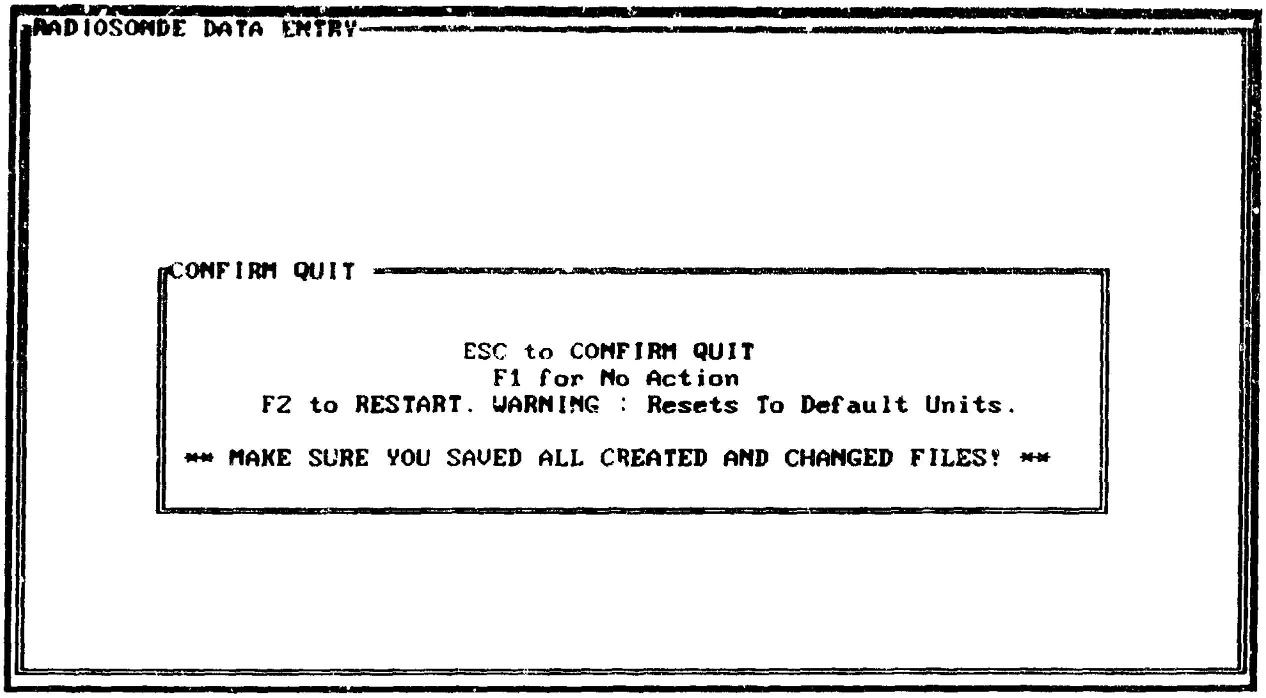

Figure 82. Message Displayed by the Radiosonde Data Entry Program When the "Quit/Restart" Option Is Selected

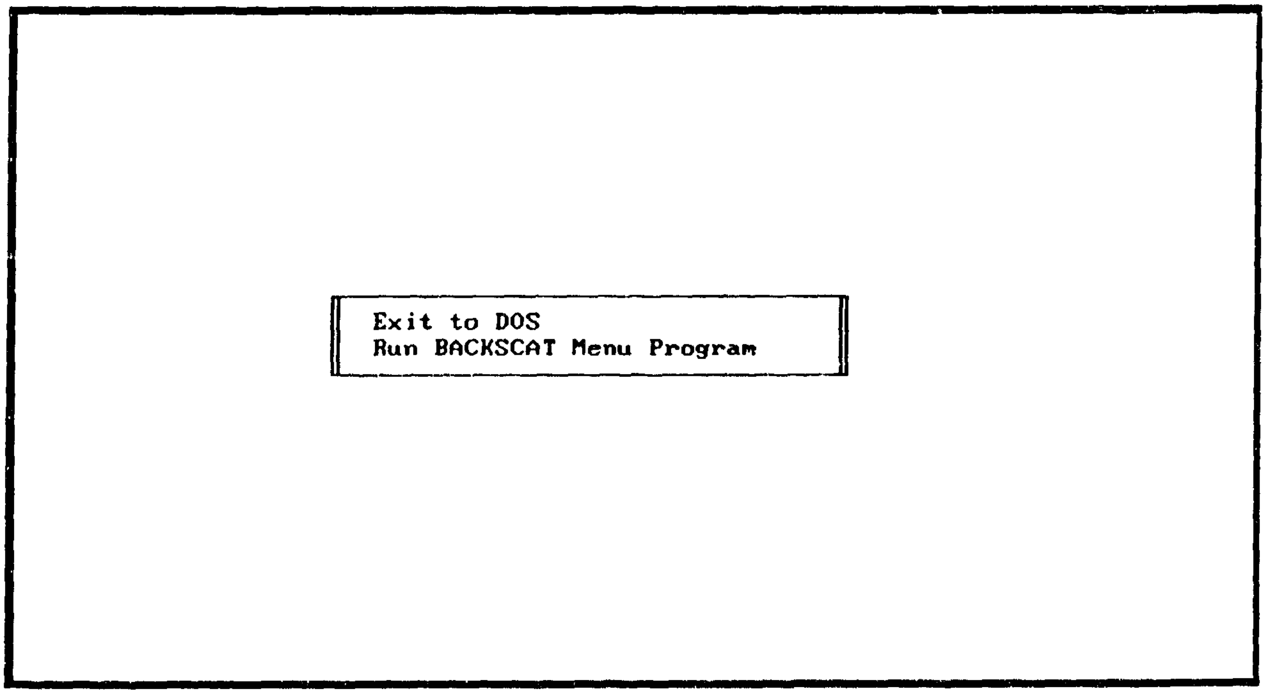

Figure 83. Menu for Exiting to DOS or Running BACKSCAT's Menu Interface System After Leaving the Radiosonde Data Entry Program

11 SUMMARY AND RECOMMENDATIONS FOR FUTURE EFFORTS

11.1 Summary

SPARTA's BACKSCAT software package simulates the performance of lidars for remote sensing and other atmospheric applications. The package accommodates a wide range of lidar systems, viewing scenarios, and atmospheric conditions, plus it contains a user-friendly menu interface system for specifying the required input parameters. This report gives technical documentation and a Users Guide for BACKSCAT Version 4.0.

In this effort, the capabilities of BACKSCAT have been expanded with the development of comprehensive and versatile signal-to-noise performance models. The signal-to-noise (SNR) models give performance and range accuracy estimates for direct detection and coherent Doppler lidar systems. Estimates of the wind speed accuracy are also provided for coherent Doppler systems. The models contain all important noise sources inherent in the detection process. Additionally, the models allow the user to select from five built-in detectors, as well as define their own detector specifications.

In response to the user community, water clouds have been added to BACKSCAT's simulation capabilities. Although they can be represented with the existing user-defined aerosol option in BACKSCAT, water clouds now can be "clicked on" automatically as built-in cloud models. For the most part, the physical properties of water clouds are consistent with those in LOWTRAN7.

An auxiliary software package has been included with the BACKSCAT package which estimates the molecular absorption profile for a particular lidar wavelength. The molecular absorption package has been nicknamed *mabs* and generates output that can be directly used in a simulation. The spectral resolution of *mabs* probably exceeds that of most lidars, so the package is not intended to be a complete treatment of the molecular absorption problem.

Finally, methods of dealing with the increased size of the BACKSCAT package have been introduced. For example, the distribution diskettes include a rudimentary installation utility that reduces the amount of user intervention when BACKSCAT is installed. Because BACKSCAT has encroached on the 640 Kbyte limit of DOS, the "science" portions of the code (*backscat.exe* and *usraer.exe*) have been compiled in protected mode and executed with the Phar Lap 286/DOS-Extender™ Run Time Kit. This solution to the memory problem does not alter the execution of BACKSCAT. However, users who wish to recompile *backscat.exe* and *usraer.exe* must have the Phar Lap software available and bind it with the protected mode programs.

11.2 Recommendations for Future Efforts

Future BACKSCAT efforts should include upgrades to the SNR performance model, additional lidar systems, and ways to improve the performance of the BACKSCAT package. Because it was not considered in BACKSCAT Version 4.0, the SNR performance model should be upgraded to include turbulence effects. Turbulence effects can cause a substantial loss in signal and greatly reduce the effectiveness of any lidar system.

The simulation capabilities of BACKSCAT should be expanded to include other lidar systems of interest to Phillips Laboratory. These lidar systems include scanning continuous wave

(CW) and DIAL systems. To develop a SNR performance model for scanning CW lidar systems, the characteristic parameters are the scan rate, total field-of-view, and instantaneous field-of-view.

BACKSCAT's menu interface system should include an on-line help feature. This on-line help would consist of two parts: First, it would tell users how to use the options in BACKSCAT. Second, it would give descriptions of the input parameters. The second form of on-line help will become more necessary as BACKSCAT expands its simulation capabilities to specific lidar systems.

Finally, BACKSCAT should be transformed into a multi-platform application (PC's using MS Windows, SUN, SGI, HP workstations, *etc.*). This could be accomplished with commercial Graphical User Interface (GUI) software that has applicable libraries for the computer platforms of interest. With this approach, the interface is only created once and it will look the same on different computers. To port BACKSCAT, the code would have to be recompiled with the aforementioned applicable GUI library on the target system. As a complete MS Windows application, BACKSCAT would not have to rely on Phar-Lap's DOS Extender to solve DOS's memory limits.

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Appendix A
DESCRIPTION OF INPUT AND OUTPUT FILES IN BACKSCAT VERSION 4.0

A number of data files are involved in Version 4.0 of the BACKSCAT package. Some files are required to run the code and others can be optionally created and accessed by the user. Table A-1 gives short descriptions of the data files that are involved in the BACKSCAT package. Detailed descriptions are given in the remainder of this appendix.

Table A-1. Description of Data Files Involved in the BACKSCAT Version 4.0 Package

FILENAME	DESCRIPTION	I/O	USER SPECIFIED
standard.scl	Aerosol and molecular extinction profiles at 0.55 μm	Input	No
model.aer	Aerosol wavelength scaling factors (27 wavelengths and 37 aerosol/cloud types)	Input	No
models.ram	Molecular constituent profiles for six model atmospheres	Input	No
models.wnd	Wind profiles for six model atmospheres	Input	No
indexof.ref	Complex indices of refraction for six aerosol types	Input	No
molecule.abs	Molecular absorption parameters	Input	No
mabs.in	Sample input file for *mabs*	Input	Yes
bscatv4.ptl	Sample propagation profile file for aerosol backscatter lidar systems	Input/ Output	Yes/No
bscatv4.rpf	Sample propagation profile file for Raman scattering lidar systems	Input/ Output	Yes/No
bscatv4.dpf	Sample propagation profile file for coherent Doppler lidar systems	Input/ Output	Yes/No
bscatv4.cfg	Sample configuration file	Input	Yes
bscatv4.ldr	Sample lidar system file	Input	Yes
bscatv4.det	Sample user-defined detector file	Input	Yes
bscatv4.vuw	Sample viewing conditions file	Input	Yes
bscatv4.atm	Sample atmospheric conditions file	Input	Yes
bscatv4.lay	Sample user-defined aerosol layer file	Input	Yes
bscatv4.siz	Sample file of particle radii and number densities for a user-defined aerosol layer	Input	Yes
bscatv4.rsd	Sample radiosonde file	Input	Yes
bscatv4.log	Sample log file	Output	No
bscatv4.dat	Sample output data file	Output	No
bscatv4.res	Sample molecular absorption data file	Input	Yes

A.1 Hardwired Input Data Files

The files *standard.sci*, *models.aer*, *models.ram*, *models.wnd*, *indexof.ref*, and *molecule.abs* contain data that describe the state of the atmosphere. These files are included with the BACKSCAT Version 4.0 package and the user should not alter them.

The file *standard.scl* contains molecular scattering and aerosol extinction profiles to be used to produce the propagation profile when a simulation uses BACKSCAT's built-in atmospheres. The file is based on data from Table 18-10(a) in the Handbook of Geophysics.[2]

The file *models.aer* contains the wavelength scaling factors for 37 aerosols and clouds. Scaling factors are given for the extinction and absorption coefficients, backscattering phase function, and asymmetry parameter. The file contains data at 27 wavelengths for each aerosol/cloud type. Using various interpolation schemes, these data provide the aerosol/cloud properties at the desired lidar wavelength.

The file *models.ram* contains the constituent profiles for six model atmospheres (tropical, midlatitude summer, midlatitude winter, subarctic summer, subarctic winter, and the 1976 US Standard Atmosphere). The data file is used in Raman simulations. The columns of data are altitude (km), pressure (mb), temperature (K), molecular number density (cm^{-3}), water vapor volume mixing ratio (ppmv), and ozone volume mixing ratio (ppmv).

The file *models.wnd* contains wind profiles for six model atmospheres. The data file is used for coherent Doppler simulations in which the Rayleigh scattering and wind field come from BACKSCAT's built-in atmospheres instead of radiosonde data. The columns of data are altitude (km) followed by wind speed ($m\ s^{-1}$) and direction (deg) for each model atmosphere.

The file *indexof.ref* contains the complex indices of refraction for six built-in aerosols. Used in the user-defined aerosol option, the file gives wavelength dependent data for water, ice, dust, maritime aerosols, background stratospheric aerosols, and smoke. The data for water, ice, dust, and maritime aerosols are taken from Table 18-9(a) and Table 18-9(b) in the Handbook of Geophysics;[2] the data for background stratospheric aerosols come from Hummel *et al.*;[19] and those for smoke come from Deepak and Gerber.[20]

Finally, the file *molecule.abs* contains molecular absorption parameters for the *mabs* package. The contents of this file come from block data statements in the LOWTRAN7 source code. Generally, molecular absorption is expressed as a function of wavenumber for different atmospheric gases. For brevity, the parameters and units of the data are not given here because the methods of specifying molecular absorption depend on the gas being considered.

A.2 Optional Propagation Profile Data Files

In BACKSCAT, propagation profile data files describe the state of the atmosphere in terms of the parameters that are used to evaluate the lidar equation. These files are optional

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because the user can supply one that has been generated off-line or BACKSCAT will create one during the lidar simulation. The parameters in the propagation profile data files depend on the lidar system being used.

A.2.1 Aerosol Backscatter Lidars

For aerosol backscatter lidar systems, the propagation profile data file contains profiles of the aerosol and molecular attenuation coefficients at the lidar wavelength. As mentioned previously, BACKSCAT creates this file during a simulation or the user can supply one that has been generated off-line. Propagation profile files for aerosol backscatter lidar systems are denoted with the extension *.pfl*. Figure A-1 shows a sample propagation profile for the default conditions in BACKSCAT Version 4.0. For aerosol backscatter lidar systems, propagation profile files consist of seven free-formatted columns where:

Column 1: Altitude (km MSL)
Column 2: Aerosol extinction coefficient (km^{-1})
Column 3: Aerosol scattering coefficient (km^{-1})
Column 4: Aerosol absorption coefficient (km^{-1})
Column 5: Aerosol backscatter coefficient ($m^{-1}sr^{-1}$)
Column 6: Molecular scattering coefficient (km^{-1})
Column 7: Molecular backscatter coefficient ($m^{-1}sr^{-1}$)

If the user generates a propagation profile file off-line, the data must be in the order given above with altitudes in increasing order. Also, the user must be sure that the minimum and maximum altitudes encompass the full altitude range of the simulation. Currently BACKSCAT limits the number of altitudes to one hundred.

A.2.2 Raman Lidars

For Raman lidar systems, the propagation profile data file contains profiles of the number density and cross section of the Raman molecule, and the aerosol and molecular attenuation coefficients at the lidar and Raman wavelengths. As mentioned previously, BACKSCAT creates this file during a simulation or the user can supply one that has been generated off-line. Propagation profile files for Raman lidar systems are denoted with the extension *.rpf*. Figure A-2 shows a sample propagation profile file for the default conditions in BACKSCAT Version 4.0. For Raman lidar systems, propagation profile files consist of eleven free-formatted columns where:

.00	1.580E-01	1.494E-01	8.560E-03	3.466E-06	1.100E-02	1.295E-06
1.00	9.910E-02	9.373E-02	5.369E-03	2.174E-06	1.000E-02	1.177E-06
1.50	7.920E-02	7.491E-02	4.291E-03	1.737E-06	9.550E-03	1.124E-06
2.00	6.210E-02	5.874E-02	3.364E-03	1.362E-06	9.100E-03	1.071E-06
3.00	2.720E-02	2.621E-02	9.928E-04	5.918E-07	8.200E-03	9.653E-07
4.00	1.200E-02	1.156E-02	4.380E-04	2.611E-07	7.440E-03	8.759E-07
5.00	4.850E-03	4.673E-03	1.770E-04	1.035E-07	6.730E-03	7.923E-07
6.00	3.540E-03	3.411E-03	1.292E-04	7.702E-08	6.080E-03	7.157E-07
7.00	2.300E-03	2.216E-03	8.395E-05	5.004E-08	5.470E-03	6.439E-07
8.00	1.410E-03	1.359E-03	5.147E-05	3.068E-08	4.920E-03	5.792E-07
9.00	9.800E-04	9.442E-04	3.577E-05	2.132E-08	4.400E-03	5.180E-07
10.00	7.870E-04	7.870E-04	4.658E-11	1.124E-08	3.930E-03	4.626E-07
11.00	7.140E-04	7.140E-04	4.226E-11	1.020E-08	3.500E-03	4.120E-07
12.00	6.630E-04	6.630E-04	3.924E-11	9.468E-09	3.110E-03	3.661E-07
13.00	6.220E-04	6.220E-04	3.682E-11	8.882E-09	2.740E-03	3.226E-07
14.00	6.450E-04	6.450E-04	3.818E-11	9.211E-09	2.420E-03	2.849E-07
15.00	6.430E-04	6.430E-04	3.806E-11	9.182E-09	2.120E-03	2.496E-07
16.00	6.410E-04	6.410E-04	3.794E-11	9.153E-09	1.840E-03	2.166E-07
17.00	6.010E-04	6.010E-04	3.557E-11	8.582E-09	1.570E-03	1.848E-07
18.00	5.630E-04	5.630E-04	3.332E-11	8.040E-09	1.300E-03	1.530E-07
19.00	4.920E-04	4.920E-04	2.912E-11	7.026E-09	1.070E-03	1.260E-07
20.00	4.230E-04	4.230E-04	2.504E-11	6.040E-09	8.920E-04	1.050E-07
21.00	3.520E-04	3.520E-04	2.084E-11	5.027E-09	7.440E-04	8.759E-08
22.00	2.960E-04	2.960E-04	1.752E-11	4.227E-09	6.220E-04	7.322E-08
23.00	2.420E-04	2.420E-04	1.432E-11	3.456E-09	5.270E-04	6.204E-08
24.00	1.900E-04	1.900E-04	1.125E-11	2.713E-09	4.470E-04	5.262E-08
25.00	1.500E-04	1.500E-04	8.879E-12	2.142E-09	3.790E-04	4.462E-08
26.00	1.150E-04	1.150E-04	6.807E-12	1.642E-09	3.200E-04	3.767E-08
27.00	8.950E-05	8.950E-05	5.298E-12	1.278E-09	2.700E-04	3.178E-08
28.00	6.700E-05	6.700E-05	3.966E-12	9.568E-10	2.290E-04	2.696E-08
29.00	5.200E-05	5.200E-05	3.078E-12	7.426E-10	1.940E-04	2.284E-08
30.00	3.320E-05	3.303E-05	1.680E-07	2.029E-09	1.650E-04	1.942E-08
35.00	1.650E-05	1.642E-05	8.348E-08	1.008E-09	7.040E-05	8.288E-09
40.00	8.000E-06	7.959E-06	4.047E-08	4.889E-10	3.920E-05	4.615E-09
45.00	4.020E-06	4.000E-06	2.034E-08	2.457E-10	1.960E-05	2.307E-09
50.00	2.100E-06	2.089E-06	1.062E-08	1.283E-10	1.030E-05	1.213E-09
55.00	1.090E-06	1.084E-06	5.514E-09	6.661E-11	5.650E-06	6.651E-10
60.00	5.780E-07	5.751E-07	2.924E-09	3.532E-11	3.080E-06	3.626E-10
65.00	3.050E-07	3.034E-07	1.543E-09	1.864E-11	1.670E-06	1.966E-10
70.00	1.600E-07	1.592E-07	8.095E-10	9.777E-12	8.650E-07	1.018E-10
75.00	6.950E-08	6.915E-08	3.516E-10	4.247E-12	4.210E-07	4.956E-11
80.00	2.900E-08	2.885E-08	1.467E-10	1.772E-12	1.940E-07	2.284E-11
85.00	1.200E-08	1.194E-08	6.071E-11	7.333E-13	8.110E-08	9.547E-12
90.00	5.100E-09	5.074E-09	2.580E-11	3.116E-13	3.170E-08	3.732E-12
95.00	2.150E-09	2.139E-09	1.088E-11	1.314E-13	1.220E-08	1.436E-12
100.00	9.300E-10	9.253E-10	4.705E-12	5.683E-14	4.950E-09	5.827E-13

Figure A-1. Sample Propagation Profile File *bscatv4.pfl* for an Aerosol Backscatter Lidar System

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9	Column 10	Column 11
[illegible]	1.912E+19	3.383E-31	1.580E-01	3.466E-06	1.100E-02	1.295E-06	1.361E-01	2.972E-06	6.294E-03	7.409E-07
1.00	1.741E+19	3.383E-31	9.910E-02	2.174E-06	1.000E-02	1.177E-06	8.535E-02	1.864E-06	5.722E-03	6.736E-07
1.50	1.662E+19	3.383E-31	7.920E-02	1.737E-06	9.550E-03	1.124E-06	6.821E-02	1.490E-06	5.464E-03	6.433E-07
2.00	1.583E+19	3.383E-31	6.210E-02	1.362E-06	9.100E-03	1.071E-06	5.348E-02	1.168E-06	5.207E-03	6.130E-07
3.00	1.426E+19	3.383E-31	2.720E-02	5.918E-07	8.200E-03	9.653E-07	2.301E-02	4.922E-07	4.692E-03	5.523E-07
4.00	1.293E+19	3.383E-31	1.200E-02	2.611E-07	7.440E-03	8.759E-07	1.015E-02	2.172E-07	4.257E-03	5.011E-07
5.00	1.170E+19	3.383E-31	4.850E-03	1.055E-07	6.730E-03	7.923E-07	4.103E-03	8.777E-08	3.851E-03	4.533E-07
6.00	1.056E+19	3.383E-31	3.540E-03	7.702E-08	6.080E-03	7.157E-07	2.995E-03	6.406E-08	3.479E-03	4.095E-07
7.00	9.509E+18	3.383E-31	2.300E-03	5.004E-08	5.470E-03	6.439E-07	1.946E-03	4.162E-08	3.130E-03	3.685E-07
8.00	8.543E+18	3.383E-31	1.410E-03	3.068E-08	4.920E-03	5.792E-07	1.193E-03	2.552E-08	2.815E-03	3.314E-07
9.00	7.640E+18	3.382E-31	9.800E-04	2.132E-08	4.400E-03	5.180E-07	8.291E-04	1.774E-08	2.518E-03	2.964E-07
10.00	6.826E+18	3.382E-31	7.870E-04	1.124E-08	3.930E-03	4.626E-07	6.575E-04	9.364E-09	2.249E-03	2.647E-07
11.00	6.072E+18	3.382E-31	[illegible]	[illegible]	[illegible]	4.120E-07	[illegible]	8.195E-09	[illegible]	2.358E-07
12.00	5.389E+18	3.382E-31	6.630E-04	9.466E-09	3.110E-03	3.661E-07	5.539E-04	7.889E-09	1.779E-03	2.095E-07
13.00	4.744E+18	3.382E-31	6.220E-04	8.882E-09	2.740E-03	3.226E-07	5.197E-04	7.401E-09	1.568E-03	1.846E-07
14.00	4.196E+18	3.382E-31	6.450E-04	9.211E-09	2.420E-03	2.849E-07	5.389E-04	7.674E-09	1.385E-03	1.630E-07
15.00	3.666E+18	3.382E-31	6.420E-04	9.182E-09	2.120E-03	2.496E-07	5.372E-04	7.651E-09	1.213E-03	1.428E-07
16.00	3.187E+18	3.382E-31	6.410E-04	9.153E-09	1.840E-03	2.166E-07	5.356E-04	7.627E-09	1.053E-03	1.239E-07
17.00	2.721E+18	3.382E-31	6.010E-04	8.582E-09	1.570E-03	1.848E-07	5.021E-04	7.151E-09	8.983E-04	1.058E-07
18.00	2.245E+18	3.382E-31	5.630E-04	8.040E-09	1.300E-03	1.530E-07	4.704E-04	6.699E-09	7.438E-04	8.757E-08
19.00	1.859E+18	3.382E-31	4.920E-04	7.026E-09	1.070E-03	1.260E-07	4.111E-04	5.854E-09	6.122E-04	7.207E-08
20.00	1.546E+18	3.382E-31	4.230E-04	6.040E-09	8.920E-04	1.050E-07	3.534E-04	5.033E-09	5.104E-04	6.008E-08
21.00	1.289E+18	3.382E-31	3.520E-04	5.027E-09	7.440E-04	8.759E-08	2.941E-04	4.188E-09	4.257E-04	5.011E-08
22.00	1.078E+18	3.382E-31	2.960E-04	4.227E-09	6.220E-04	7.322E-08	2.473E-04	3.522E-09	3.559E-04	4.190E-08
23.00	9.124E+17	3.382E-31	2.420E-04	[illegible]	5.270E-04	6.204E-08	2.022E-04	2.879E-09	3.015E-04	3.550E-08
24.00	7.742E+17	3.382E-31	1.900E-04	2.713E-09	4.470E-04	5.262E-08	1.587E-04	2.261E-09	2.558E-04	[illegible]
25.00	6.566E+17	3.382E-31	1.500E-04	2.142E-09	3.790E-04	4.462E-08	1.253E-04	1.785E-09	2.169E-04	2.553E-08
26.00	5.697E+17	3.382E-31	1.150E-04	1.642E-09	3.200E-04	3.767E-08	9.608E-05	1.368E-09	1.831E-04	2.155E-08
27.00	4.828E+17	3.382E-31	8.950E-05	1.278E-09	2.700E-04	3.178E-08	7.478E-05	1.065E-09	1.545E-04	1.819E-08
28.00	4.109E+17	3.382E-31	6.700E-05	9.568E-10	2.290E-04	2.696E-08	5.598E-05	7.972E-10	1.310E-04	1.543E-08
29.00	3.540E+17	2.382E-31	5.200E-05	7.426E-10	1.940E-04	2.284E-08	4.345E-05	6.187E-10	1.110E-04	1.307E-08
30.00	2.971E+17	3.382E-31	3.320E-05	2.029E-09	1.650E-04	1.942E-08	3.226E-05	1.846E-09	9.441E-05	1.111E-08
35.00	1.296E+17	3.382E-31	1.650E-05	1.008E-09	7.040E-05	8.288E-09	1.603E-05	9.176E-10	4.028E-05	4.742E-09
40.00	[illegible]	3.383E-31	8.200E-06	4.889E-10	3.920E-05	4.615E-09	7.773E-06	4.449E-10	2.243E-05	2.640E-09
45.00	3.397E+16	3.383E-31	4.020E-06	2.457E-10	1.960E-05	2.307E-09	3.906E-06	2.226E-10	1.121E-05	1.320E-09
50.00	1.786E+16	3.383E-31	2.100E-06	1.283E-10	1.030E-05	1.213E-09	2.041E-06	1.168E-10	5.893E-06	6.938E-10
55.00	9.793E+15	3.383E-31	1.090E-06	6.661E-11	5.650E-06	6.651E-10	1.059E-06	6.062E-11	3.233E-06	3.806E-10
60.00	5.242E+15	3.383E-31	5.780E-07	3.532E-11	3.080E-06	[illegible]	5.616E-07	3.214E-11	1.762E-06	2.075E-10
65.00	2.900E+15	3.382E-31	3.050E-07	1.864E-11	1.670E-06	[illegible]	2.964E-07	1.696E-11	9.555E-07	1.125E-10
70.00	1.499E+15	3.382E-31	1.600E-07	9.777E-12	8.650E-07	1.018E-10	1.555E-07	8.898E-12	4.949E-07	5.827E-11
75.00	7.288E+14	3.382E-31	6.950E-08	4.247E-12	4.210E-07	4.956E-11	6.753E-08	3.865E-12	2.409E-07	2.836E-11
80.00	3.367E+14	3.382E-31	2.900E-08	1.772E-12	1.940E-07	2.284E-11	2.818E-08	[illegible]	1.110E-07	1.307E-11
85.00	1.405E+14	3.382E-31	1.200E-08	7.333E-13	8.110E-08	9.547E-12	1.166E-08	[illegible]	4.640E-08	5.463E-12
90.00	5.497E+13	3.382E-31	5.100E-09	3.116E-13	3.170E-08	3.732E-12	4.956E-09	[illegible]	1.814E-08	2.135E-12
95.00	2.112E+13	3.382E-31	2.150E-09	1.314E-13	1.220E-08	1.436E-12	2.089E-09	1.196E-13	6.981E-09	8.218E-13
100.00	8.573E+12	3.382E-31	9.300E-10	[illegible]	4.950E-09	5.827E-13	9.037E-10	5.172E-14	2.832E-09	[illegible]

Figure A-2. Sample Propagation Profile File *bscatv4.rpf* for a Raman Lidar System

Column 1: Altitude (km MSL)
Column 2: Number density of Raman molecule (cm^{-3})
Column 3: Raman scattering cross section ($cm^2\ sr^{-1}$)
Column 4: Aerosol extinction coefficient at lidar wavelength (km^{-1})
Column 5: Aerosol backscatter coefficient at lidar wavelength ($m^{-1}sr^{-1}$)
Column 6: Molecular scattering coefficient at lidar wavelength (km^{-1})
Column 7: Molecular backscatter coefficient at lidar wavelength ($m^{-1}sr^{-1}$)
Column 8: Aerosol extinction coefficient at Raman wavelength (km^{-1})
Column 9: Aerosol backscatter coefficient at Raman wavelength ($m^{-1}sr^{-1}$)
Column 10: Molecular scattering coefficient at Raman wavelength (km^{-1})
Column 11: Molecular backscatter coefficient at Raman wavelength ($m^{-1}sr^{-1}$)

If the user generates a propagation profile file off-line, the data must be in the order given above with altitudes in increasing order. As mentioned in the main text, the file must contain the first three columns of data and the last eight columns are optional. If the last eight columns are not included, BACKSCAT uses its built-in values. Also, the user must be sure that the minimum and maximum altitudes encompass the full altitude range of the simulation. Currently, the code limits the number of altitudes to one hundred.

A.2.3 Coherent Doppler Lidars

For coherent Doppler lidar systems, the propagation profile data file contains profiles of the aerosol and molecular attenuation coefficients at the lidar wavelength, plus an existing wind field. As mentioned previously, BACKSCAT creates this file during a simulation or the user can supply one that has been generated off-line. Propagation profile files for coherent Doppler lidar systems are denoted with the extension *.dpf.* Figure A-3 shows a sample propagation profile for the default conditions in BACKSCAT Version 4.0 for a CO_2 coherent Doppler lidar. For coherent Doppler lidar systems, propagation profile files consist of nine free-formatted columns where:

Column 1: Altitude (km MSL)
Column 2: Aerosol extinction coefficient (km^{-1})
Column 3: Aerosol scattering coefficient (km^{-1})
Column 4: Aerosol absorption coefficient (km^{-1})
Column 5: Aerosol backscatter coefficient ($m^{-1}sr^{-1}$)
Column 6: Molecular scattering coefficient (km^{-1})
Column 7: Molecular backscatter coefficient ($m^{-1}sr^{-1}$)
Column 8: Wind Speed ($m\ s^{-1}$)
Column 9: Wind Direction (deg)

If the user generates a propagation profile file off-line, the data must be in the order given above with altitudes in increasing order. Also, the user must be sure that the minimum and maximum altitudes encompass the full altitude range of the simulation. Currently, BACKSCAT limits the number of altitudes to one hundred.

A.3 Optional Input Files for Groups of Related Parameters

Some of the files in Table A-1 contain the input data for groups of related parameters. These files include the configuration, lidar system, detector, viewing conditions, and atmospheric conditions files. In the BACKSCAT package, these files are used to save and recall the specifications for a particular BACKSCAT simulation. Note that these data files are optional and they can be created with the menu interface system or a standard text editor. Furthermore, these files can be used for simulations with or without the menu interface system, and in batch mode.

Table A-2 describes the format of a configuration file and shows a sample configuration file. Likewise, Tables A-3, A-4 A-5, and A-6 describe the formats and give samples of the detector, lidar system, atmospheric conditions, and viewing conditions files, respectively. The sample files, which are included on the distribution diskettes, correspond to the default values in BACKSCAT Version 4.0.

.00	1.255E-02	7.426E-03	5.126E-03	1.075E-07	7.669E-08	9.028E-12	5.100E+00	7.870E+01
1.00	7.873E-03	4.658E-03	3.215E-03	6.745E-08	6.972E-08	8.207E-12	6.550E+00	8.435E+01
1.50	6.292E-03	3.722E-03	2.570E-03	5.391E-08	6.658E-08	7.838E-12	7.275E+00	8.718E+01
2.00	4.934E-03	2.919E-03	2.015E-03	4.227E-08	6.344E-08	7.469E-12	8.000E+00	9.000E+01
3.00	3.552E-04	1.940E-05	3.358E-04	1.568E-09	5.717E-08	6.730E-12	7.500E+00	9.000E+01
4.00	1.567E-04	8.557E-06	1.481E-04	6.917E-10	5.187E-08	6.106E-12	7.000E+00	9.000E+01
5.00	6.333E-05	3.459E-06	5.988E-05	2.796E-10	4.692E-08	5.524E-12	6.050E+00	9.565E+01
6.00	4.623E-05	2.524E-06	4.370E-05	2.041E-10	4.239E-08	4.990E-12	5.100E+00	1.013E+02
7.00	3.003E-05	1.640E-06	2.839E-05	1.326E-10	3.814E-08	4.489E-12	3.650E+00	1.089E+02
8.00	1.841E-05	1.005E-06	1.741E-05	8.128E-11	3.430E-08	4.038E-12	2.200E+00	1.166E+02
9.00	1.280E-05	6.988E-07	1.210E-05	5.649E-11	3.068E-08	3.611E-12	1.600E+00	1.483E+02
10.00	3.195E-05	2.136E-07	3.174E-05	2.450E-11	2.740E-08	3.226E-12	1.000E+00	1.800E+02
11.00	2.899E-05	1.938E-07	2.880E-05	2.223E-11	2.440E-08	2.873E-12	2.000E+00	2.250E+02
12.00	2.692E-05	1.799E-07	2.674E-05	2.064E-11	2.168E-08	2.553E-12	3.000E+00	2.700E+02
13.00	2.525E-05	1.688E-07	2.508E-05	1.936E-11	1.910E-08	2.249E-12	4.050E+00	2.756E+02
14.00	2.619E-05	1.751E-07	2.601E-05	2.008E-11	1.687E-08	1.986E-12	5.100E+00	2.813E+02
15.00	2.611E-05	1.745E-07	2.593E-05	2.002E-11	1.478E-08	1.740E-12	2.550E+00	3.206E+02
16.00	2.603E-05	1.740E-07	2.585E-05	1.996E-11	1.283E-08	1.510E-12	0.000E+00	0.000E+00
17.00	2.440E-05	1.631E-07	2.424E-05	1.871E-11	1.095E-08	1.289E-12	4.000E+00	4.500E+01
18.00	2.286E-05	1.528E-07	2.271E-05	1.753E-11	9.063E-09	1.067E-12	8.000E+00	9.000E+01
19.00	1.998E-05	1.335E-07	1.984E-05	1.532E-11	7.460E-09	8.782E-13	1.000E+01	8.760E+01
20.00	1.717E-05	1.148E-07	1.706E-05	1.317E-11	6.219E-09	7.321E-13	1.200E+01	8.520E+01
21.00	1.429E-05	9.554E-08	1.420E-05	1.096E-11	5.187E-09	6.106E-13	1.200E+01	9.000E+01
22.00	1.202E-05	8.034E-08	1.194E-05	9.215E-12	4.336E-09	5.105E-13	1.200E+01	9.480E+01
23.00	9.826E-06	6.568E-08	9.760E-06	7.534E-12	3.674E-09	4.325E-13	1.300E+01	9.445E+01
24.00	7.714E-06	5.157E-08	7.663E-06	5.915E-12	3.116E-09	3.669E-13	1.400E+01	9.410E+01
25.00	6.090E-06	4.071E-08	6.049E-06	4.670E-12	2.642E-09	3.111E-13	1.450E+01	9.395E+01
26.00	4.669E-06	3.121E-08	4.638E-06	3.580E-12	2.231E-09	2.626E-13	1.500E+01	9.380E+01
27.00	3.634E-06	2.429E-08	3.609E-06	2.786E-12	1.882E-09	2.216E-13	1.700E+01	9.340E+01
28.00	2.720E-06	1.818E-08	2.702E-06	2.086E-12	1.597E-09	1.880E-13	1.900E+01	9.300E+01
29.00	2.111E-06	1.411E-08	2.097E-06	1.619E-12	1.353E-09	1.592E-13	2.050E+01	9.280E+01
30.00	8.110E-06	1.458E-06	6.653E-06	4.503E-11	1.150E-09	1.354E-13	2.200E+01	9.260E+01
35.00	4.031E-06	7.247E-07	3.307E-06	2.238E-11	4.908E-10	5.778E-14	2.900E+01	8.805E+01
40.00	1.954E-06	3.514E-07	1.603E-06	1.085E-11	2.733E-10	3.217E-14	3.300E+01	9.170E+01
45.00	9.820E-07	1.766E-07	8.056E-07	5.452E-12	1.366E-10	1.609E-14	3.565E+01	9.560E+01
50.00	5.130E-07	9.224E-08	4.208E-07	2.848E-12	7.181E-11	8.454E-15	3.510E+01	9.490E+01
55.00	2.663E-07	4.788E-08	2.184E-07	1.478E-12	3.939E-11	4.637E-15	1.845E+01	1.035E+02
60.00	1.412E-07	2.539E-08	1.158E-07	7.839E-13	2.147E-11	2.528E-15	1.400E+00	2.250E+02
65.00	7.451E-08	1.340E-08	6.112E-08	4.137E-13	1.164E-11	1.371E-15	1.400E+00	2.250E+02
70.00	3.908E-08	7.028E-09	3.206E-08	2.170E-13	6.031E-12	7.099E-16	1.400E+00	2.250E+02
75.00	1.698E-08	3.053E-09	1.393E-08	9.426E-14	2.935E-12	3.455E-16	1.400E+00	2.250E+02
80.00	7.084E-09	1.274E-09	5.812E-09	3.933E-14	1.353E-12	1.592E-16	1.400E+00	2.250E+02
85.00	2.931E-09	5.271E-10	2.405E-09	1.628E-14	5.654E-13	6.656E-17	1.400E+00	2.250E+02
90.00	1.246E-09	2.240E-10	1.022E-09	6.917E-15	2.210E-13	2.602E-17	1.400E+00	2.250E+02
95.00	5.252E-10	9.443E-11	4.309E-10	2.916E-15	8.506E-14	1.001E-17	1.400E+00	2.250E+02
100.00	2.272E-10	4.085E-11	1.864E-10	1.261E-15	3.451E-14	4.063E-18	1.400E+00	2.250E+02

Figure A-3. Sample Propagation Profile File *bscatv4.dpf* for a Coherent Doppler Lidar System. The lidar wavelength is 10.6 μm

Table A-2. BACKSCAT Configuration File. (a.) Description of Parameters

RECORD	FORMAT	DESCRIPTION
1	(4X.A8)	Name of lidar system file
2	(4X.A8)	Name of viewing conditions file
3	(4X.A8)	Name of atmospheric conditions file
4	(4X.A8)	Name of aerosol backscatter propagation profile file
5	(4X.A8)	Name of molecular absorption file, if used
6	(I2.2X.A8)	Flag for user-defined aerosol layer (1=yes, 0=no) Name of user-defined aerosol layer file
7	(4X.A8)	Name of output log file
8	(4X.A8)	Name of output data File
9	(L2.L2.I2.A8)	Logical flag indicating propagation profile source T = Built-in aerosol models F = User-supplied data Logical flag indicating rayleigh scattering T = Rayleigh scattering included F = Rayleigh scattering not included Model atmosphere number 1 = Tropical 2 = Midlatitude summer 3 = Midlatitude winter 4 = Subarctic summer 5 = Subarctic winter 6 = U.S. standard >6 = Radiosonde profile (uses radiosonde data file) Name of radiosonde data file
10	(2I2.2X.A8)	Index to identify Raman system & Raman molecule 0 = Not Raman scattering lidar 1 = Raman lidar with nitrogen 2 = Raman lidar with carbon dioxide 3 = Raman lidar with water vapor 4 = Raman lidar with ozone 5 = Raman lidar with molecular oxygen Source of Raman molecular concentration profile 0 = User-defined file 1 = Tropical 2 = Midlatitude summer 3 = Midlatitude winter 4 = Subarctic summer 5 = Subarctic winter 6 = U.S. standard Name of Raman scattering propagation profile file
11	(L2.4X.A8)	Flag indicating coherent Doppler system (T=yes. F=no) Name of coherent Doppler propagation profile file
12	(A64)	Directory path for BACKSCAT data files

Table A-2. (cont.) (b.) Sample File Listing of *bscatv4.cfg*

```
       none             Lidar System File
       none             Detector File
       none             Viewing Conditions File
       none             Atmospheric Parameters File
    DEFAULT             Aerosol B-sct Propagation Profile File
    (NONE)              Molecular Absorption File
0      none             Flag, User-Defined Aerosol Layer File
    DEFAULT             Simulation Log File
    DEFAULT             Simulation Output File
T T 1                   Flags, Model Atm #, Rawinsonde File
0 1  DEFAULT            Raman Molecule, Concentration and Prop File
F    DEFAULT            Coherent Doppler Flag and Propagation File
C:\BSCAT\DATA\
```

Table A-3. BACKSCAT Detector File, (a.) Description of Parameters

RECORD	FORMAT	DESCRIPTION
1	(F15.5)	Quantum efficiency (-)
2	(F15.5)	Current gain (-)
3	(F15.5)	Detector excess noise factor (-)
4	(F15.5)	Spectral NEP (Watts/Hz$^{1/2}$)
5	(F15.5)	Anode dark current (namp)
6	(F15.5)	Load resistor (ohm)
7	(F15.5)	Effective load temperature (K)
8	(F15.5)	Other amplifier/detector noise (namp)

Table A-3. (b.) Sample File Listing of *bscatv4.det*

```
       0.15462     Quantum Efficiency (-)
   1.80000e+005    Current Gain (-)
       1.20000     Detector excess Noise Factor (-)
   0.00000e+000    Spectral NEP (W/sqrt(Hz)
       0.00000     Anode Dark Current (namp)
       0.00000     Load Resistor (ohm)
       0.00000     Effective Load Temperature (K)
       0.00000     Other Amplifier/Detector Noise (namp)
```

Table A-4. BACKSCAT Lidar Systems File. (a.) Description of Parameters

RECORD	FORMAT	DESCRIPTION
1	(E15.5)	Lidar wavelength (μm)
2	(E15.5)	Pulse energy (J)
3	(E15.5)	Pulse duration (μsec)
4	(E15.5)	Aperture diameter (cm)
5	(E15.5)	Obscuration diameter (cm)
6	(E15.5)	Transmitter optical efficiency (-)
7	(E15.5)	Receiver optical efficiency (-)
8	(E15.5)	Receiver field-of-view (μrad)
9	(E15.5)	Background radiance (Watts cm^{-2} μm^{-1} sr^{-1})
10	(E15.5)	Spectral filter width (A)
11	(I15)	Type of detector flag 1 = APD 2 = Dimpled APD 3 = PMT-Visible 4 = PMT-UV 5 = HgCdTe 6 = User-defined with spectral NEP 7 = User-defined without spectral NEP

Table A-4. (b.) Sample File Listing of *bscatv4.ldr*

```
      0.55000        Wavelength (microns)
      1.00000        Pulse Energy (J)
      1.00000        Pulse Duration (usec)
    100.00000        Aperture Diameter (cm)
      2.00000        Obscuration Diameter (cm)
      1.00000        Transmitter Optical Efficiency (-)
      1.00000        Receiver Optical Efficiency (-)
    300.00000        Receiver Field-of-View (urad)
      0.00000        B'ground Radiance (W/(m2*sr*um))
      0.00000        Spectral Filter Width (A)
            3        PMT-VIS (R636)
```

Table A-5. BACKSCAT Atmospheric Conditions File. (a.) Description of Parameters

RECORD	FORMAT	DESCRIPTION
1	(11X.I1)	Seasonal flag (1 = Fall/Winter, 0 = Spring/Summer)
2	(F12.5)	Boundary layer altitude (km MSL)
3	(10X.I2)	Boundary layer aerosol flag
4	(F12.5)	Relative humidity at the surface (%)
5	(F12.5)	Visibility at the surface (km)
6	(F12.5)	Wind speed at the surface (m/sec)
7	(F12.5)	Altitude of the tropopause (km MSL)
8	(10X.I2)	Tropospheric aerosol flag
9	(F12.5)	Tropospheric relative humidity (%)
10	(F12.5)	Altitude of the stratopause (km MSL)
11	(10X.I2)	Stratospheric aerosol flag
12	(10X.I2)	Stratospheric loading flag
13	(F12.5)	Top of model atmosphere (km MSL)
14	(10X.I2)	Upper atmospheric aerosol flag
15	(10X.I2)	Upper atmosperic loading flag
16	(10X.I2)	Cloud flag 0 = None 1 = Standard cirrus 2 = Subvisual cirrus 3 = Cumulus 4 = Altostratus 5 = Stratus 6 = Stratocumulus 7 = Nimbostratus
17	(F12.5)	Thickness of cloud (km)
18	(F12.5)	Base altitude of cloud (km)
19	(F12.5)	Cloud extinction coefficient at 0.55 μm (km^{-1})

Table A-5. (cont.) (b.) Sample File Listing of *bscatv4.atm*

```
        1        Season: 1 = F/W  2 = S/S
  2.00000        Boundary Layer Height (km)
        1        Type of Aerosol
 70.00000        Relative Humidity (%)
 23.00000        Surface Visibility (km)
 10.00000        Wind Speed at 10 m (m/s)
  9.00000        Tropopause Height (km)
       13        Type of Aerosol
 70.00000        Relative Humidity (%)
 29.00000        Stratopause Height (km)
       23        Type of Aerosol
        1        Aerosol Loading
100.00000        Top of Atmosphere (km)
       26        Type of Aerosol
        1        Aerosol Loading
        0        0=none,1=ci,2=subci,3=cu,4=al,5=st,6=sc,7=nb
  1.00000        Cloud thickness (km)
 10.00000        Cloud base (km)
  0.14000        Cloud extinction at 0.55
```

Table A-6. BACKSCAT Viewing Conditions File. (a.) Description of Parameters

RECORD	FORMAT	DESCRIPTION
1	(F12.5)	Nearest range for simulation output (km)
2	(F12.5)	Farthest range for simulation output (km)
3	(F12.5)	Range resolution for output (km)
4	(F12.5)	Height of lidar system (km MSL)
5	(F12.5)	Viewing azimuth angle (deg)
6	(F12.5)	Viewing elevation angle (deg)
7	(F12.5)	Ground altitude (km MSL)
8	(F12.5)	Surface albedo at lidar wavelength (-)

Table A-6. (b.) Sample File Listing of *bscatv4.vuw*

```
  0.00000        Nearest Range (km)
100.00000        Farthest Range (km)
  0.50000        Range Resolution (km)
  0.00000        Sensor Height (km)
  0.00000        Viewing Azimuth Angle (deg)
 90.00000        Viewing Elevation Angle (deg)
  0.00000        Ground Altitude (km)
  0.25000        Surface Albedo
```

A.4 Optional Input Files for User-Defined Aerosol Layers

Chapter 9 describes the option to add a customized aerosol layer to the assumed aerosol profile. This feature uses either one or two input file(s) to describe the aerosol size distribution shape and number density profile. The first input file is required and must be specified according to format given in Table A-7. The default extension of this data file is *.lay* and a sample file is shown in the second part of Table A-7. Note that the user-defined aerosol is only permitted when the simulation is for an aerosol backscatter or coherent Doppler system and the propagation profile comes from the built-in aerosol models.

As indicated in Table A-7, the second input file is specified only when the aerosol size distribution is given in terms of user-defined radii and number densities. The default extension of this data file is *.siz* and a sample file is shown in Figure A-4.

A.5 Optional Radiosonde Data Files

In BACKSCAT, the profiles of Rayleigh scattering and the existing wind field can be represented by radiosonde data files. Chapter 10 describes how to specify radiosonde data with BACKSCAT's Radiosonde Data Entry Program. Alternately, the user can supply a radiosonde data file that has been generated off-line. The default extension of radiosonde data files is *.rsd*.

The first record in the radiosonde data file is a series of flags that define the physical units of the data. The unit flags are described in Table A-8. The units flags must be set to 0 when the radiosonde data file is created off-line. The format of the first record is (5X,7I3).

After the record with the units flags, the radiosonde data are specified in six column records. When the radiosonde data file is created off-line, each record of radiosonde data must be formatted as (6(5X,F8.2)) and must be use the following <u>mandatory</u> units:

Column 1: Altitude (m MSL)
Column 2: Pressure (mb)
Column 3: Temperature (C)
Column 4: Relative humidity (%)
Column 5: Wind speed (m s^{-1})
Column 6: Wind direction (deg)

In Column 6, the wind direction is defined clockwise from North (N=0°, E=90°, *etc.*). An example of a radiosonde data file is shown in Figure A-5. The minimum and maximum altitudes must encompass the full altitude range of the simulation. The data must be arranged with the altitudes in increasing order. Currently, BACKSCAT limits the number of altitudes to one hundred.

Table A-7. Input File for a User-Defined Aerosol Layer, (a.) Description of Parameters. Detailed explanations of the log normal and modified gamma distributions can be found in the Handbook of Geophysics[2]

RECORD	FORMAT	DESCRIPTION
1	14X,I1	Size distribution flag
		1 = Log normal
		2 = Modified gamma
		3 = User-defined radii and number densities
		If log normal distribution used
2a	F15.5	Total number density of mode 1 (cm^{-3})
2b	F15.5	Mode radius of mode 1 (μm)
2c	F15.5	Log of standard deviation of mode 1
2d	F15.5	Total number density of mode 2 (cm^{-3})
2e	F15.5	Mode radius of mode 2 (μm)
2f	F15.5	Log of standard deviation of mode 2
		If modified gamma distribution used
2a	F15.6	A Parameter
2b	I15	α Parameter
2c	F15.6	B Parameter
2d	I15	γ Parameter
		If user defined size distribution used
2a	A15	Name of size distribution data file
3	I15	Aerosol type flag
		0 = User defined
		1 = Water
		2 = Ice
		3 = Dust
		4 = Maritime
		5 = Background stratospheric
		6 = Smoke
		If uscr defined aerosol type
3b	F15.5	Real part of index of refraction
3c	F15.5	Imaginary part of index of refraction
4a	I15	Number of altitudes in density profile (2-5)
4b	F15.5	Altitude #1 (km)
4c	F15.5	Number density at altitude #1 (cm^{-3})
		Repeat Records 4b and 4c for each altitude

Table A-7. (cont.) (b.) Sample File Listing of *bscatv4.lay*

1	Size distribution flag
1	Total # density of Mode 1
0.03000	Mode Radius of Mode 1
0.35	Standard deviation of Mode 1
0	Total # density of Mode 2
0.00000	Mode Radius of Mode 2
0	Standard deviation of Mode 2
0	Refractive Index Flag
1.39600	Real part of Refractive Index
0	Imag part of Refractive Index
2	Number of altitudes defined
5.00000	Altitude (km)
1	# Density (particles/cm**3)
6.00000	Altitude (km)
2	# Density (particles/cm**3)

```
27
       0.001       2.295E-06
       1.000       1.177E-06
       1.500       1.124E-06
       2.000       1.071E-06
       3.000       9.653E-07
       4.000       8.759E-07
       5.000       7.923E-07
       6.000       7.157E-07
       7.000       6.439E-07
       8.000       5.792E-07
       9.000       5.180E-07
      10.000       4.626E-07
      11.000       4.120E-07
      12.000       3.661E-07
      13.000       3.226E-07
      14.000       2.849E-07
      15.000       2.496E-07
      20.000       1.050E-07
      25.000       4.462E-08
      30.000       1.942E-08
      40.000       4.615E-09
      50.000       1.213E-09
      60.000       3.626E-10
      70.000       1.018E-10
      80.000       2.284E-11
      90.000       3.732E-12
     100.000       5.827E-13
```

Figure A-4. Sample Listing of the Input File for the Size Distribution of a User-Defined Aerosol Layer, *.bscatv4.siz*. The first record gives the number of particle radii. Subsequent records are particle radii (μm) and the corresponding number densities (particles per cm^3) in free format

Table A-8. Description of the First Record of a Radiosonde Data File. The format is (5X,7I3)

FLAG NO.	MEANING	POSSIBLE VALUES
1	Reference altitude units	0 = Mean sea level 1 = Station altitude
2	Altitude units	0 = Meters 1 = Feet
3	Pressure units	0 = Millibars 1 = Pascals
4	Temperature units	0 = Celsius 1 = Kelvin 2 = Farenheit
5	Moisture units	0 = Relative humidity (%) 1 = Dew point (Celsius) 2 = Dew point (Kelvin) 3 = Dew point (Farenheit)
6	Wind speed units	0 = Meters per second 1 = Mile per hour 2 = Knots
7	Wind direction units	0 = Degrees, clockwise from North (N=0°, E=90°, *etc.*)

```
UNITS  0  0  0  0  0  0  0
        79.00      1005.80       27.90       64.00       11.00      120.00
       300.00       980.93       23.70       70.00       12.00      123.00
       600.00       947.81       19.60       85.00       11.00      121.00
       900.00       915.44       17.80       82.00        7.00      111.00
      1200.00       883.96       16.20       72.00        4.00       74.00
      1500.00       853.38       14.20       69.00        4.00       46.00
      1800.00       823.68       13.80       48.00        2.00       81.00
      2100.00       795.03       14.60       22.00        1.00       72.00
      2400.00       767.26       12.80       23.00        3.00       26.00
      2700.00       740.29       10.60       25.00        4.00       26.00
      3000.00       714.06        8.10       25.00        3.00       37.00
      3300.00       688.60        7.30       21.00        4.00       73.00
      3600.00       663.99        6.60       19.00        6.00       87.00
      3900.00       640.20        5.80       19.00        5.00       90.00
      4200.00       617.15        3.90       19.00        4.00       82.00
      4500.00       594.77        1.90       19.00        3.00       74.00
      4800.00       573.05        0.10       19.00        2.00       24.00
      5100.00       551.98       -1.90       20.00        2.00      279.00
      5400.00       531.56       -3.50       19.00        2.00      218.00
      5700.00       511.80       -4.70       18.00        4.00      148.00
      6000.00       492.66       -6.60       19.00        6.00      137.00
      6300.00       474.10       -8.80       19.00        8.00      141.00
      6600.00       456.10      -11.20       20.00        6.00      138.00
      6900.00       438.63      -13.30       20.00        2.00      139.00
      7200.00       421.67      -16.00       21.00        1.00       32.00
      7500.00       405.21      -18.50       21.00        6.00       29.00
      7800.00       389.27      -19.80       20.00        9.00       25.00
      8100.00       373.85      -21.90       21.00       10.00       24.00
      8400.00       358.96      -23.20       21.00       12.00       28.00
      8700.00       344.58      -24.70       23.00       12.00       21.00
      9000.00       330.68      -26.60       25.00       10.00        1.00
      9300.00       317.24      -28.70       24.00        9.00      334.00
      9600.00       304.22      -31.30       26.00       11.00      324.00
           ..           ..          ..          ..          ..          ..
           ..           ..          ..          ..          ..          ..
           ..           ..          ..          ..          ..          ..
     30000.00        12.09      -40.10        0.40       21.00       89.00
     30300.00        11.57      -38.40        0.40       15.00       85.00
     30600.00        11.09      -36.80        0.30       12.00       83.00
     30900.00        10.62      -35.10        0.00        8.00       78.00
     31200.00        10.18      -33.20        0.30        6.00       68.00
     31500.00         9.76      -31.80        0.00        3.00       29.00
     31800.00         9.36      -31.40        0.10        5.00      325.00
     32100.00         8.98      -31.70        0.00        8.00      308.00
     32400.00         8.61      -32.50        0.10        8.00      299.00
     32700.00         8.25      -33.10        0.00        8.00      296.00
     33000.00         7.19      -33.70        0.10        7.00      295.00
     33300.00         7.18      -34.40        0.00        6.00      299.00
     33600.00         7.17      -35.10        0.00        6.00      299.00
```

Figure A-5. Sample Listing of a Radiosonde Data File, *bscatv4.rsd*. The file has been shortened for brevity

A.6 Optional Molecular Absorption Data Files

BACKSCAT permits molecular absorption to be included in simulations for aerosol backscatter and coherent Doppler lidar. This is achieved with an input data file that contains a set of molecular absorption coefficients as a function of altitude. This data file can be created off-line by the user, or by the *mabs* package. The data **must** be for the lidar wavelength of the simulation.

A.6.1 Input Files for the *mabs* Package

The input file for *mabs* is called *mabs.in*. The format of *mabs.in* is described in Table A-9. The first and second records of *mabs.in* are always required. Subsequent records, which correspond to the Card 2C series in LOWTRAN7, are specified only when the user-defined atmosphere (MODEL=7) is selected. Detailed information about the format of the Card 2C series can be found in the Users Guide for LOWTRAN7. Note that the IRD2 parameter on the third record, which indicates aerosol data, always equals 0. Sample input files are given in Figures A-6 and A-7.

A.6.2 Input Files for BACKSCAT Simulations

The name of a molecular absorption data file must be eight characters (or less), and the default extension is *.res*. The first record is the number of altitudes in the file. Subsequent records consist of two columns of free-formatted data. The first column is altitude (km) and the second column is the corresponding molecular absorption coefficient (km^{-1}). The minimum and maximum altitudes must encompass the full altitude range of the simulation. The data must be arranged with the altitudes in increasing order. Currently, BACKSCAT limits the number of altitudes to one hundred. A sample molecular absorption data file is shown in Figure A-8.

When a molecular absorption data file is created with the *mabs* package, the output file is called *mabs.out*. Users must rename this file to a *.res* file.

A.7 Output Files

BACKSCAT generates two output files during a simulation: a log file and an abbreviated output data file. The log file contains a summary of the simulation conditions, the propagation profile, and the results for the lidar simulation. The file extension for the log file is *.log*. Figure A-9 shows a sample log file.

The output data file only contains the results for the lidar simulation. Here, the output is structured in a tabular form and is intended for use as input to off-line analysis and graphics packages. The file extension for the second output file is *.dat*. Figure A-10 shows a sample output data file. The last two columns, which refer to wind field information, are set to zero when aerosol backscatter or Raman scattering systems are simulated.

Table A-9. Description of Parameters in the Input File, *mabs.in*. The third and subsequent records are only required when the model atmosphere parameter on the second record is set to 7

RECORD	FORMAT	DESCRIPTION	POSSIBLE VALUES
1	(A64)	Full path to *molecule.abs*	Any valid path. Add trailing '\'
2	(I5,2F10.3)	Model atmosphere number	1 = Tropical 2 = Midlatitude summer 3 = Midlatitude winter 4 = Subarctic summer 5 = Subarctic winter 6 = U.S. standard 7 = User-defined atmosphere
		Station Altitude	0-6 km
		Wavelength	≥ 0.2 μm
3	(3I5,18A4)	Number of levels in the user-defined atmosphere	2-34
		Flag to read Card 2C2	0,1
		Flag to read Card 2C3	0 (always)
		Identification	72 character limit
4, 5, ...	See Users Guide	Pressure, temperature, and amounts for molecular species at each level	Refer to the LOWTRAN7 Users Guide for details

```
G:\USER\BSCAT\DATA\
    2      0.015      1.060
```

Figure A-6. Sample Input File, *mabs.in*, When a Model Atmosphere is Selected

```
G:\USER\BSCAT\DATA\
    7      0.000      1.060
   33    1      0 TROPICAL
     0.000 1.013E+03 2.997E+02 2.593E+04 3.300E+02 2.869E-02AAAAAAAAAAAAAAA
 3.200E-01 1.500E-01 1.700E+00 2.090E+05 3.000E-04 3.000E-04 2.300E-05 5.000E-04 5.000E-05

     1.000 9.040E+02 2.937E+02 1.949E+04 3.300E+02 3.150E-02AAAAAAAAAAAAAAA
 3.200E-01 1.450E-01 1.700E+00 2.090E+05 3.000E-04 2.740E-04 2.300E-05 5.000E-04 5.960E-05

     2.000 8.050E+02 2.877E+02 1.534E+04 3.300E+02 3.342E-02AAAAAAAAAAAAAAA
 3.200E-01 1.399E-01 1.700E+00 2.090E+05 3.000E-04 2.360E-04 2.300E-05 4.630E-04 6.930E-05

     3.000 7.150E+02 2.837E+02 8.600E+03 3.300E+02 3.504E-02AAAAAAAAAAAAAAA
 3.200E-01 1.349E-01 1.700E+00 2.090E+05 3.000E-04 1.900E-04 2.300E-05 3.800E-04 7.910E-05

     4.000 6.330E+02 2.770E+02 4.441E+03 3.300E+02 3.561E-02AAAAAAAAAAAAAAA
 3.200E-01 1.312E-01 1.700E+00 2.090E+05 3.000E-04 1.460E-04 2.300E-05 2.880E-04 8.870E-05

     5.000 5.590E+02 2.703E+02 3.346E+03 3.300E+02 3.767E-02AAAAAAAAAAAAAAA
 3.200E-01 1.303E-01 1.700E+00 2.090E+05 3.000E-04 1.180E-04 2.300E-05 2.040E-04 9.750E-05

     6.000 4.920E+02 2.636E+02 2.101E+03 3.300E+02 3.989E-02AAAAAAAAAAAAAAA
 3.200E-01 1.288E-01 1.700E+00 2.090E+05 3.000E-04 9.710E-05 2.300E-05 1.460E-04 1.110E-04

     7.000 4.320E+02 2.570E+02 1.289E+03 3.300E+02 4.223E-02AAAAAAAAAAAAAAA
 3.200E-01 1.247E-01 1.699E+00 2.090E+05 3.000E-04 8.300E-05 2.300E-05 9.880E-05 1.260E-04

     8.000 3.780E+02 2.503E+02 7.637E+02 3.300E+02 4.471E-02AAAAAAAAAAAAAAA
 3.200E-01 1.185E-01 1.697E+00 2.090E+05 3.000E-04 7.210E-05 2.300E-05 6.480E-05 1.390E-04

     9.000 3.290E+02 2.436E+02 4.098E+02 3.300E+02 5.000E-02AAAAAAAAAAAAAAA
 3.195E-01 1.094E-01 1.693E+00 2.090E+05 3.000E-04 6.560E-05 2.320E-05 3.770E-05 1.530E-04

    10.000 2.860E+02 2.370E+02 1.912E+02 3.300E+02 5.595E-02AAAAAAAAAAAAAAA
 3.179E-01 9.962E-02 1.685E+00 2.090E+05 3.000E-04 6.080E-05 2.380E-05 2.030E-05 1.740E-04

    11.000 2.470E+02 2.301E+02 7.306E+01 3.300E+02 6.613E-02AAAAAAAAAAAAAAA
 3.140E-01 8.964E-02 1.675E+00 2.090E+05 3.000E-04 5.790E-05 2.620E-05 1.090E-05 2.020E-04

    12.000 2.130E+02 2.236E+02 2.905E+01 3.300E+02 7.815E-02AAAAAAAAAAAAAAA
 3.095E-01 7.814E-02 1.662E+00 2.090E+05 3.000E-04 5.600E-05 3.150E-05 6.300E-06 2.410E-04

    13.000 1.820E+02 2.170E+02 9.900E+00 3.300E+02 9.289E-02AAAAAAAAAAAAAAA
 3.048E-01 6.374E-02 1.645E+00 2.090E+05 2.990E-04 5.590E-05 4.450E-05 3.120E-06 2.760E-04

    14.000 1.560E+02 2.103E+02 6.220E+00 3.300E+02 1.050E-01AAAAAAAAAAAAAAA
 2.999E-01 5.025E-02 1.626E+00 2.090E+05 2.950E-04 5.640E-05 7.480E-05 1.110E-06 3.330E-04

    15.000 1.320E+02 2.037E+02 4.000E+00 3.300E+02 1.256E-01AAAAAAAAAAAAAAA
 2.944E-01 3.941E-02 1.605E+00 2.090E+05 2.830E-04 5.750E-05 1.710E-04 4.470E-07 4.520E-04

      ...            ...            ...            ...
      ...            ...            ...            ...
      ...            ...            ...            ...

    70.000 5.800E-02 2.189E+02 4.500E+00 3.300E+02 3.000E-01AAAAAAAAAAAAAAA
 1.149E-03 1.938E-01 1.500E-01 2.090E+05 1.150E-02 4.320E-05 2.310E-04 2.570E-12 3.270E-05

   100.000 2.890E-04 1.907E+02 4.000E-01 1.950E+02 4.000E-01AAAAAAAAAAAAAAA
 3.323E-04 1.705E+01 1.200E-01 1.600E+05 2.080E+00 3.580E-07 1.700E-04 1.480E-12 2.730E-05
```

Figure A-7. Abbreviated Sample Input File, *mabs.in*, When a User-Defined Atmosphere is Selected

```
33
      .015 5.707E-03
     1.013 4.381E-03
     2.010 3.316E-03
     3.007 2.401E-03
     4.005 1.791E-03
     5.003 1.315E-03
     6.000 1.033E-03
     7.000 8.186E-04
     8.000 6.474E-04
     9.000 5.211E-04
    10.000 4.203E-04
    11.000 3.278E-04
    12.000 2.626E-04
    13.000 2.184E-04
    14.000 1.842E-04
    15.000 1.550E-04
    16.000 1.321E-04
    17.000 1.129E-04
    18.000 9.591E-05
    19.000 8.154E-05
    20.000 6.944E-05
    21.000 5.919E-05
    22.000 5.037E-05
    23.000 4.315E-05
    24.000 3.678E-05
    25.000 3.147E-05
    30.000 1.299E-05
    35.000 6.139E-06
    40.000 2.980E-06
    45.000 1.490E-06
    50.000 7.749E-07
    70.000 5.960E-08
   100.000 0.000E+00
```

Figure A-8. Sample Output File. *mabs.out.* The results are for the input file shown in Figure A-6

```
**************************************
*                                    *
*     LIDAR Backscatter Simulation   *
*           (Version 4.0)            *
*                                    *
*          Simulation Log            *
*                                    *
**************************************


      ***** LIDAR SYSTEM PARAMETERS *****

Type of Lidar System:                  COHERENT DOPPLER

Transmitter Parameters:
          Wavelength (um)                    10.60000
          Pulse Energy (J)                    1.00000
          Pulse Duration (us)                 1.00000
          Transmitter Efficiency (-)          1.00000

Receiver Parameters:
          Aperture Diameter (cm)            100.00000
          Obscuration Diameter (cm)           2.00000
          Receiver Efficiency (-)             1.00000
          Receiver Field-of-View (urad)     300.00000
          B-grd Radiance (W/(m2*sr*um))        .00000
          Spectral Filter Width (A)            .00000

      ***** DETECTOR PARAMETERS *****

Hardware Information:
          Detector Type                        HgCdTe
          Quantum Efficiency (-)               .40000
          Current Gain (-)                1.00000E+00
          Detector Excess Noise Factor (-)    1.00000
          Spectral NEP (W/sqrt(Hz))       1.00000E-12


      ***** COHERENT DOPPLER INFORMATION *****

      Signal-to-noise relationships assume the local
      oscillator power is large enough to make system
      shot-noise limited. For the current detector,
      the local oscillator power >>  3.031E-04 Watts
```

Figure A-9. Sample Log File for a Coherent Doppler Lidar System, *bscatv4.log* (Cont'd on next page)

```
                ***** VIEWING PARAMETERS *****

Lidar Orientation:
          Sensor Height (km)                          .00000
          Viewing Azimuth Angle (Deg)              270.00000
          Viewing Elevation Angle (Deg)             45.00000

Range of the Lidar Calculation:
          Nearest (Minimum) Range (km)                .00000
          Farthest (Maximum) Range (km)            100.00000
          Range Resolution (km)                       .50000

Ground Characteristics:
          Ground Altitude (km MSL)                    .00000
          Surface Albedo (-)                          .25000


                ***** ATMOSPHERIC MODEL *****

Boundary Layer:
          Aerosol                                      RURAL
          Surface Visibility (km)                   23.00000
          Relative Humidity (Percent)                 70.000
          Wind Speed (m/s) at 10 m                  10.00000

Troposphere:
          Relative Humidity (Percent)                 70.000

Stratosphere:
          Aerosol Composition                  STRATOSPHERIC
          Aerosol Profile                         BACKGROUND

Upper Atmosphere:
          Aerosol Profile                             NORMAL

Season:                                          FALL/WINTER

Layer Heights:
          Boundary Layer (km)                        2.00000
          Troposphere (km)                           9.00000
          Stratosphere (km)                         29.00000
          Top of Atmosphere (km)                   100.00000

Molecular Scattering INCLUDED.

Molecular Scattering/Wind Field Source:             TROPICAL

No Molecular Absorption.
```

Figure A-9. (cont'd). Sample Log File for a Coherent Doppler Lidar System. *bscatv4.log* (cont'd on next page)

```
Propagation profile written to file DEFAULT.dpf

***** LIDAR PROPAGATION PROFILE *****
```

Height (km)	Aerosol Extinct (1/km)	Aerosol Scatter (1/km)	Aerosol Absorp (1/km)	Aerosol B'scatter (1/m-sr)	Mol Scat (1/km)	Mol B'scat (1/m-sr)
.00	1.255E-02	7.426E-03	5.126E-03	1.075E-07	7.669E-08	9.028E-12
1.00	7.873E-03	4.658E-03	3.215E-03	6.745E-08	6.972E-08	8.207E-12
1.50	6.292E-03	3.722E-03	2.570E-03	5.391E-08	6.658E-08	7.838E-12
2.00	4.934E-03	2.919E-03	2.015E-03	4.227E-08	6.344E-08	7.469E-12
3.00	3.552E-04	1.940E-05	3.358E-04	1.568E-09	5.717E-08	6.730E-12
4.00	1.567E-04	8.557E-06	1.481E-04	6.917E-10	5.187E-08	6.106E-12
5.00	6.333E-05	3.459E-06	5.988E-05	2.796E-10	4.692E-08	5.524E-12
6.00	4.623E-05	2.524E-06	4.370E-05	2.041E-10	4.239E-08	4.990E-12
7.00	3.003E-05	1.640E-06	2.839E-05	1.326E-10	3.814E-08	4.489E-12
8.00	1.841E-05	1.005E-06	1.741E-05	8.128E-11	3.430E-08	4.038E-12
9.00	1.280E-05	6.988E-07	1.210E-05	5.649E-11	3.068E-08	3.611E-12
10.00	3.195E-05	2.136E-07	3.174E-05	2.450E-11	2.740E-08	3.226E-12
11.00	2.899E-05	1.938E-07	2.880E-05	2.223E-11	2.440E-08	2.873E-12
12.00	2.692E-05	1.799E-07	2.674E-05	2.064E-11	2.168E-08	2.553E-12
13.00	2.525E-05	1.688E-07	2.508E-05	1.936E-11	1.910E-08	2.249E-12
14.00	2.619E-05	1.751E-07	2.601E-05	2.008E-11	1.687E-08	1.986E-12
15.00	2.611E-05	1.745E-07	2.593E-05	2.002E-11	1.478E-08	1.740E-12
16.00	2.603E-05	1.740E-07	2.585E-05	1.996E-11	1.283E-08	1.510E-12
17.00	2.440E-05	1.631E-07	2.424E-05	1.871E-11	1.055E-08	1.289E-12
18.00	2.286E-05	1.528E-07	2.271E-05	1.753E-11	9.063E-09	1.067E-12
19.00	1.998E-05	1.335E-07	1.984E-05	1.532E-11	7.460E-09	8.782E-13
20.00	1.717E-05	1.148E-07	1.706E-05	1.317E-11	6.219E-09	7.321E-13
21.00	1.429E-05	9.554E-08	1.420E-05	1.096E-11	5.187E-09	6.106E-13
22.00	1.202E-05	8.034E-08	1.194E-05	9.215E-12	4.336E-09	5.105E-13
23.00	9.826E-06	6.568E-08	9.760E-06	7.534E-12	3.674E-09	4.325E-13
24.00	7.714E-06	5.157E-08	7.663E-06	5.915E-12	3.116E-09	3.669E-13
25.00	6.090E-06	4.071E-08	6.049E-06	4.670E-12	2.642E-09	3.111E-13
26.00	4.669E-06	3.121E-08	4.638E-06	3.580E-12	2.231E-09	2.626E-13
27.00	3.634E-06	2.429E-08	3.609E-06	2.786E-12	1.882E-09	2.216E-13
28.00	2.720E-06	1.818E-08	2.702E-06	2.086E-12	1.597E-09	1.880E-13
29.00	2.111E-06	1.411E-08	2.097E-06	1.619E-12	1.353E-09	1.592E-13
30.00	8.110E-06	1.458E-06	6.653E-06	4.503E-11	1.150E-09	1.354E-13
35.00	4.031E-06	7.247E-07	3.307E-06	2.238E-11	4.908E-10	5.778E-14
40.00	1.954E-06	3.514E-07	1.603E-06	1.085E-11	2.733E-10	3.217E-14
45.00	9.820E-07	1.766E-07	8.056E-07	5.452E-12	1.366E-10	1.609E-14
50.00	5.130E-07	9.224E-08	4.208E-07	2.848E-12	7.181E-11	8.454E-15
55.00	2.663E-07	4.788E-08	2.184E-07	1.478E-12	3.939E-11	4.637E-15
60.00	1.412E-07	2.539E-08	1.158E-07	7.839E-13	2.147E-11	2.528E-15
65.00	7.451E-08	1.340E-08	6.112E-08	4.137E-13	1.164E-11	1.371E-15
70.00	3.908E-08	7.028E-09	3.206E-08	2.170E-13	6.031E-12	7.099E-16
75.00	1.698E-08	3.053E-09	1.393E-08	9.426E-14	2.935E-12	3.455E-16
80.00	7.084E-09	1.274E-09	5.812E-09	3.933E-14	1.353E-12	1.592E-16
85.00	2.931E-09	5.271E-10	2.405E-09	1.628E-14	5.654E-13	6.656E-17
90.00	1.246E-09	2.240E-10	1.022E-09	6.917E-15	2.210E-13	2.602E-17
95.00	5.252E-10	9.443E-11	4.309E-10	2.916E-15	8.506E-14	1.001E-17
100.00	2.272E-10	4.085E-11	1.864E-10	1.261E-15	3.451E-14	4.063E-18

Figure A-9. (cont'd). Sample Log File for a Coherent Doppler Lidar System, *bscatv4.log* (cont'd on next page)

***** PROPAGATION WIND FIELD *****

Height (km)	Wind Speed (m/s)	Wind Direction (deg)
.00	5.1	78.7
2.00	8.0	90.0
4.00	7.0	90.0
6.00	5.1	101.3
8.00	2.2	116.6
10.00	1.0	180.0
12.00	3.0	270.0
14.00	5.1	281.3
16.00	.0	.0
18.00	8.0	90.0
20.00	12.0	85.2
22.00	12.0	94.8
24.00	14.0	94.1
26.00	15.0	93.8
28.00	19.0	93.0
30.00	22.0	92.6
32.00	26.0	90.0
34.00	28.0	88.0
36.00	30.0	88.1
38.00	32.0	90.0
40.00	33.0	91.7
42.00	33.1	95.2
44.00	35.1	94.9
46.00	36.2	96.3
48.00	37.2	96.2
50.00	35.1	94.9
52.00	30.0	91.9
54.00	23.3	99.9
56.00	13.6	107.1
58.00	3.6	123.7
60.00	1.4	225.0

Figure A-9. (cont'd). Sample Log File for a Coherent Doppler Lidar System. *bscatv4.log* (cont'd on next page)

Simulation output written to DEFAULT.dat

***** COHERENT DOPPLER SYSTEM *****

Range (km)	Height (km)	Optical Depth (-)	Lidar Return (W)	Range Ind. Lidar (W-sq m)	Range Accuracy (m)	Signal-to-Noise (-)
5.000E-01	3.536E-01	5.854E-03	4.344E-05	1.086E+01	2.461E-03	4.307E+04
1.000E+00	7.071E-01	1.089E-02	9.120E-06	9.120E+00	5.372E-03	1.973E+04
1.500E+00	1.061E+00	1.511E-02	3.340E-06	7.515E+00	8.877E-03	1.194E+04
2.000E+00	1.414E+00	1.867E-02	1.594E-06	6.376E+00	1.285E-02	8.249E+03
2.500E+00	1.768E+00	2.169E-02	8.597E-07	5.373E+00	1.750E-02	6.058E+03
3.000E+00	2.121E+00	2.422E-02	4.651E-07	4.186E+00	2.379E-02	4.456E+03
3.500E+00	2.475E+00	2.600E-02	2.093E-07	2.564E+00	3.546E-02	2.989E+03
4.000E+00	2.828E+00	2.697E-02	5.964E-08	9.542E-01	6.643E-02	1.596E+03
4.500E+00	3.182E+00	2.726E-02	7.787E-09	1.577E-01	1.838E-01	5.766E+02
5.000E+00	3.536E+00	2.740E-02	4.924E-09	1.231E-01	2.312E-01	4.585E+02
5.500E+00	3.889E+00	2.751E-02	2.928E-09	8.856E-02	2.998E-01	3.535E+02
6.000E+00	4.243E+00	2.758E-02	1.849E-09	6.656E-02	3.773E-01	2.809E+02
6.500E+00	4.596E+00	2.764E-02	1.191E-09	5.030E-02	4.701E-01	2.255E+02
7.000E+00	4.950E+00	2.768E-02	6.949E-10	3.405E-02	6.154E-01	1.722E+02
7.500E+00	5.303E+00	2.771E-02	5.186E-10	2.917E-02	7.123E-01	1.488E+02
8.000E+00	5.657E+00	2.774E-02	4.090E-10	2.618E-02	8.021E-01	1.321E+02
8.500E+00	6.010E+00	2.777E-02	3.211E-10	2.320E-02	9.053E-01	1.171E+02
9.000E+00	6.364E+00	2.779E-02	2.513E-10	2.035E-02	1.023E+00	1.036E+02
9.500E+00	6.718E+00	2.781E-02	1.941E-10	1.752E-02	1.164E+00	9.104E+01
1.000E+01	7.071E+00	2.782E-02	1.485E-10	1.485E-02	1.331E+00	7.962E+01
1.050E+01	7.425E+00	2.784E-02	1.162E-10	1.281E-02	1.505E+00	7.043E+01
1.100E+01	7.778E+00	2.785E-02	8.904E-11	1.077E-02	1.719E+00	6.165E+01
1.150E+01	8.132E+00	2.786E-02	6.901E-11	9.126E-03	1.953E+00	5.428E+01
1.200E+01	8.485E+00	2.787E-02	5.649E-11	8.134E-03	2.158E+00	4.911E+01
1.250E+01	8.839E+00	2.787E-02	4.571E-11	7.142E-03	2.400E+00	4.417E+01
1.300E+01	9.192E+00	2.788E-02	3.548E-11	5.996E-03	2.723E+00	3.892E+01
1.350E+01	9.546E+00	2.789E-02	2.591E-11	4.722E-03	3.187E+00	3.326E+01
1.400E+01	9.899E+00	2.790E-02	1.759E-11	3.448E-03	3.868E+00	2.740E+01
1.450E+01	1.025E+01	2.792E-02	1.432E-11	3.012E-03	4.286E+00	2.473E+01
1.500E+01	1.061E+01	2.794E-02	1.293E-11	2.908E-03	4.512E+00	2.349E+01
1.550E+01	1.096E+01	2.795E-02	1.168E-11	2.806E-03	4.747E+00	2.233E+01
1.600E+01	1.131E+01	2.796E-02	1.065E-11	2.727E-03	4.971E+00	2.132E+01
1.650E+01	1.167E+01	2.798E-02	9.739E-12	2.651E-03	5.198E+00	2.039E+01
1.700E+01	1.202E+01	2.799E-02	8.919E-12	2.578E-03	5.432E+00	1.951E+01
1.750E+01	1.237E+01	2.801E-02	8.212E-12	2.515E-03	5.661E+00	1.872E+01
1.800E+01	1.273E+01	2.802E-02	7.570E-12	2.453E-03	5.896E+00	1.798E+01
1.850E+01	1.308E+01	2.803E-02	7.038E-12	2.409E-03	6.115E+00	1.733E+01
1.900E+01	1.344E+01	2.804E-02	6.722E-12	2.427E-03	6.257E+00	1.694E+01
1.950E+01	1.379E+01	2.806E-02	6.428E-12	2.444E-03	6.398E+00	1.657E+01
2.000E+01	1.414E+01	2.807E-02	6.125E-12	2.450E-03	6.555E+00	1.617E+01
2.050E+01	1.450E+01	2.808E-02	5.801E-12	2.438E-03	6.735E+00	1.574E+01
2.100E+01	1.485E+01	2.810E-02	5.501E-12	2.426E-03	6.917E+00	1.532E+01
2.150E+01	1.520E+01	2.811E-02	5.222E-12	2.414E-03	7.099E+00	1.493E+01
2.200E+01	1.556E+01	2.812E-02	4.964E-12	2.402E-03	7.281E+00	1.456E+01
2.250E+01	1.591E+01	2.813E-02	4.722E-12	2.391E-03	7.465E+00	1.420E+01
2.300E+01	1.626E+01	2.815E-02	4.433E-12	2.345E-03	7.705E+00	1.376E+01
2.350E+01	1.662E+01	2.816E-02	4.141E-12	2.287E-03	7.971E+00	1.330E+01
2.400E+01	1.697E+01	2.817E-02	3.870E-12	2.229E-03	8.246E+00	1.285E+01
2.450E+01	1.732E+01	2.819E-02	3.622E-12	2.174E-03	8.524E+00	1.243E+01
2.500E+01	1.768E+01	2.820E-02	3.390E-12	2.119E-03	8.811E+00	1.203E+01
2.550E+01	1.803E+01	2.821E-02	3.168E-12	2.060E-03	9.115E+00	1.163E+01
2.600E+01	1.838E+01	2.822E-02	2.907E-12	1.965E-03	9.514E+00	1.114E+01
2.650E+01	1.874E+01	2.823E-02	2.664E-12	1.871E-03	9.938E+00	1.066E+01
2.700E+01	1.909E+01	2.824E-02	2.439E-12	1.778E-03	1.039E+01	1.020E+01
2.750E+01	1.945E+01	2.825E-02	2.231E-12	1.688E-03	1.086E+01	9.760E+00

Figure A-9. (cont'd). Sample Log File for a Coherent Doppler Lidar System. *bscatv4.log* (cont'd on next page)

2.800E+01	1.980E+01	2.326E-02	2.037E-12	1.597E-03	1.137E+01	9.326E+00
2.850E+01	2.015E+01	2.827E-02	1.855E-12	1.506E-03	1.191E+01	8.898E+00
2.900E+01	2.051E+01	2.828E-02	1.682E-12	1.415E-03	1.251E+01	8.474E+00
2.950E+01	2.086E+01	2.828E-02	1.520E-12	1.323E-03	1.316E+01	8.056E+00
3.000E+01	2.121E+01	2.829E-02	1.381E-12	1.243E-03	1.380E+01	7.678E+00
3.050E+01	2.157E+01	2.830E-02	1.258E-12	1.170E-03	1.446E+01	7.329E+00
3.100E+01	2.192E+01	2.830E-02	1.142E-12	1.098E-03	1.518E+01	6.984E+00
...			...			...
...			...			...
...			...			...
9.550E+01	6.753E+01	2.846E-02	3.843E-15	3.505E-05	2.617E+02	4.050E-01
9.600E+01	6.788E+01	2.846E-02	3.634E-15	3.350E-05	2.691E+02	3.939E-01
9.650E+01	6.824E+01	2.846E-02	3.430E-15	3.194E-05	2.770E+02	3.827E-01
9.700E+01	6.859E+01	2.846E-02	3.230E-15	3.039E-05	2.854E+02	3.713E-01
9.750E+01	6.894E+01	2.846E-02	3.034E-15	2.884E-05	2.945E+02	3.599E-01
9.800E+01	6.930E+01	2.846E-02	2.842E-15	2.729E-05	3.043E+02	3.483E-01
9.850E+01	6.965E+01	2.846E-02	2.653E-15	2.574E-05	3.150E+02	3.365E-01
9.900E+01	7.000E+01	2.846E-02	2.473E-15	2.423E-05	3.262E+02	3.249E-01
9.950E+01	7.036E+01	2.846E-02	2.346E-15	2.323E-05	3.349E+02	3.165E-01
1.000E+02	7.071E+01	2.846E-02	2.226E-15	2.226E-05	3.438E+02	3.083E-01

***** WIND SPEED ACCURACY *****

Range (km)	Height (km)	Existing Wind Speed (m/s)	Radial Wind Speed (m/s)	Wind Speed Accuracy (m/s)
5.000E-01	3.536E-01	5.6	-3.9	.0
1.000E+00	7.071E-01	6.1	-4.3	.0
1.500E+00	1.061E+00	6.6	-4.7	.0
2.000E+00	1.414E+00	7.2	-5.0	.0
2.500E+00	1.768E+00	7.7	-5.4	.0
3.000E+00	2.121E+00	7.9	-5.6	.0
3.500E+00	2.475E+00	7.8	-5.5	.0
4.000E+00	2.828E+00	7.6	-5.4	.0
4.500E+00	3.182E+00	7.4	-5.2	.0
5.000E+00	3.536E+00	7.2	-5.1	.0
5.500E+00	3.889E+00	7.1	-5.0	.0
6.000E+00	4.243E+00	6.8	-4.8	.0
6.500E+00	4.596E+00	6.4	-4.5	.0
7.000E+00	4.950E+00	6.1	-4.3	.0
7.500E+00	5.303E+00	5.8	-4.0	.0
8.000E+00	5.657E+00	5.4	-3.8	.0
8.500E+00	6.010E+00	5.1	-3.5	.0
9.000E+00	6.364E+00	4.6	-3.1	.0
9.500E+00	6.718E+00	4.1	-2.7	.0
1.000E+01	7.071E+00	3.5	-2.4	.0
1.050E+01	7.425E+00	3.0	-2.0	.0
1.100E+01	7.778E+00	2.5	-1.6	.0
1.150E+01	8.132E+00	2.1	-1.3	.0
1.200E+01	8.485E+00	1.9	-1.0	.0
1.250E+01	8.839E+00	1.7	-.7	.0
1.300E+01	9.192E+00	1.5	-.5	.1
1.350E+01	9.546E+00	1.3	-.2	.1
1.400E+01	9.899E+00	1.1	.0	.1
1.450E+01	1.025E+01	1.3	.2	.1
1.500E+01	1.061E+01	1.6	.5	.1
1.550E+01	1.096E+01	2.0	.9	.1
1.600E+01	1.131E+01	2.3	1.4	.1
1.650E+01	1.167E+01	2.7	1.8	.1
1.700E+01	1.202E+01	3.0	2.1	.1
1.750E+01	1.237E+01	3.4	2.4	.1
1.800E+01	1.273E+01	3.8	2.7	.1
1.850E+01	1.308E+01	4.1	2.9	.1

Figure A-9. (cont'd). Sample Log File for a Coherent Doppler Lidar System. *bscatv4.log* (cont'd on next page)

1.900E+01	1.344E+01	4.5	3.2	.1
1.950E+01	1.379E+01	4.9	3.4	.1
2.000E+01	1.414E+01	4.7	3.2	.1
2.050E+01	1.450E+01	3.8	2.3	.1
2.100E+01	1.485E+01	2.9	1.5	.1
2.150E+01	1.520E+01	2.0	.7	.1
2.200E+01	1.556E+01	1.1	.2	.1
2.250E+01	1.591E+01	.2	.0	.1
2.300E+01	1.626E+01	1.1	-.2	.2
2.350E+01	1.662E+01	2.5	-.8	.2
2.400E+01	1.697E+01	3.9	-1.9	.2
2.450E+01	1.732E+01	5.3	-3.2	.2
2.500E+01	1.768E+01	6.7	-4.6	.2
2.550E+01	1.803E+01	8.1	-5.7	.2
2.600E+01	1.838E+01	8.8	-6.2	.2
2.650E+01	1.874E+01	9.5	-6.7	.2
2.700E+01	1.909E+01	10.2	-7.2	.2
2.750E+01	1.945E+01	10.9	-7.7	.2
2.800E+01	1.980E+01	11.6	-8.2	.2
2.850E+01	2.015E+01	12.0	-8.5	.2
2.900E+01	2.051E+01	12.0	-8.5	.2
2.950E+01	2.086E+01	12.0	-8.5	.3
3.000E+01	2.121E+01	12.0	-8.5	.3
3.050E+01	2.157E+01	12.0	-8.5	.3
3.100E+01	2.192E+01	12.0	-8.5	.3
3.150E+01	2.227E+01	12.3	-8.6	.3
3.200E+01	2.263E+01	12.6	-8.9	.3
3.250E+01	2.298E+01	13.0	-9.2	.3
3.300E+01	2.333E+01	13.3	-9.4	.4
3.350E+01	2.369E+01	13.7	-9.7	.4
3.400E+01	2.404E+01	14.0	-9.9	.4
3.450E+01	2.440E+01	14.2	-10.0	.4
3.500E+01	2.475E+01	14.4	-10.1	.5
3.550E+01	2.510E+01	14.6	-10.3	.5
3.600E+01	2.546E+01	14.7	-10.4	.5
3.650E+01	2.581E+01	14.9	-10.5	.5
3.700E+01	2.616E+01	15.3	-10.8	.6
3.750E+01	2.652E+01	16.0	-11.3	.6
3.800E+01	2.687E+01	16.7	-11.8	.6
3.850E+01	2.722E+01	17.4	-12.3	.7
3.900E+01	2.758E+01	18.2	-12.8	.7
3.950E+01	2.793E+01	18.9	-13.3	.8
4.000E+01	2.828E+01	19.4	-13.7	.8
4.050E+01	2.864E+01	20.0	-14.1	.9
4.100E+01	2.899E+01	20.5	-14.5	.9
4.150E+01	2.934E+01	21.0	-14.8	.3
4.200E+01	2.970E+01	21.5	-15.2	.2
4.250E+01	3.005E+01	22.1	-15.6	.2
4.300E+01	3.041E+01	22.8	-16.1	.2
4.350E+01	3.076E+01	23.5	-16.6	.2
4.400E+01	3.111E+01	24.2	-17.1	.2
4.450E+01	3.147E+01	24.9	-17.6	.2
4.500E+01	3.182E+01	25.6	-18.1	.2
4.550E+01	3.217E+01	26.2	-18.5	.2
4.600E+01	3.253E+01	26.5	-18.8	.2
4.650E+01	3.288E+01	26.9	-19.0	.2
4.700E+01	3.323E+01	27.2	-19.3	.3
4.750E+01	3.359E+01	27.6	-19.5	.3
4.800E+01	3.394E+01	27.9	-19.7	.3
4.850E+01	3.429E+01	28.3	-20.0	.3
...		...		...
...		...		...
...		...		...

Figure A-9. (cont'd). Sample Log File for a Coherent Doppler Lidar System, *bscatv4.log*

5.000E-01	3.536E-01	5.854E-03	4.344E-05	1.086E+01	2.461E-03	4.307E+04	-3.917E+00	4.798E-05
1.000E+00	7.071E-01	1.089E-02	9.120E-06	9.120E+00	5.372E-03	1.973E+04	-4.296E+00	1.047E-04
1.500E+00	1.061E+00	1.511E-02	3.340E-06	7.515E+00	8.877E-03	1.194E+04	-4.674E+00	1.730E-04
2.000E+00	1.414E+00	1.867E-02	1.594E-06	6.376E+00	1.285E-02	8.249E+03	-5.048E+00	2.505E-04
2.500E+00	1.768E+00	2.169E-02	8.597E-07	5.373E+00	1.750E-02	6.058E+03	-5.417E+00	3.411E-04
3.000E+00	2.121E+00	2.422E-02	4.651E-07	4.186E+00	2.379E-02	4.456E+03	-5.614E+00	4.637E-04
3.500E+00	2.475E+00	2.600E-02	2.093E-07	2.564E+00	3.546E-02	2.989E+03	-5.489E+00	6.913E-04
4.000E+00	2.828E+00	2.697E-02	5.964E-08	9.542E-01	6.643E-02	1.596E+03	-5.364E+00	1.295E-03
4.500E+00	3.182E+00	2.726E-02	7.787E-09	1.577E-01	1.838E-01	5.766E+02	-5.239E+00	3.584E-03
5.000E+00	3.536E+00	2.740E-02	4.924E-09	1.231E-01	2.312E-01	4.585E+02	-5.114E+00	4.506E-03
5.500E+00	3.889E+00	2.751E-02	2.928E-09	8.856E-02	2.998E-01	3.535E+02	-4.989E+00	5.845E-03
6.000E+00	4.243E+00	2.758E-02	1.849E-09	6.656E-02	3.773E-01	2.809E+02	-4.785E+00	7.354E-03
6.500E+00	4.596E+00	2.764E-02	1.191E-09	5.030E-02	4.701E-01	2.255E+02	-4.541E+00	9.165E-03
7.000E+00	4.950E+00	2.768E-02	6.949E-10	3.405E-02	6.154E-01	1.722E+02	-4.293E+00	1.200E-02
7.500E+00	5.303E+00	2.771E-02	5.186E-10	2.917E-02	7.123E-01	1.488E+02	-4.041E+00	1.389E-02
8.000E+00	5.657E+00	2.774E-02	4.090E-10	2.618E-02	8.021E-01	1.321E+02	-3.786E+00	1.564E-02
8.500E+00	6.010E+00	2.777E-02	3.211E-10	2.320E-02	9.053E-01	1.171E+02	-3.525E+00	1.765E-02
9.000E+00	6.364E+00	2.779E-02	2.513E-10	2.035E-02	1.023E+00	1.036E+02	-3.136E+00	1.995E-02
9.500E+00	6.718E+00	2.781E-02	1.941E-10	1.752E-02	1.164E+00	9.104E+01	-2.748E+00	2.270E-02
1.000E+01	7.071E+00	2.782E-02	1.485E-10	1.485E-02	1.331E+00	7.962E+01	-2.364E+00	2.595E-02
1.050E+01	7.425E+00	2.784E-02	1.162E-10	1.281E-02	1.505E+00	7.043E+01	-1.987E+00	2.934E-02
1.100E+01	7.778E+00	2.785E-02	8.904E-11	1.077E-02	1.719E+00	6.165E+01	-1.617E+00	3.251E-02
1.150E+01	8.132E+00	2.786E-02	6.901E-11	9.126E-03	1.953E+00	5.428E+01	-1.289E+00	3.807E-02
1.200E+01	8.485E+00	2.787E-02	5.649E-11	8.134E-03	2.158E+00	4.911E+01	-1.003E+00	4.208E-02
1.250E+01	8.839E+00	2.787E-02	4.571E-11	7.142E-03	2.400E+00	4.417E+01	-7.188E-01	4.678E-02
1.300E+01	9.192E+00	2.788E-02	3.548E-11	5.996E-03	2.723E+00	3.892E+01	-4.536E-01	5.309E-02
1.350E+01	9.546E+00	2.789E-02	2.591E-11	4.722E-03	3.187E+00	3.326E+01	-2.237E-01	6.213E-02
1.400E+01	9.899E+00	2.790E-02	1.759E-11	3.448E-03	3.868E+00	2.740E+01	-4.167E-02	7.540E-02
1.450E+01	1.025E+01	2.792E-02	1.432E-11	3.012E-03	4.286E+00	2.473E+01	1.749E-01	8.355E-02
1.500E+01	1.061E+01	2.794E-02	1.293E-11	2.908E-03	4.512E+00	2.349E+01	5.210E-01	8.796E-02
1.550E+01	1.096E+01	2.795E-02	1.168E-11	2.806E-03	4.747E+00	2.233E+01	9.489E-01	9.254E-02
1.600E+01	1.131E+01	2.796E-02	1.065E-11	2.727E-03	4.971E+00	2.132E+01	1.404E+00	9.690E-02
1.650E+01	1.167E+01	2.798E-02	9.739E-12	2.651E-03	5.198E+00	2.039E+01	1.822E+00	1.013E-01
1.700E+01	1.202E+01	2.799E-02	8.919E-12	2.578E-03	5.432E+00	1.951E+01	2.137E+00	1.059E-01
1.750E+01	1.237E+01	2.801E-02	8.212E-12	2.515E-03	5.661E+00	1.872E+01	2.398E+00	1.104E-01
1.800E+01	1.273E+01	2.802E-02	7.570E-12	2.453E-03	5.896E+00	1.798E+01	2.655E+00	1.149E-01
1.850E+01	1.308E+01	2.803E-02	7.038E-12	2.409E-03	6.115E+00	1.733E+01	2.908E+00	1.192E-01
1.900E+01	1.344E+01	2.804E-02	6.722E-12	2.427E-03	6.257E+00	1.694E+01	3.155E+00	1.220E-01
1.950E+01	1.379E+01	2.806E-02	6.428E-12	2.444E-03	6.398E+00	1.657E+01	3.396E+00	1.247E-01
2.000E+01	1.414E+01	2.807E-02	6.125E-12	2.450E-03	6.555E+00	1.617E+01	3.205E+00	1.278E-01
2.050E+01	1.450E+01	2.808E-02	5.801E-12	2.438E-03	6.735E+00	1.574E+01	2.330E+00	1.313E-01
2.100E+01	1.485E+01	2.810E-02	5.501E-12	2.426E-03	6.917E+00	1.532E+01	1.474E+00	1.348E-01
2.150E+01	1.520E+01	2.811E-02	5.222E-12	2.414E-03	7.099E+00	1.493E+01	7.483E-01	1.384E-01
2.200E+01	1.556E+01	2.812E-02	4.964E-12	2.402E-03	7.281E+00	1.456E+01	2.400E-01	1.419E-01
2.250E+01	1.591E+01	2.813E-02	4.722E-12	2.391E-03	7.465E+00	1.420E+01	1.004E-02	1.455E-01
2.300E+01	1.626E+01	2.815E-02	4.433E-12	2.345E-03	7.705E+00	1.376E+01	-1.531E-01	1.502E-01
2.350E+01	1.662E+01	2.816E-02	4.141E-12	2.287E-03	7.971E+00	1.330E+01	-8.130E-01	1.554E-01
2.400E+01	1.697E+01	2.817E-02	3.870E-12	2.229E-03	8.246E+00	1.285E+01	-1.896E+00	1.607E-01
2.450E+01	1.732E+01	2.819E-02	3.622E-12	2.174E-03	8.524E+00	1.243E+01	-3.230E+00	1.662E-01
2.500E+01	1.768E+01	2.820E-02	3.390E-12	2.119E-03	8.811E+00	1.203E+01	-4.594E+00	1.718E-01
2.550E+01	1.803E+01	2.821E-02	3.168E-12	2.060E-03	9.115E+00	1.163E+01	-5.701E+00	1.777E-01
2.600E+01	1.838E+01	2.822E-02	2.907E-12	1.965E-03	9.514E+00	1.114E+01	-6.200E+00	1.855E-01
2.650E+01	1.874E+01	2.823E-02	2.664E-12	1.871E-03	9.938E+00	1.066E+01	-6.698E+00	1.937E-01
2.700E+01	1.909E+01	2.824E-02	2.439E-12	1.778E-03	1.039E+01	1.020E+01	-7.193E+00	2.025E-01
2.750E+01	1.945E+01	2.825E-02	2.231E-12	1.688E-03	1.086E+01	9.760E+00	-7.687E+00	2.117E-01
2.800E+01	1.980E+01	2.826E-02	2.037E-12	1.597E-03	1.137E+01	9.326E+00	-8.178E+00	2.216E-01
2.850E+01	2.015E+01	2.827E-02	1.855E-12	1.506E-03	1.191E+01	8.898E+00	-8.464E+00	2.322E-01
2.900E+01	2.051E+01	2.828E-02	1.682E-12	1.415E-03	1.251E+01	8.474E+00	-8.478E+00	2.438E-01
2.950E+01	2.086E+01	2.828E-02	1.520E-12	1.323E-03	1.316E+01	8.056E+00	-8.485E+00	2.565E-01
3.000E+01	2.121E+01	2.829E-02	1.381E-12	1.243E-03	1.380E+01	7.678E+00	-8.484E+00	2.691E-01
3.050E+01	2.157E+01	2.830E-02	1.258E-12	1.170E-03	1.446E+01	7.329E+00	-8.476E+00	2.819E-01
3.100E+01	2.192E+01	2.830E-02	1.142E-12	1.098E-03	1.518E+01	6.984E+00	-8.460E+00	2.959E-01
3.150E+01	2.227E+01	2.831E-02	1.036E-12	1.028E-03	1.594E+01	6.650E+00	-8.650E+00	3.107E-01
3.200E+01	2.263E+01	2.831E-02	9.363E-13	9.588E-04	1.677E+01	6.322E+00	-8.900E+00	3.268E-01
3.250E+01	2.298E+01	2.832E-02	8.422E-13	8.896E-04	1.768E+01	5.996E+00	-9.151E+00	3.446E-01
3.300E+01	2.333E+01	2.832E-02	7.559E-13	8.232E-04	1.866E+01	5.681E+00	-9.402E+00	3.637E-01
3.350E+01	2.369E+01	2.833E-02	6.745E-13	7.570E-04	1.975E+01	5.366E+00	-9.653E+00	3.850E-01
3.400E+01	2.404E+01	2.833E-02	5.994E-13	6.929E-04	2.095E+01	5.058E+00	-9.889E+00	4.085E-01
3.450E+01	2.440E+01	2.834E-02	5.388E-13	6.414E-04	2.210E+01	4.796E+00	-1.001E+01	4.308E-01
3.500E+01	2.475E+01	2.834E-02	4.818E-13	5.902E-04	2.337E+01	4.535E+00	-1.014E+01	4.556E-01

Figure A-10. Sample Output Data File for a Coherent Doppler Lidar System, *bscatv4.dat* (Shortened for brevity)

Appendix B
RUNNING BACKSCAT VERSION 4.0 IN BATCH MODE

The user can perform a simulation from outside BACKSCAT's menu interface in batch mode. To do this, type *backscat* at the MS-DOS command prompt and at the program prompt, enter an existing configuration file name. BACKSCAT automatically appends the *.cfg* extension to the file name. In the configuration file, the file names are specified without extensions because BACKSCAT automatically appends the appropriate extension. For simulations that include a user-defined aerosol layer, the user must execute the user-defined aerosol program before typing *backscat*. (Note that a user-defined aerosol layer is only permitted when aerosol backscatter and coherent Doppler systems are simulated with the built-in aerosol models.) To do this, use a standard text editor to create the file named *usraer.tmp* which is very similar to the *.lay* file. The format of *usraer.tmp* is given in Table B-1. Copy *usraer.tmp* into the executable directory and type *usraer* at the MS-DOS command prompt.

It is important to note that the user must supply a "complete" configuration file in which the names of the I/O files and the accompanying flags fully describe the simulation. For BACKSCAT to execute in batch mode, the configuration file must include the names of existing Lidar System, Detector, Viewing Conditions, and Atmospheric Conditions (if applicable) files. Also, the propagation profile file must exist if it is an input file for the simulation. Otherwise, the built-in models must be used and the propagation profile file will be created by BACKSCAT during the simulation. Finally, it is worth noting that all input files can be created within the menu interface or using a standard text editor. For reference, the contents and formats of all input files are given in Appendix A.

To plot simulation results from outside the menu interface system, type *quikview* at the MS-DOS command prompt. The program issues prompts for the data file to plot, the type of plot, and the range limits for the plot. The program will then plot the data file and exit when the user hits ESC.

Table B-1. Description and Format of the Input File, *usraer.tmp,* for the User-Defined Aerosol Program. Parameters are entered in free format form. Detailed explanations of the log normal and modified gamma distributions can be found in the Handbook of Geophysics[2]

RECORD	DATA TYPE	DESCRIPTION
1	Integer	Size distribution flag
		1 = Log normal
		2 = Modified gamma
		3 = User-defined radii and number densities
	Integer	Aerosol type flag
		0 = User defined
		1 = Water
		2 = Ice
		3 = Dust
		4 = Maritime
		5 = Background stratospheric
		6 = Smoke
		If log normal distribution used
2a	Real	Total number density of mode 1 (cm^{-3})
	Real	Mode radius of mode 1 (μm)
	Real	Log of standard deviation of mode 1
2b	Real	Total number density of mode 2 (cm^{-3})
	Real	Mode radius of mode 2 (μm)
	Real	Log of standard deviation of mode 2
		If modified gamma distribution used
2	Real	A Parameter
	Integer	α Parameter
	Real	B Parameter
	Integer	γ Parameter
		If user defined size distribution used
2	Character	Name of size distribution data file
3	Real	Lidar wavelength
		If user defined aerosol type
4	Real	Real part of index of refraction
	Real	Imaginary part of index of refraction
		If built-in aerosol type used
4	Character	Full directory path to *indexof.ref* file
5	Integer	Number of altitudes in density profile (2-5)
6	Real	Altitude #1 (km)
	Real	Number density at altitude #1 (cm^{-3})
		Repeat Record 6 for each altitude