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EXTINCTION AND VISIBILITY MEASUREMENTS IN THE LOWER ATMOSPHERE WITH UV-YAG-LIDAR

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With the intention to investigate methods for slant path visibility measurements and to develop information for modelling of extinction profiles in the atmospheric boundary layer, we performed measurements with a lidar based on a YAG-laser. The third harmonic at 355 nm in UV is used and thus eye safety problems are avoided. At this wavelength the lens of the human eye is not transparent and the safety distance for our laser is 50 meters as compared to several km for a corresponding green laser.

The lidar is a coaxial system with a turntable mirror system for beam steering. Laser output data are: pulse rep. rate 10 Hz, pulse energy at 355 nm: 125 mJ, pulse length 15 ns and beam divergence 0,6 mrad. The receiver is a Cassegrainian telescope with 30 cm aperture diam. and 1 mrad field of view. A double grating monochromator is used for spectral background suppression with a bandwidth of 0.5 nm. The system is also used for Raman sounding. The detector is a photomultiplier with Rubidium cathode. By a waveform recorder the signal is digitized to 8 bit words at 100 MHz sampling rate. In an averaging unit controlled by a microprocessor a number of lidar returns are added and stored as 20 bit words for analysis and presentation.

A laser nephelometer is part of the lidar system. A part of the laser pulse energy is used in the nephelometer to measure the extinction coefficient at the lidar site. Green light from the second harmonic can also be used in the nephelometer. Thus the extinction coefficient at both 355 nm and 532 nm can be measured and their ratio determined. Provided that the wavelength dependence of the aerosol extinction is range independent, the measured extinction profile at 355 nm can be converted to a corresponding profile at 532 nm, which is more relevant for visibility determination.

In order to calculate the extinction profile the lidar equation is inverted by a method, which is based on Klett's (1) method. A reference return obtained in clear homogeneous conditions is used to correct for the lidar system function, which accounts for geometric optic functions. The backscattering coefficient β and the extinction coefficient α are the sum of parts due to aerosol (A) and Rayleigh (R) scattering

$$\beta(r) = \beta_A(r) + \beta_R(r)$$

$$\alpha(r) = \alpha_A(r) + \alpha_R(r) \qquad (1)$$

where r is range. We assume that the ratio β/α for aerosols is known either as a constant or a function of range. According to Fernald (2) we can then define an extinction coefficient α_L (which we may call the equivalent lidar extinction coefficient).

$$\alpha_L = \alpha_A + b\alpha_R \tag{2}$$

where b is $\beta_R\alpha_A/\beta_A\alpha_R$

Thus the lidar equation can be written in a form which can be inverted. A recorded lidar return P(r) is divided with the reference return $P_O(r)$ and multiplied with a known attenuation function (due to Rayleigh scattering and attenuation of the reference return) to get

$$q(r)\cdot\alpha_{LO} = \alpha_L(r)\ \exp(-2\int_0^r \alpha_L(x)\ dx) \tag{3}$$

where q(r) is the normalized lidar return and α_{LO} is obtained from the nephelometer.

The solution can now be written:

$$\alpha_L(r) = \alpha_L(r_m)\ \frac{q(r)/q(r_m)}{1+2\alpha_L(r_m)\int_r^{r_m}[q(x)/q(r_m)]dx} \tag{4}$$

where r_m is the range to a distant point and $\alpha_L(r_m)$ is the estimated extinction coefficient at that point. The real α value is then obtained from equations 1 and 2.

Measurements have so far been performed along a horizontal path with a calibration target at 2.5 km distance. Transmission values obtained from the aerosol return can thus be compared to values obtained from the target returns. Contrast transmission has been measured simultaneously with a CCD camera looking at a calibrated contrast screen. In planned experiments lidar measurements along slant paths will be compared to observations from aircraft.

References:

(1) Klett J.D., Appl. Optics, Vol. 24, No 11, 1 June, 1985.

(2) Fernald F.G., Appl. Optics, Vol. 23, No 5, 1 March, 1984.