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MEASUREMENTS OF THE EFFECT OF HORIZONTAL VARIABILITY OF ATMOSPHERIC BACKSCATTER ON DIAL MEASUREMENTS

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The horizontal variability of atmospheric backscatter may have a substantial effect on how Differential Absorption Lidar (DIAL) data must be taken and analyzed. To minimize errors, lidar pulse pairs must be taken with time separations which are short compared to the time scales associated with variations in atmospheric backscatter. These time scales have typically been considered to be on the order of hundreds of microseconds. We have found low levels of variability in the atmospheric backscatter for time scales on the order of ten seconds which correspond to spatial distances of 1 km for data taken from an aircraft in clear nighttime conditions.

To assess the atmospheric variability for time scales which are long compared to the lidar pulse repetition rate, one can compute the variance of the lidar return signal in a given channel. The variance in a given signal, $\sigma^2(S_j)$, has contributions from both instrumental, $\sigma^2{}_I$, and atmospheric, $\sigma^2{}_A$, effects:

$$\sigma^2(S_j) = \sigma^2{}_I(S_j) + \sigma^2{}_A(S_j) \tag{1}$$

where j represents either the on- or off-line signal. In general, the instrumental and atmospheric terms cannot be easily separated. However, if we take data in two channels with sufficiently short temporal separation, then the atmospheric effects are essentially the same in the two channels. Thus, a ratio of the two channels yields a quantity which is essentially free of atmospheric backscatter variability. The variance in this ratio is given as:

$$\sigma^2(S_1/S_2) = \sigma^2{}_I(S_1) + \sigma_I^2\,(S_2) \tag{2}$$

It follows from equations (1) and (2) that the atmospheric variance is given as:

$$\sigma^2{}_A = \frac{\sigma^2(S_1) + \sigma^2(S_2) - \sigma^2(S_1/S_2)}{2} \tag{3}$$

We calculated the variances (as the square of the standard deviation in percent) of the on-line, off-line, and ratio of the on- to off-line signals at given altitudes obtained with our dual solid-state Alexandrite laser system. We have made these evaluations for both down-looking aircraft and up-looking ground-based lidar data. Data were taken with 200 μsec separation between on- and off-line laser pulses, 30 m altitude resolution, 5 Hz repetition rate, and the signals are normalized for outgoing laser energy. Figure 1 shows the horizontal atmospheric variability versus altitude for a 50 shot (10 sec) average of data taken from aircraft. This averaging time corresponds to a 1 km horizontal spatial scale. It is seen that very low levels of atmospheric variability occur for these clear, nighttime conditions. This shows that if the atmospheric transmission at a given altitude is calculated using on- and off-line signals that are separated by as much as 1 km in space or 10 sec in time, then the errors in the transmission are between 1 and 2 percent.

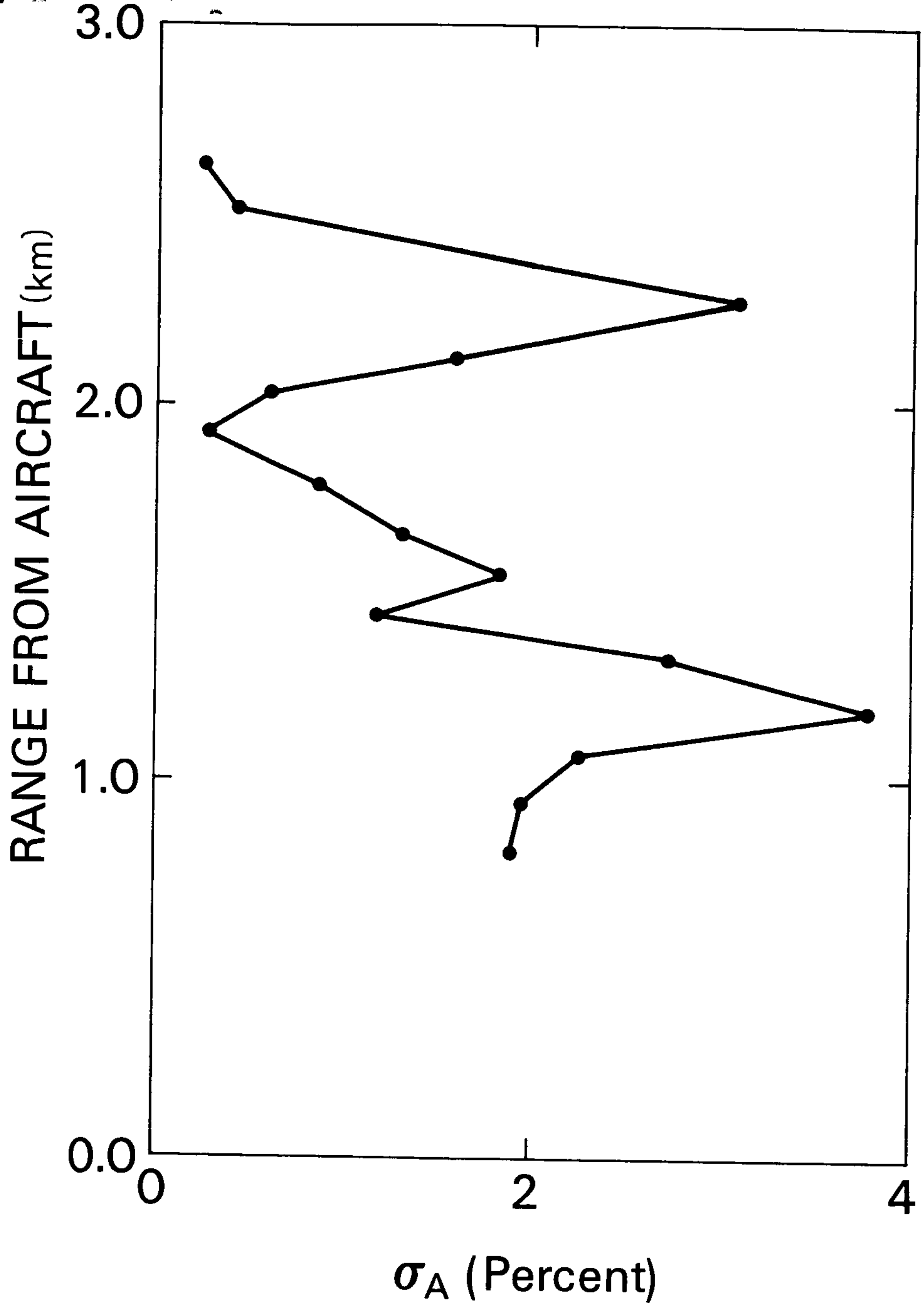

Figure 1 – Horizontal atmospheric variability for various altitudes for a 50 shot (10 sec.) average of data taken from aircraft (1 km spatial average) at 2790m altitude.