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# SIMULTANEOUS AEROSOL SIZE DISTRIBUTIONS AND TURBIDITY MEASUREMENTS OVER A METROPOLITAN AREA

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SIMULTANEOUS AEROSOL SIZE DISTRIBUTIONS AND TURBIDITY MEASUREMENTS OVER A METROPOLITAN AREA*

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ABSTRACT

*The particle size distributions measured in the St. Louis city plume is shown to be bimodel. The total particle volume decreases dramatically above the inversion. The peak in the volume distribution is shifted toward larger particles at higher altitudes. Aerosol extinction coefficients derived from sunphotometer optical depth measurements at 5 wavelengths are compared to those calculated from the measured size distributions using Mie theory with two different particle refractive indices. For an entirely real refractive index of 1.5, the measured values are consistently larger by factor of 2 to 4 than the calculated values. Including a large imaginary part to the refractive index, n=1.5-0.31, improves the agreement, suggesting that the aersol in the city plume may have significant absorptive characteristics.*

A DC-3 instrumented aircraft was used to measure simultaneously aerosol particle size distributions and turbidities at different altitudes over metropolitan St. Louis, Missouri. An Electrical Aerosol Analyzer (Liu et al, 1974) and a Royco Optical Sensor model 220 were used to determine the particle size distribution in the range of 0.01 μm to 5.0 μm. The sensor was interfaced with a 15 channel pluse height analyzer and a printer. A multiwavelength sunphotometer was employed to measure solar intensities in four narrow wavelength bands (∿10) centered at 448.2, 500.7, 557.8 and 618.9 nm respectively, and in two broad wavelength bands (∿60 nm) centered at 500 and 598.4 nm respectively. Using calibrated instrumented response of the photometer, turbidities were determined for each of the wavelength bands.

The flight was made on August 8, 1975, under clear and hazy sky. Wind was from the southeast at less than 10 knots. The measurements were made at about 12 miles northwest of Civic Memorial Airport in Alton, Illinois. The vertical temperature profile shows an inversion between 4000 to 5000 ft MSL (Fig. 1). The particle size distributions measured during this flight are shown in Figure 2. Clearly the distributions are bimodel. The total volume decreases dramatically above the temperature inversion. The peak in the volume distribution is shifted to larger particle sizes with increasing altitude. The figure also shows that the volume concentration just below the inversion is higher than at 2000 ft MSL which indicated that the material is accumulating beneath the inversion. This is also reflected in an $SO_2$ measurement which shows a similar behavior. The material above the inversion probably represents a well aged pollutant trapped above the inversion. The $SO_2$ level was 7 ppb which is an order of magnitude lower than below the inversion.

Aerosol extinction coefficients derived from the sunphotometer turbidity measurements are given in Table 1, Column A for each wavelength band. The coefficients were determined according to Eq. 1:

$$b = \Delta\tau/\Delta h \quad , \tag{1}$$

where b is the average extinction coefficient for the layer between h and h+Δh, Δτ is the difference between the turbidities (aerosol optical depths) measured at h and h+Δh, and h is the altitude. Since τ is unitless, b has units of $(\text{length})^{-1}$.

For comparison, aerosol extinction coefficients were calculated from the measured size distributions at each altitude with Mie theory with two different particle retractive indices according to Eq. 2:

$$b = \sum_i Q(\alpha_i, h)\Delta S(D_{pi}) \cdot \frac{10^{-6}}{4} \quad , \tag{2}$$

where $Q^{(\alpha_i, n)}$ is the unitless Mie extinction efficiency for size parameter $\alpha_i = \pi D_{pi}/\lambda$ and refractive index n and $\Delta S(D_{pi})$ is the measured particle surface area ($\mu m^2/cm^3$) in the geometric mean particle diameter size class $D_{pi}$. The summation is over all size intervals from about 0.04 μm to 5 μm. Calculated extinction coefficients for n = 1.5 are given in Table 1, Column B, while coefficients for $n = 1.5 - 0.3_i$ are listed in Table 1, Column C.

For n = 1.5, the measured values are consistently larger, by factors ranging from 3 to 4, than the calculated values. Including a alrge imaginary term to the refractive index, $n = 1.5 - 0.3_i$, improves the agreement; significant discrepancies still exist however. The comparison suggests that the aerosol in the St. Louis city plume may have significant absorptive characteristics, a result found by others (Waggoner and Choalson, 1975). Spatial inhomogenaities in the city plume may be responsible for some of the observed discrepancies between neasured and calculated extinction coefficients.

The inversion layer also has a dramatic effect on the transmission of solar radiation. Table 2 shows the solar radiation transmission losses due to aerosol through a turbid atmosphere as one decends from above the inversion (6000 ft MSL reference level) down to well below the inversion. As expected the predominance submicron particles has the greatest effect for the shorter wavelengths.

REFERENCES

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2 A. P. Waggoner and R. J. Charlson, "Measurements of Aerosol Optical Parameters", paper presented at Symposium on Fine Particles, University of Minnesota, May 28-30, 1975.

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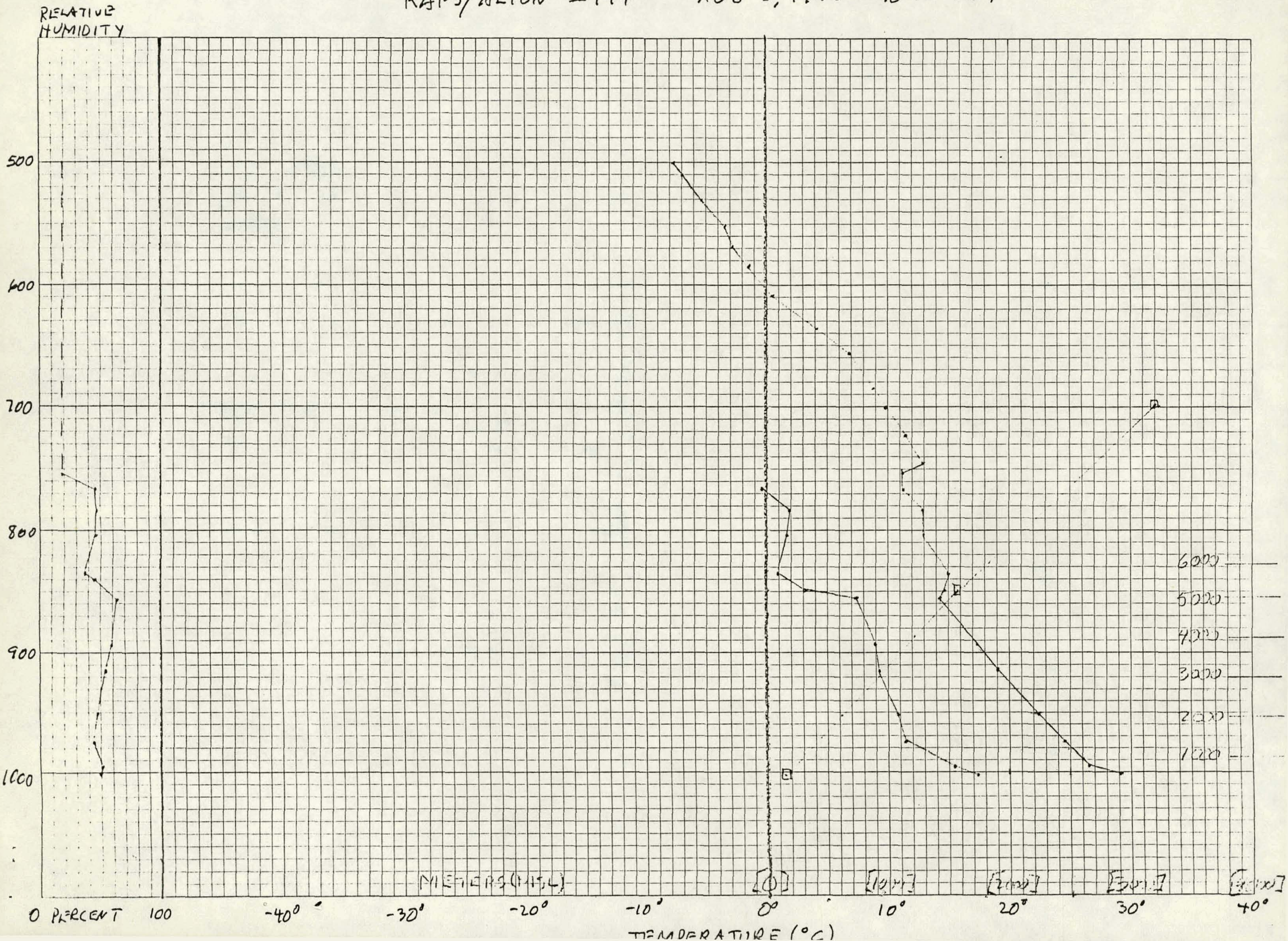

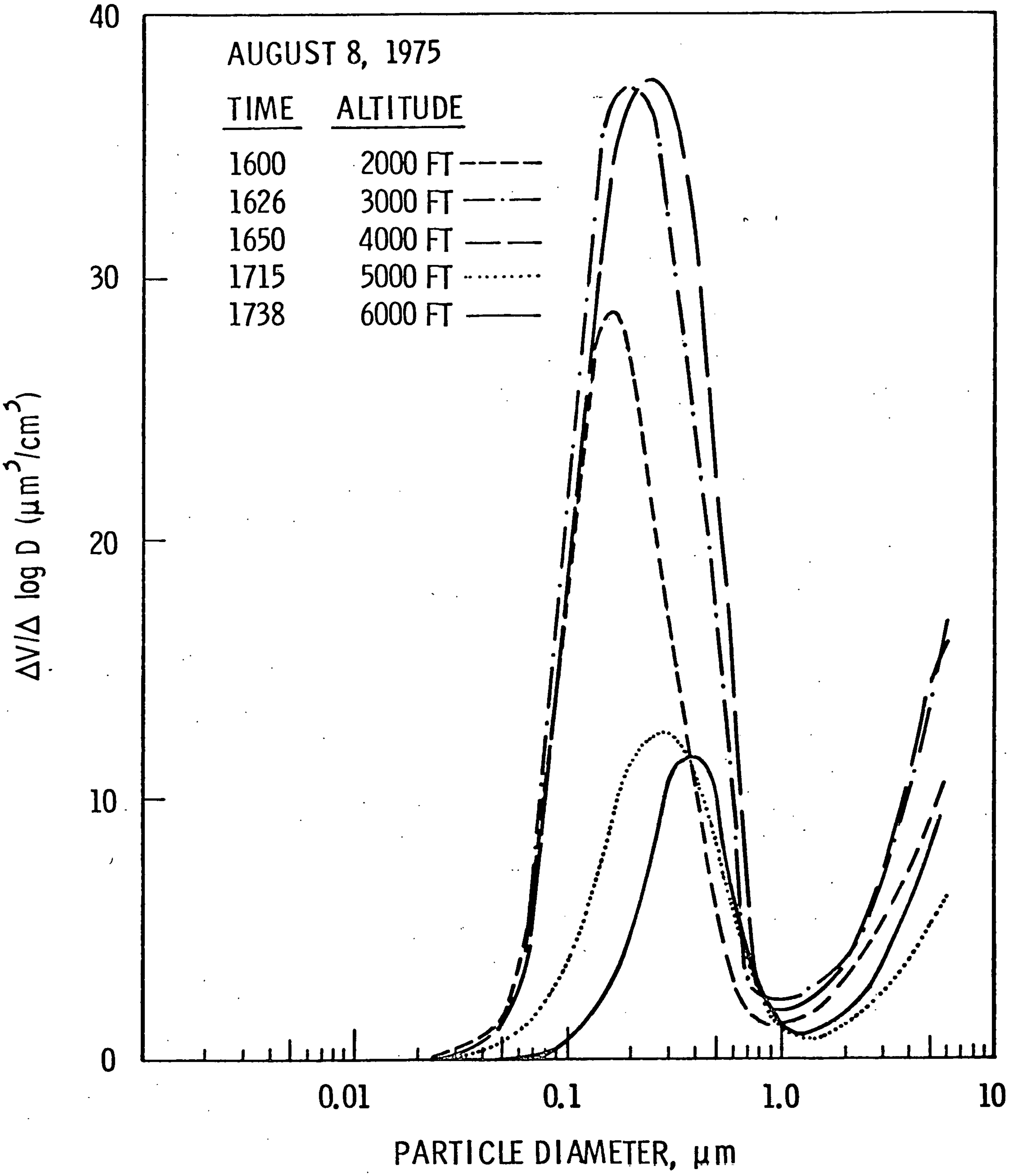
AUGUST 8, 1975
TIME ALTITUDE
1600 2000 FT
1626 3000 FT
1650 4000 FT
1715 5000 FT
1738 6000 FT
40
30
20
10
0
ΔV/Δ log D (μm³/cm³)
0.01
0.1
1.0
10
PARTICLE DIAMETER, μm

Table 1. COMPARISON OF AEROSOL EXTINCTION COEFFICIENTS DERIVED FROM SUNPHOTOMETER OPTICAL DEPTH MEASUREMENTS AT 5 WAVELENGTHS AND EXTINCTION COEFFICIENTS CALCULATED FROM MEASURED SIZE DISTRIBUTIONS USING TWO DIFFERENT PARTICLE REFRACTIVE INDICES.

| Altitude (ft) | Extinction Coefficient, b, $10^{-4}$ $m^{-1}$ | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 448.2 nm | | | 500.0 nm | | | 557.8 nm | | | 598.4 nm | | | 618.9 nm | | |
| | A | B | C | A | B | C | A | B | C | A | B | C | A | B | C |
| 2500 | 2.0±.7 | 1.20 | 2.30 | 0.9±.5 | 0.96 | 2.03 | 0.4±.4 | 0.72 | 1.85 | 0.7±.7 | 0.65 | 1.72 | 2.3±4.4 | 0.61 | 1.64 |
| 3500 | 5.1±.6 | 1.62 | 2.83 | 6.0±.5 | 1.30 | 2.52 | 4.6±.5 | 0.98 | 2.30 | 3.1±.6 | 0.90 | 2.15 | 3.1±1.0 | 0.85 | 2.05 |
| 4500 | 3.3±.5 | 1.22 | 1.94 | 1.1±.4 | 1.00 | 1.74 | 1.4±.4 | 0.75 | 1.60 | 2.2±.6 | 0.69 | 1.50 | 2.1±1.0 | 0.65 | 1.43 |
| 5500 | 1.9±.5 | 0.59 | 0.74 | 1.3±.3 | 0.50 | 0.68 | 1.3±.4 | 0.38 | 0.63 | 0.1±.4 | 0.36 | 0.60 | .7±1.0 | 0.34 | 0.58 |

Table 2. SOLAR RADIATION TRANSMISSION LOSSES DUE TO AEROSOL THROUGH A TURBID ATMOSPHERE REFERENCED TO 6000 FT AND DECENDING TO 2000 FT

| Altitude (ft) | Transmission Loss Due to Aerosol | | | | |
|---|---|---|---|---|---|
| | 448.2 nm | 500.0 nm | 557.8 nm | 598.4 nm | 618.9 nm |
| 5000 | 6% | 4% | 4% | 0.3% | 2% |
| 4000 | 15% | 7% | 8% | 7% | 8% |
| 3000 | 27% | 23% | 20% | 15% | 16% |
| 2000 | 31% | 25% | 21% | 17% | 22% |