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EFFECT OF BACKSCATTER-TO-EXTINCTION RATIO ON LIDAR INVERSIONS

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One way of deriving the atmospheric extinction coefficient from lidar measurements is to start from the single scattering lidar equation, which we will write in the form:

$$(1) \qquad P(r)=P_0 A \frac{c\lambda}{2} \frac{\beta(r)}{r^2} \exp\left[-\int_0^r \sigma(r^1)dr^1\right]$$

This equation cannot be solved directly, since both $\beta(r)$ and $\sigma(r)$ are unknown. In the approach under consideration here, one attempts to solve the equation by postulating a relation between β and σ of the form:

$$(2) \qquad \beta(r)=c\left[\sigma(r)\right]^k$$

Such a relation cannot hold in general, but may be approximately valid for a wide range of realistic atmospheric conditions. Real atmospheres will deviate from this relation, of course, so it is important to know how large are the errors which we should expect due to such deviations.

In the present study this question has been addressed by conducting simulations of lidar experiments and extinction coefficient calculations and examining the resulting errors. In order to make the simulations realistic, the volume backscatter coefficients and extinction coefficients used in the simulations were based on measured particle distributions, in this case on the particle size distributions measured in Meppen, Germany in the fall of 1980 by J. D. Lindberg and others of the Atmospheric Sciences Laboratory (Lindberg, 1982).

In that experiment particle size distributions were measured with a balloon-borne particle spectrometer (a PMS FSSP 100) during balloon descents from about 600 meters above ground to the surface. Each particle spectrum represents a layer of at most a few meters thickness so an altitude resolved profile of particle size spectra is measured.

T. L. Barber (Barber, 1985) used a Mie code to compute linear extinction coefficient and volume backscatter coefficient profiles from the particle size spectra for each balloon sounding. In these computations it was assumed that the individual droplets consisted purely of water.

Simulated lidar returns were constructed by inserting the computed values of extinction and backscatter coefficients into a discrete version of equation

(1). In order to mimic the range gating characteristics of an actual lidar used by the author (Measure and Rubio, 1982) at the Meppen experiment, the interval in the discrete version of the lidar equation was chosen to be three meters, and the backscatter and extinction coefficient profiles were interpolated at the chosen points. This resulted in a set of values P(r) for r = 3n meters, n = 1, 2, . . . which constituted the simulated lidar return. (For simplicity, the factor $P_0 c\lambda A/2$ was set to 1).

This simulated lidar return was then used to compute the extinction coefficient by Klett's algorithm (Klett, 1981):

$$(3) \qquad \sigma(r) = \frac{\exp[(S(r) - S(r_m))/k]}{\left[\sigma_m(r_m)\right]^{-1} + \frac{2}{k}\int_r^{r_m} \exp[(S(r) - S(r_m))/k]}$$

where $S(r) = \ln(r^2 P(r))$. This algorithm requires that the boundary value $\sigma(r_m)$ be specified. In the simulation, the value used was that computed from the particle spectra, so that the simulations were "perfect" at the point r_m and the only error should be that due to the deviation from the backscatter to extinction relation (2).

Figure 1 indicates the data flow in the simulation. Representative results of the simulation are indicated in figures 2 - 4. Note that using a k value other than 1 may result in a significantly smaller error. Note also that no other potential sources of error are considered in the simulation. Absorption, multiple scattering, and instrumental errors all may contribute to error in a real lidar measurement but are not represented here.

References

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Lindberg, J. D., ed., Early Wintertime European Fog and Haze on Project Meppen 80, ASL Technical Report TR-0108, U.S. Army Atmospheric Sciences Laboratory, WSMR, NM (1982).

Measure, Edward M., and Roberto Rubio, 1982, "Quantitative Lidar Measurement of Extinction Coefficient," in Conference Abstracts of the Eleventh International Laser Radar Conference, NASA Conference Publication 2228, (June 21-25, 1982).

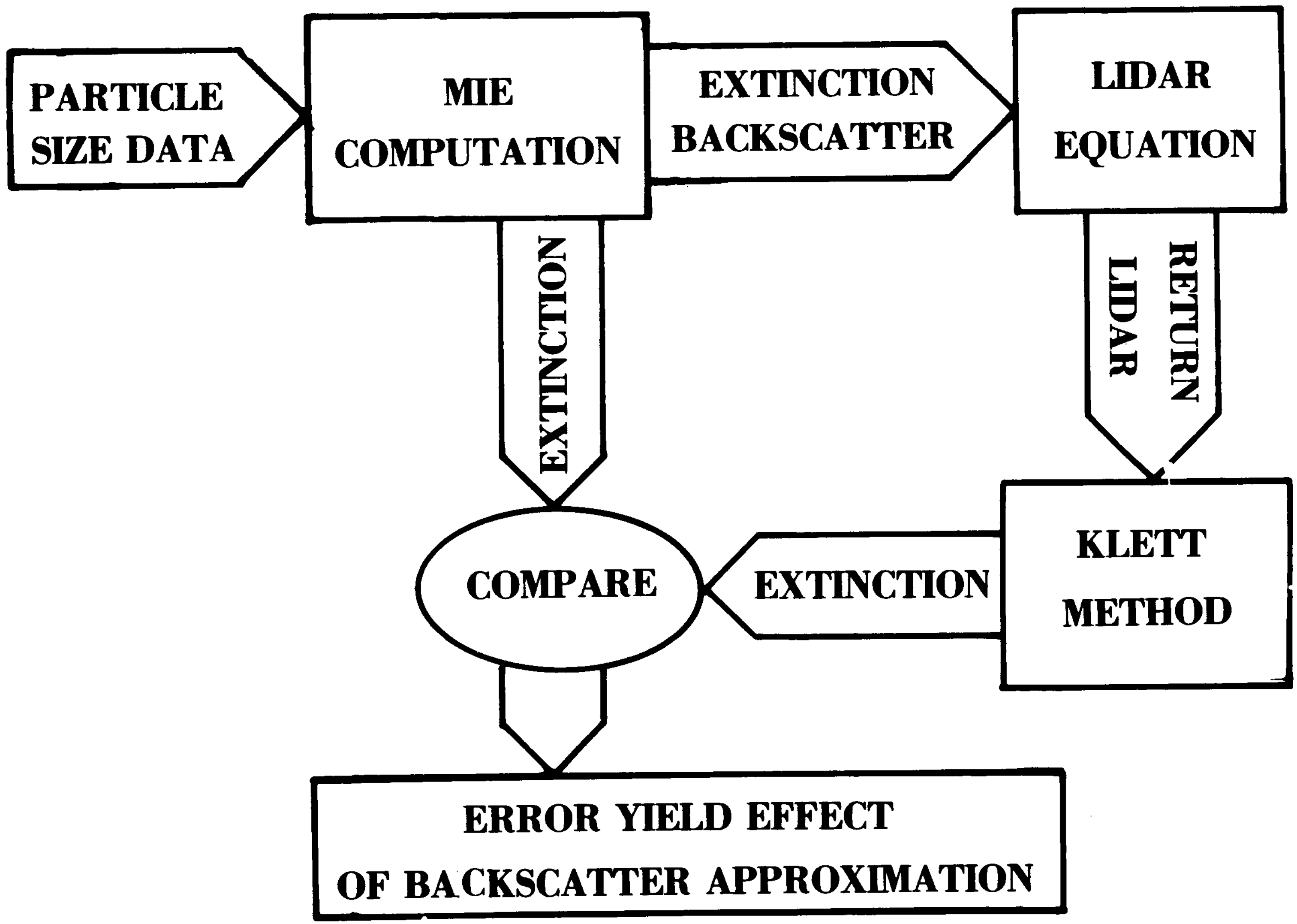
PARTICLE
SIZE DATA
MIE
COMPUTATION
EXTINCTION
BACKSCATTER
LIDAR
EQUATION
RETURN
LIDAR
KLETT
METHOD
EXTINCTION
EXTINCTION
COMPARE
ERROR YIELD EFFECT
OF BACKSCATTER APPROXIMATION

FIG. 1 METHOD

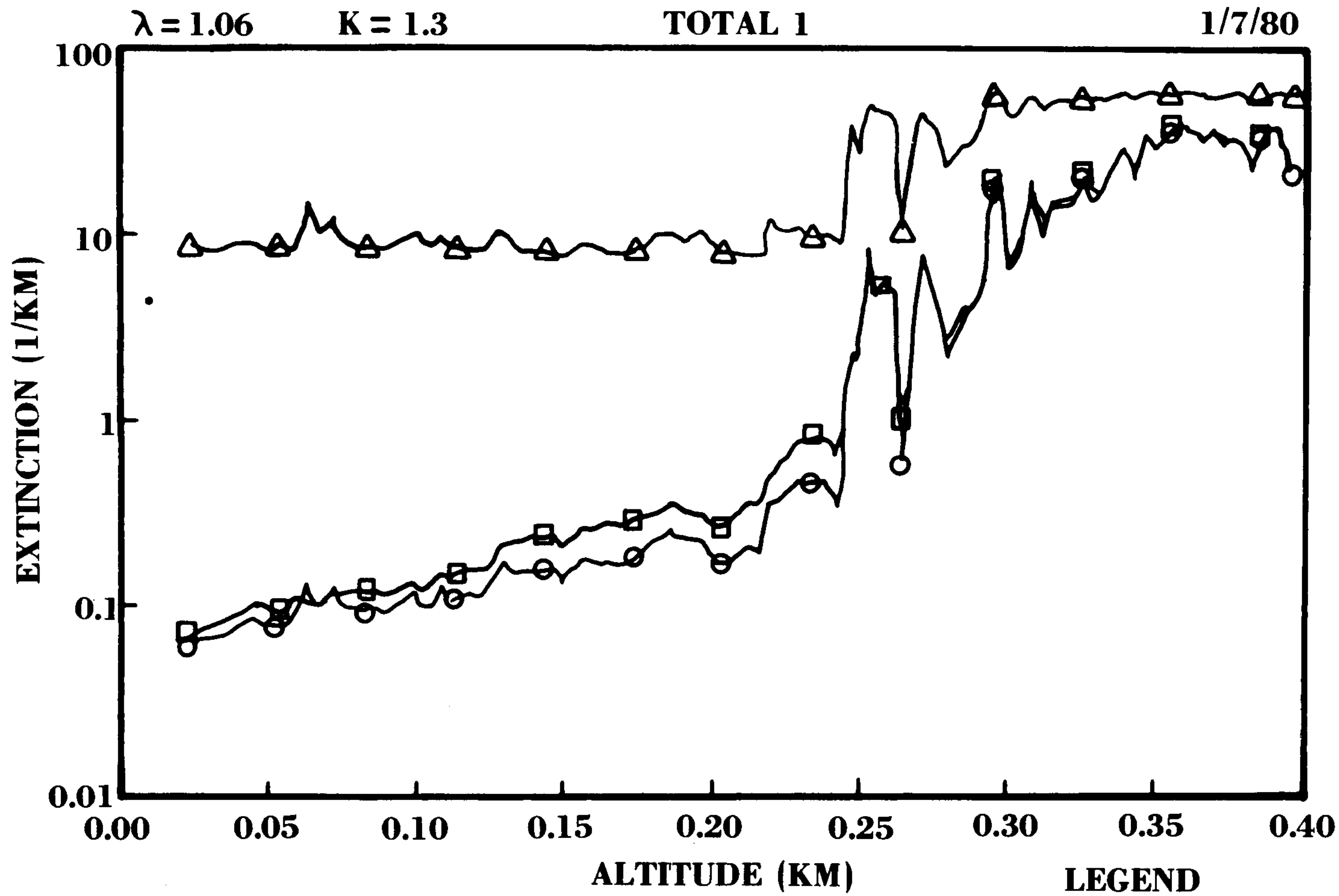

FIG. 2 DATA SET TOTAL 1 PROCESSED
WITH K = 1.3

EFFECT OF β/σ RATIO

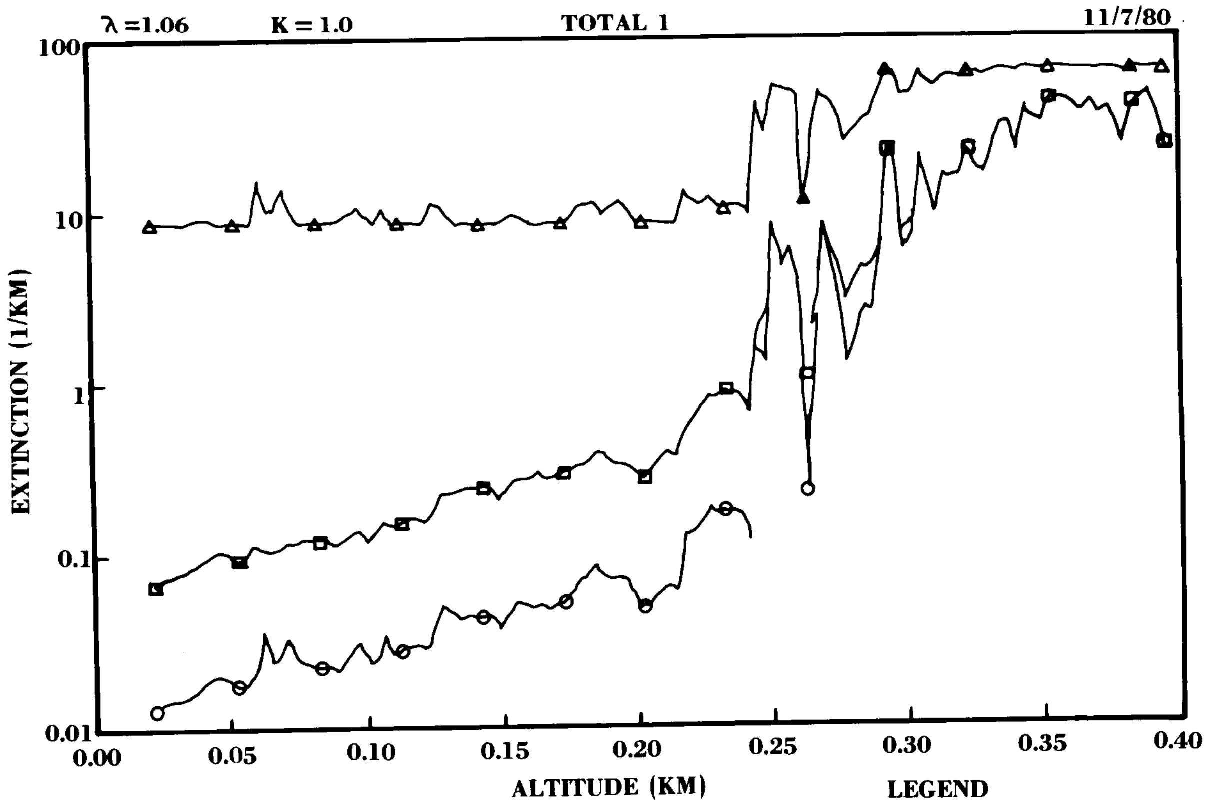

FIG. 3 DATA SET TATAL 1 PROCESSED WITH K = 1.0

LEGEND

□ - LIDAR SIMULATION

o - PARTICLE SPECTROMETER

Δ - 1000. x β/σ

EFFECT OF β/σ RATIO

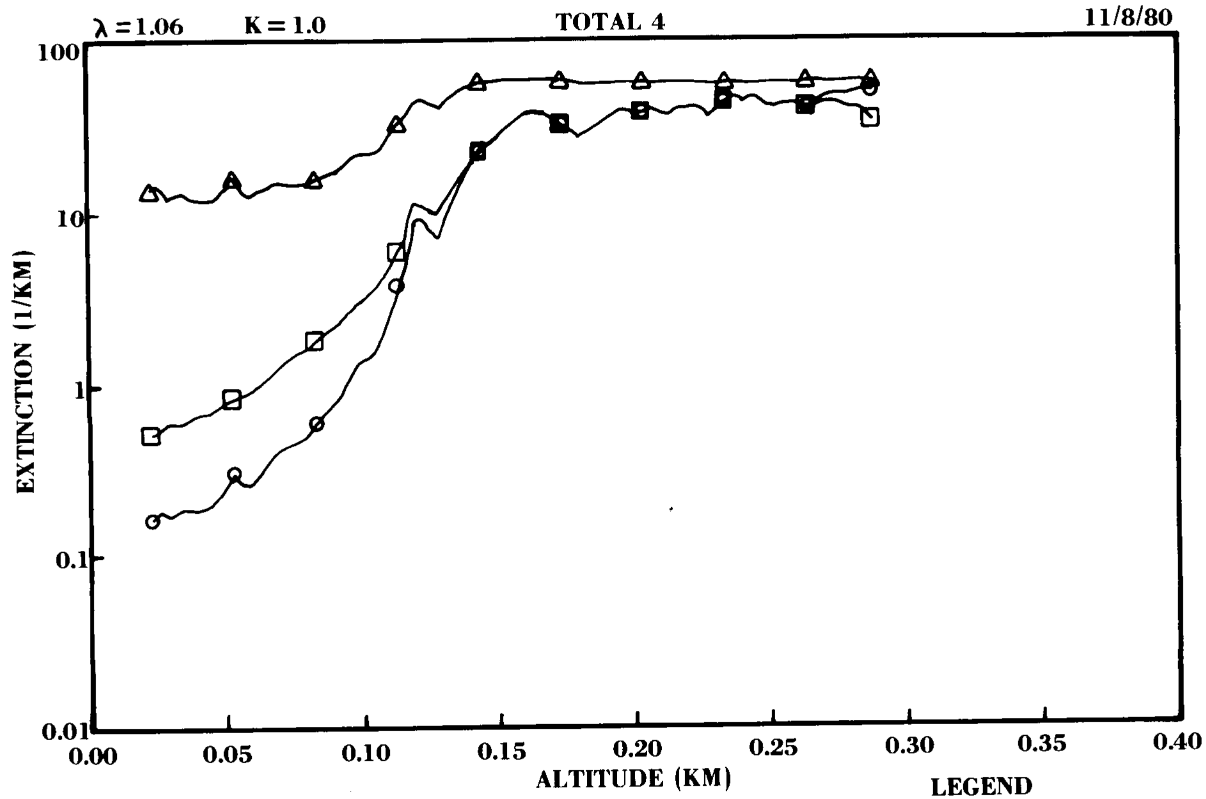

FIG. 4 DATA SET TOTAL 4 PROCESSED WITH K = 1.0

LEGEND

□ - PARTICLE SPECTROMETER

o - LIDAR SIMULATION

Δ - 1000. x β/σ